Responding to climate change to sustain community-managed water services in Vanuatu

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CERTIFICATE OF ORIGINAL AUTHORSHIP

I certify that the work in this thesis has not previously been submitted for a degree nor has it been submitted as part of requirements for a degree except as part of the collaborative doctoral degree and/or fully acknowledged within the text.

I also certify that the thesis has been written by me. Any help that I have received in my research work and the preparation of the thesis itself has been acknowledged. In addition, I certify that all information sources and literature used are indicated in the thesis.

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Dedicated to the memory of my mother

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Abbreviations

ACFID: Australian Council for International Development

DoW: Department of Water

DLA: Department of Local Authorities

DWSSP: Drinking Water Safety and Security Plan

IPCC: Intergovernmental Panel on Climate Change

IWRM: Integrated Water Resources Management

NAB: National Advisory Board for Climate Change and Disaster Risk Reduction

NGO: Non-governmental organisation

NWP: National Water Policy

NWS: National Water Strategy

SDG: Sustainable Development Goal

SES: Social-ecological system

TAC: Technical Advisory Commission

UTS: University of Technology Sydney

VCRF: Vanuatu Community Resilience Framework

WASH: Water, sanitation, and hygiene

Abstract

The aim of this research was to provide holistic, detailed, and integrated knowledge and guidance on the ways in which community-managed water services are affected by and sustained against climate change disturbances.

Climate change poses one of the most significant challenges to the world with potential for far-reaching, detrimental impacts on water access in rural areas of developing countries. The water, sanitation, and hygiene (WASH) sector has yet to adequately and explicitly conceptualise the different ways that climate change affects water services and how water services are sustained against climate change disturbances. Without clear conceptualisations, actions taken to adapt water services to climate change run the risk of being ineffective, inefficient, inequitable, or environmentally unsustainable. This research filled the conceptualisation gap in the context of community-managed water services in a developing country setting using Vanuatu as a country of reference.

To conduct this research, I followed tenets of transdisciplinarity and utilised a case study methodology in two rural sites in Vanuatu that included 70 participants from rural communities and local and central government. Methods included semi-structured interviews, technological and environmental surveys, observations, participatory workshops, and document analyses.

I first drew on three bodies of climate change theory-practice to fill the conceptualisation gap: risk-hazard, vulnerability, and resilience. I demonstrated that using risk-hazard, vulnerability, and resilience lenses each make different, but valuable, contributions to conceptualising the biophysical, social, and social-ecological impacts of climate change on community-managed water services. I argued that the WASH sector currently favours a technocratic framing of the climate change problem and must consider the wider range of perspectives that I demonstrated.

I then synthesised key concepts from risk-hazard, vulnerability, and resilience theories, such as those relating to risk management, agency, and human-environment feedbacks, into an integrated conceptual framework to emphasise their synergies and manage tensions between them. My proposed framework acts as a heuristic for assessing the capacity of community-managed water services to

sustain water access against climate change disturbances. The framework sensitises WASH stakeholders to the different ways of regarding climate change impacts and facilitates interdisciplinary research.

Lastly, I showed how my findings are useful in a real-world setting. I discussed how my proposed framework can be used to inform Government of Vanuatu strategic decision-making processes. I also considered how my framework can be used to evolve a Vanuatu-based NGO framework and I shared lessons learned from carrying out my analyses with other researchers in Vanuatu.

Chapter 1. Introduction

1.1 Research problem

Climate change[1] poses one of the most significant challenges to society in the 21st century and likely beyond. Anthropogenic greenhouse gas emissions, increased by economic and population growth, are continuously driving atmospheric concentrations of carbon dioxide, methane, and nitrous oxide to unprecedented levels, resulting in a clear global warming trend (IPCC, 2014a). Without substantial worldwide success in curbing current rates of greenhouse gas emissions, the Earth could experience a 4°C rise in temperature above pre-industrial levels by 2100 (Steffen et al., 2015, p. 22). A 4°C rise in temperature would be catastrophic with possible outcomes such as one in six species threatened by extinction (Urban, 2015), the displacement of well over 100 million people due to sea-level rise (Nicholls et al., 2011), and severely reduced economic growth in poor countries (Dell et al., 2012). Following the Paris Agreement, nearly all states of the world have committed to limiting global warming to no more than 2°C above pre-industrial levels and pursuing limitation of the temperature increase to just 1.5°C (UNFCC, 2015). However, climate change has already had widespread impacts on human and natural systems and impacts are more likely to be severe, pervasive, and irreversible as temperatures continue to rise (IPCC, 2014a). Indeed, the 2°C goal is unlikely to be met given current national policies on greenhouse gas emissions and current world development trajectories (Nordhaus, 2016), thus indicating that worsening impacts are inevitable.

A major concern about continuing climate change is how it is likely to affect water access[2]. Climate change effects such as changing rainfall patterns, intensification of extreme weather events, and an increase in mean sea-level rise directly and indirectly impact water resources, water infrastructure, and water demand in many ways (Howard et al., 2016; Smits et al., 2009). Consequently, it is expected that climate change will reduce renewable surface water and groundwater resources in many parts of the world, resulting in an intensification of competition for fresh water (Jiménez Cisneros et al., 2014) and significantly exacerbated water stress

[1] "Climate change refers to a change in the state of the climate that can be identified (e.g., by using statistical tests) by changes in the mean and/or the variability of its properties, and that persists for an extended period, typically decades or longer" (IPCC, 2014b)

[2] In this thesis, I refer to water access as the availability of water for domestic purposes that is safe to drink, affordable, physically accessible, and deemed acceptable by its users

(Schlosser et al., 2014). Epidemiological studies further suggest waterborne diseases stemming from increased exposure to water related pathogens, chemical hazards, and cyanotoxins will become more prevalent due to climate change (Braks and de Roda Husman, 2013; Cann et al., 2013; Funari et al., 2012). Climate change also threatens to undermine progress made in increasing the proportion of populations with access to an improved water source and the achievement of Sustainable Development Goals (SDGs) relating to improving water quality, increasing water-use efficiency, implementing integrated water resources management (IWRM), and restoring water ecosystems (Howard et al., 2016, 2010). Finally, many of these impacts are expected to disproportionally affect developing countries and the poor, thus worsening inequalities in water access and undermining the achievement of the human right to water (OHCHR, n.d.).

These impacts are concerning because of the importance of water access for enabling healthy and dignified lives. Water access is tied closely with mortality and morbidity rates in developing countries and improved water access generally results in economic benefits at both the household and macroeconomic levels (Bartram and Cairncross, 2010). Adequate water access is further linked to educational outcomes, convenience, and dignity, and can be foundational for poverty reduction and promotion of gender equality (Hutton and Chase, 2016). Thus, the potential for climate change to deteriorate water access threatens to degrade quality of life in many ways.

The potential for climate change to detrimentally affect community-managed water services[3] is especially worrying. Large proportions of developing country populations reside in rural areas where community management, a form of water management where households in a community collectively manage their own water services, is the most common approach for providing water access (Howard et al., 2016). Community-managed water services frequently encounter troubles in sustaining the provision of adequate water access over extended periods of time for a variety of reasons, including difficulty in recovering operation and maintenance costs, arranging for repairs to be made, sustaining voluntary labour from community members, and maintaining trust and coordination between

[3] In this thesis, I refer to water services as the linked water resource, infrastructure, and social systems that facilitate water access (Moriarty et al., 2010)

community water managers and users (Chowns, 2015; Harvey and Reed, 2007; Lockwood and Smits, 2011, p. 1). Climate change will add to these troubles and consequently threatens to further inhibit water access for the millions of people that depend on community-managed water services.

In response to the threats of climate change, researchers and practitioners are showing increased interest in taking action to ensure that people in developing countries, especially the poor, are still able to access water to meet their basic needs. These researchers and practitioners mostly come from a sector within the field of international development known as the water, sanitation, and hygiene (WASH) sector. Initially, WASH professionals were relatively slow to tackle the climate change issue (Batchelor et al., 2011, p. 8). However, over the past five to seven years, climate change has begun to feature more heavily in WASH scholarly and grey literature (Carrard and Willetts, 2017; Howard et al., 2016; Kohlitz et al., 2017). A Google search of the term "climate change" with the terms "water, sanitation, and hygiene" or "WASH" also reveals a wide range of WASH non-governmental organisations (NGOs) and international development agencies with projects and programmes meant to support and secure water access in developing countries against climate change. Furthermore, climate change is now regularly a theme at high-profile WASH conferences.

The WASH literature and programme descriptions frequently speak of and recommend activities for "building resilience" of water services to climate change, but it is often not clear what building resilience is intended to mean. Authors seldom attempt to conceptualise resilience, how it improves or sustains water services against climate change, or how exactly their recommended activities build their conceptualisation of resilience (see section 4.5 for my critique of the academic literature). WASH authors that use related climate change terms (e.g. vulnerability or adaptive capacity) similarly often do not conceptualise them clearly. Without clear conceptualisations, climate change resilience-building (or adaptation, vulnerability-reducing, etc.) activities potentially neglect important dimensions of water service, create redundancies, clash with one another, do not have a clear theory of change that can be evaluated, or generate overall confusion that wastes time and resources. These potential issues diminish the efficiency, effectiveness,

legitimacy, and equality of activities ostensibly meant to adapt water services to climate change in order to improve or sustain water access.

My research seeks to address the climate change conceptualisation problem within the WASH sector (the community of researchers, practitioners, and policy-makers worldwide working on WASH issues). More specifically, it seeks to directly address the problem that the WASH sector to-date has inadequately conceptualised how climate change affects community-managed water services and what can be done to respond. Indirectly, my research aims to contribute to addressing the higher order problem of improving or sustaining community-managed water services against climate change.

My research also aims to address this problem in a small island developing state setting. Small islands are uniquely affected by climate change due to their geophysical characteristics, community dependency on coral reef ecosystems, and relatively fragile economies, amongst other reasons (Nurse et al., 2014). I situate my research in the country of Vanuatu where a large proportion of the population depends on community-managed water services, there is wide geographic diversity with potential to yield rich data, and climate change is widely recognised by the government, development practitioners, and researchers as a major issue.

Climate change is especially recognised as a development issue in Vanuatu and relevant research is called for in policy. The 2016 – 2030 National Sustainable Development Plan lists "enhanced resilience and adaptive capacity to climate change and natural disasters" as one of its five development aspirations and climate and disaster resilience is a goal with several measurable objectives set against it (Government of Vanuatu, 2016a). To this end, the government approved of the Vanuatu Climate Change and Disaster Risk Reduction Policy 2016-2030 which outlines strategic priorities to guide development work in the space of climate change adaptation and disaster risk reduction (Government of Vanuatu, 2015). Amongst the strategic priorities, the policy calls for research on "social and economic elements of climate and disaster resilience, including community vulnerability and capacity, and adoption of appropriate adaptation approaches" (Government of Vanuatu, 2015).

Such research is needed with respect to community-managed water services in Vanuatu due to the potential for climate change to detrimentally affect rural water access. Access to basic water services in rural areas of Vanuatu already lags behind urban areas (WHO and UNICEF, 2017) and the burdens of climate change for water users are likely to be disproportionally beared by people who already struggle to access water (OHCHR, n.d.). Consequently, the newly drafted National Water Policy, which describes seven priorities for supporting the sustainability of water services in rural areas of Vanuatu, includes a priority for securing water against climate change impacts (Government of Vanuatu, 2017). Hence, this PhD research aligns well with national development priorities.

1.2 Research aim, objectives, and questions

Given the problem that I described above, the aim of my research is to provide holistic, detailed, and integrated knowledge and guidance for WASH researchers and other stakeholders on the ways in which community-managed water services are affected by and sustained against climate change disturbances. In particular, the thesis offers new ideas for planning and maintaining water services that continue to function despite climate change disturbances, and contributes to strengthening existing policies and frameworks in Vanuatu for preparing the rural water sector for climate change. Achieving this aim provides WASH policy-makers, researchers, and practitioners with new knowledge on ways to sustain community-managed water services against climate change impacts, and advances knowledge on the conceptual relationships between different approaches.

I seek to achieve this research aim through three objectives. My first objective is to examine different theoretical approaches for understanding and responding to climate change impacts on society and nature, and critically assess the application of these approaches to community-managed water services in Vanuatu. The approaches that I examine and assess in this thesis are named the risk-hazard, vulnerability, and resilience approaches. These approaches exist in varying forms and under different labels in the general climate change and global environmental change literature, but have seldom been explicitly applied in any form in the WASH context. I describe them in detail in Chapter 2.

My second objective is to propose a conceptual framework for assessing the capacity of community-managed water services to sustain water access against climate change disturbances. I intend this conceptual framework to build on and integrate the risk-hazard, vulnerability, and resilience approaches, and to be directly applicable to community-managed water services.

My third objective is to demonstrate how my research findings actually provide guidance in a real-world context. In this research, I use the country of Vanuatu as my reference point for a real-world context. I explain my choice of Vanuatu in section 3.2.

These three objectives are reflected in my three research questions:

> Research question #1: What contributions do the risk-hazard, vulnerability, and resilience approaches make to understanding how community-managed water services are affected by and sustained against climate change disturbances?
>
> Research question #2: How can climate change risk-hazard, vulnerability, and resilience assessments be conceptually integrated with respect to community-managed water services?
>
> Research question #3: How can the findings from research questions #1 and #2 be drawn on to develop recommendations for policy-makers, practitioners, and researchers in Vanuatu to better assess the capacity of community-managed water services to sustain water access against climate change disturbances?

I investigate these questions using a case study methodology which includes community and local and central government research participants, and an examination of water supply technologies and water catchments, in two rural case study sites in Vanuatu. The data from my research are primarily qualitative and my findings include both empirical evidence and theoretical insights.

Meeting my research aim through answering the research questions provides three significant contributions to the WASH sector. One is that it provides orientation to the WASH sector on the strengths and limitations of taking different perspectives on problematising climate change for community-managed water services. Another contribution is that it provides guidance on integrating these different perspectives to maximise their synergies and manage tensions between them. The

implication of these two contributions is that WASH sector stakeholders can have more informed and meaningful discussions about what could and should be done to ensure that community-managed water services are sustained against climate change disturbances, and take more informed actions. This research also provides practical insights relevant to government authorities, NGOs, and researchers based in Vanuatu which inform their operational and strategic decisions related to supporting community-managed water services against climate change.

Before proceeding with the rest of the thesis which explains my research, it is appropriate to introduce myself as the researcher. All research is influenced by the qualities of the researchers who conduct it. As such, in the next section, I aim to inform the reader about the ways in which I, both unintentionally and intentionally, have influenced the fundamental nature of this research.

1.3 Positionality and my personal approach to this research

The purpose of this section is to describe my positionality and how I formed my approach to this research. Positionality refers to the researcher's position in relation to the study (Qin, 2016). It is the direct and indirect influence of the researcher's background or "identity" (race, gender, age, nationality, etc.) and worldview on their research (Foote and Bartell, 2011; Sumner and Tribe, 2008, p. 4). A research approach refers to the general plans and procedures for conducting research (Creswell, 2009, p. 1). I discuss my positionality and how I formed my research approach here to inform the reader of how I may have been predisposed to certain ways of thinking throughout my research. In the following sections, I first describe my personal background and how it consciously and unconsciously influenced my motivation for and implementation of this research. I then describe philosophies that I purposefully took while approaching this research project.

1.3.1 My personal background

This research was motivated and influenced by experiences that I consciously realise, as well as social identities that sub-consciously influence all decisions that I make. I first present some key relevant experiences of my life and then my social background.

In 2009, I had my first direct exposure to development work when I moved to Fiji as a Peace Corps Volunteer. I spent two years living in an indigenous Fijian rural

community where I worked with community members on a variety of issues that they identified, including water supply. Over this time, I gained a keen appreciation of the values and norms of rural communities in Fiji as well as the hardships that they faced. I also learned much about my own values and my strengths and weaknesses with respect to working with and relating to people cross-culturally. The experience left a permanent impression on me and spurred my interest in rural development work that helps communities deal with their hardships in a way that aligns with their own values and norms.

My experience in rural Fiji stayed at the forefront of my mind as I moved on to other opportunities. I later worked at the Secretariat of the Pacific Community (an international development agency based in the Pacific island region) where I provided research and programmatic support for WASH projects across different Pacific island countries. I also later undertook a Master's degree program in water and waste engineering focusing on low- and middle-income countries. This work and study often focused on the technical side of WASH service delivery; pumps and weirs and budgets and water quality tests. However, I always found my mind drawn back to the "soft" side of WASH services. I thought about what my former community in Fiji would have wanted, how they would (or would not) cooperate with one another to look after the hardware, and how a WASH intervention might change the community. As a result of my technical training and cross-cultural experiences in development work, I developed a pragmatic worldview through which I see multiple forms of knowledge as being necessary for engendering change in communities.

When I decided to pursue a PhD (motivated by my aspiration for a career in research), I wanted a research topic that would blend my engineering training with my community development experiences to create positive change in Pacific island rural communities. I chose to examine research issues pertaining to climate change and rural WASH services (which I later narrowed down to just water services) in a Pacific island context because the scope of climate change reaches across multiple domains and it is a highly relevant problem for Pacific island communities. From my years of experience living in rural Fiji and researching in a Pacific-based international development agency, I had an interest and the competency to research cross-culturally in the Pacific island region. As I would later discover, my

chosen research topic also led me to reach beyond my comfort zone into environmental sciences in line with the personal value that I place on environmental sustainability. Thus, my personal motivation for this research is a product of my interests and skills in community-based development, engineering, academic research, and environmental sustainability.

In addition to these experiences, my research is influenced by my social identity which I recognise is different from that of my research participants. I am a young, white, American, heterosexual, cisgender male without any disabilities. The number of ways in which these social identities have potentially influenced different phases of my research is countless. I am particularly mindful of how my American upbringing affected my interactions with and representations of the ni-Vanuatu[4] research participants. Like many students in international development, I did much worrying and soul-searching about whether I could, or even should, research a social group so different from my own. Similarly, I ruminated frequently about how and if, as a male, I should be commenting on issues facing ni-Vanuatu women. However, I came to agree with commentators that write that we are all, to a degree, "insiders" and "outsiders" to research participant groups due to our multiple social identities, and that the viewpoints of outsiders can still be valuable and have merit in the eyes of the research participants (Scheyvens and McLennan, 2014, pp. 6–7). I also concur that people in positions with relatively more power have an ethical responsibility to assist those with less power (Sumner, 2007) which includes lifting up the voices of less powerful people through research.

Throughout my research, especially when I was collecting data in the field, I recognised that my background influenced my research and I considered the consequences. My goal was not necessarily to abrogate this influence, but to question how it limited my perspective to a narrow (but still valuable) field of vision, what that perspective meant for the participants, and how that perspective could be complemented by other perspectives. I discuss this strategy further in the next section where I comment on "empathic neutrality".

[4] Ni-Vanuatu is the demonym for the indigenous population of Vanuatu

1.3.2 Philosophies that shaped my approach to this research

In order to research a problem-driven topic that spans multiple domains and is situated in an international development context, I drew inspiration from a few paradigms or philosophies: transdisciplinarity, pragmatism, and empathic neutrality. I describe my interpretation of each to give the reader a sense of what I value as important elements of research in this thesis.

Transdisciplinary research has different contested meanings, but the meanings that inspired my research approach align with those summarised by Riedy (2017):

1. Research that integrates knowledge and perspectives across different disciplines;
2. Research that is informed by multi-stakeholder discourses;
3. Research that has a problem-solving focus to address real-world sustainability challenges; and
4. Research that generates tangible improvement within the field of inquiry, relevant stocks and flows of knowledge, and mutual and transformational learning between researchers and research participants

Transdisciplinary research aspires to efficiently use and produce knowledge by joining different epistemics (i.e. ways of knowing) in relation to a complex, real-world problem (Scholz and Steiner, 2015). The integration of knowledge may cross disciplinary, empirical-intuitive, qualitative-quantitative, or theoretical-practical divides (Gaziulusoy and Boyle, 2013). There are different methods for synthesising and integrating knowledge, including structured and unstructured dialogue between stakeholders; the development of a shared model, product, or vision between different stakeholders; or the use of a single metric (such as monetary value) to measure different concepts (Bammer, 2013, pp. 45–48). I discuss my method for the integration of knowledge in section 3.9.

Interdisciplinary research similarly seeks to achieve the integration of different knowledge bases, but a main aspect that sets transdisciplinary research apart is its explicit inclusion of perspectives from non-academic stakeholders to enhance the societal relevance of the research (Tress et al., 2005). Non-academic stakeholder perspectives are incorporated during the research design (e.g. problem framing or research question definition), the production of knowledge (e.g. ensuring the

knowledge has societal relevance), and the dissemination of results (e.g. translating results into accessible language for various stakeholders) (Mauser et al., 2013). Striking a balance between committing time to research analysis and to engagement of non-academic stakeholders to create real-world change is a common challenge in transdisciplinary doctoral research (Willetts et al., 2012). My research has a strong academic focus, but I have included non-academic perspectives by engaging Government of Vanuatu officials and NGO practitioners early on in my research design (discussed in section 3.4) and by seeking feedback from non-academic stakeholders through a wide-ranging dissemination strategy (discussed in section 7.5).

Throughout the conception, design, and implementation of my research, I sought to actualise the four meanings listed by Riedy (2017) to the greatest extent possible within the time and resource constraints of my doctoral programme[5]. These constraints, and needing to create new networks of contacts in Vanuatu, limited the extent to which I could co-produce knowledge with a wide range of stakeholders and develop practical tools. There are tensions between achieving each of the four transdisciplinary meanings which each require significant time and resources, so a research project may achieve them to varying degrees. However, I still consider my research to be transdisciplinary. I evaluate my work as transdisciplinary research against relevant quality criteria in section 7.5.

Pragmatism is a philosophy that puts forth the idea that the truth of any judgement is determined through practical activity (Hammersley, 2004). Pragmatic inquiry begins with a problem (Hammersley, 2004) and uses any set of methods, worldviews, and assumptions that are appropriate for addressing the problem (Creswell, 2009, p. 11). As such, pragmatic inquiry is not methodologically constrained by the orthodoxy of any particular epistemology (Patton, 2002, p. 72). I view this as the freedom to deliberately explore different epistemologies for addressing a problem and not an excuse to eschew consideration of epistemology altogether. My interpretation of pragmatism emphasises the problem-solving meaning of transdisciplinary research listed above. Thus, I view my research as a

[5] The University of Technology Sydney expects doctoral students to submit their thesis within three years of commencement of the doctoral programme

means to addressing a specific problem that I and others have identified rather than just simply generating knowledge about the world.

I perceive a couple of potential drawbacks with my interpretation of pragmatism. One is that focusing on solutions to problems as a form of inquiry may limit "out-of-the-box" thinking. When trying to find a solution to a problem, it is tempting to go toward the most obvious, expedient, or convenient ideas. I tried to be aware of this during my research and pushed myself to be creative. Another potential drawback of pragmatism relates to who gets to decide what is practical or useful. This is significant in cross-cultural, development research where my ideas of practicality may not be the same as the people engaging with my research. I addressed this through practicing empathic neutrality as described below.

While transdisciplinarity and pragmatism relate to my position toward my research in general, empathic neutrality relates to my position toward the people participating in and influenced by my research. Empathic neutrality is a social research strategy whereby the researcher leverages his or her empathy to learn more about a person while staying neutral (i.e. unbiased) toward the person's thoughts, emotions, and behaviours (Patton, 2002, p. 53). Empathy in research involves actively attempting to see the world from the participants' perspective which can give the researcher a better understanding of the meaning that participants give to their experiences, but it also risks diminishing the researcher's objectivity through over-identification (Hedican, 2008). Therefore, it is necessary to aim to keep selective perception and biases in check (Patton, 2002, p. 51).

Empathic neutrality is not an epistemology akin to interpretivism, but rather a strategy I used in my research, from beginning to end, to think about my research topic from different perspectives and to make my research more legitimate in the eyes of the research participants. Empathy enables me to see situations in different lights which allows me to analyse situations in different ways and develop a richer picture of them. It further helps me to develop a picture of the situation that more closely aligns with how my participants view it. A richer and more legitimate picture of a situation helps to ensure that I do not overlook important dimensions. Practising empathy also enables me to practise reflexivity by allowing me to see how the viewpoints of others conflict with my own. Reflexivity is needed in

development research in order to manage research-participant power relationships wherein foreign researchers can impose their own values and beliefs over those of the participant (Kapoor, 2004). I discuss the practice of reflexivity in my research in section 3.6.5. Empathy can perhaps go too far, however, and lead researchers to develop an idealised or romanticised picture of a community without its own flaws (Crow, 2014). Thus, I aimed to remain as neutral as possible and remain critical of both my perspective and those of my participants.

This introduction of myself as the researcher helps explain some of the fundamental decisions I have made around the design and presentation of this thesis. I now return to presenting the thesis with a description of how I lay out the forthcoming chapters.

1.4 Thesis structure

I structure this thesis in seven chapters:

In Chapter 1, I have defined the research problem and explained my research aim and questions for addressing the problem. I have also given background on myself and my personal approach to this research to give the reader a sense of my positionality.

In Chapter 2, I introduce and critique each of the risk-hazard, vulnerability, and resilience approaches to climate change research that I later use to answer research questions #1 and #2. I also provide background information on the country of Vanuatu, where my field research was located, in order to give the reader necessary context for answering research question #3.

In Chapter 3, I present the methodology for answering my research questions. This chapter includes discussion on the justification for my choice of a case study methodology, my decision to situate my research in Vanuatu, steps that I took to prepare for data collection activities, how I chose the case study sites, ethical considerations, my data collection methods, my data analysis techniques, and limitations of my research.

In Chapter 4, I present and discuss findings of my research in order to answer research question #1. The findings include examples from my review of the WASH

literature, empirical evidence from two rural community case study sites in Vanuatu, and analysis of the literature and my collected evidence.

In Chapter 5, I present and discuss findings pertaining to research question #2. The primary contribution of this chapter is my proposed conceptual framework for guiding assessments of the capacity of community-managed water services to sustain water access against climate change disturbances. I also retrospectively apply this framework to one of the rural community case study sites.

In Chapter 6, I present and discuss findings on research question #3. I present empirical evidence from government interviews, analysis on relevant policy documents, and discussion on how the findings of research questions #1 and #2 inform government, NGO, and researcher stakeholders and processes.

In Chapter 7, I conduct a self-assessment of my research. I return to my research aim and questions and summarise how I addressed them, discuss my contributions to WASH and climate change research and practice, suggest future opportunities for related research, assess my thesis against five quality criteria, and make concluding remarks.

The chapters of this thesis combine to present my research in three parts. The first part comprises Chapters 1, 2, and 3. These chapters together provide the required background and information to understand the research problem, its context, and how I went about addressing it. The second part comprises Chapters 4, 5, and 6. Each of these chapters contain results from my research as well as discussion on their importance and relevance to theory and practice on the impacts of climate change on water services. The discussions from these chapters sequentially feed into and inform the subsequent chapters. The third part of the thesis consists of Chapter 7 in which I reflect on the contributions of my research and conduct a self-assessment.

Chapter 2. The risk-hazard, vulnerability, and resilience approaches and background to Vanuatu

2.1 Introduction

In this chapter, I introduce three approaches to assessing how systems are impacted by and respond to climate change, and the geographic context of my research fieldwork. The purpose of this chapter is twofold. First, in Chapter 1, I identified a need in the WASH sector for more rigorous and systematic ways of considering how climate change affects community-managed water services and what could and should be done to respond. I describe three theoretical approaches in this chapter that the WASH sector could usefully draw on to fill this need. Describing the three approaches sets the stage for Chapter 4 where I demonstrate the contributions of each approach through a literature review and my case study analyses. Second, I describe the country and government administrative contexts in which I conducted my fieldwork. This serves to contextualise my fieldwork and also provides needed background for Chapter 6 in which I consider how my research findings may be used to inform Vanuatu stakeholders in order to strengthen their assessments of the capacity of community-managed water services to sustain water access against climate change disturbances

2.2 Three approaches to assessing climate impacts

Three common approaches to assessing how systems are impacted by and respond to climate change are often used: risk-hazard, vulnerability, and resilience. These approaches were largely developed in parallel by different researcher/practitioner communities (Eakin et al., 2009), although cross-fertilisation is increasingly common (Béné et al., 2016; Maru et al., 2014; Tanner et al., 2015). Each of the approaches that I cover here have substantial potential to provide a rigorous and systematic way of assessing climate change impacts on water services and what can be done to sustain water access against climate change.

Although different terms are used to label them, many authors agree that three broad, but distinct, approaches to researching and informing policy decision-making on climate change or wider global environmental change in general have emerged to prominence (Eakin et al., 2009; Eakin and Luers, 2006; Fünfgeld and McEvoy, 2011; Janssen et al., 2006; O'Brien et al., 2007). In my research, I refer to these bodies of theory-practice as the risk-hazard, vulnerability, and resilience approaches. There is some conceptual overlap between the approaches and certain

aspects of them are similar in practice. However, I present them discretely to illustrate how they represent different paradigms. Before going further, it is helpful to clarify some of the terminology that I use in this thesis.

First, each of the approaches is concerned with how a system experiences disturbances and its capacity to respond to the disturbances (Adger, 2006). Disturbances are forces or pressures that disrupt the functioning of a system. They comprise perturbations or shocks (a major spike in pressure such as caused by a cyclone) and stresses (continuous or slowly increasing pressure such as caused by soil degradation) (Turner et al., 2003a). A system can be physical (e.g. infrastructure), social (e.g. a community), environmental (e.g. an aquatic ecosystem), or some combination of these. A common unit of analysis, especially in the resilience literature, is the social-ecological system (SES).

An SES is a system comprising social/human and ecological/environmental sub-systems that interact in complex ways to produce outcomes at the SES level (Ostrom, 2009). A water service generally can be represented as an SES because it includes social systems (water users, managers, and the water management systems they operate) and natural resource systems (water resources, water catchments, and engineered infrastructure for accessing water) that interact to produce an overall outcome (some level of water access). In this chapter, I refer to any kind of system in general to describe the three approaches, but later in Chapter 4 and beyond I consider the water service, represented as an SES, as my system unit of analysis.

Next, I distinguish between the risk-hazard and vulnerability approaches although elsewhere in the literature they are at times grouped together. The term vulnerability is often interpreted broadly in two different ways. These two interpretations have been labelled “end-point” and “starting-point” vulnerability (Kelly and Adger, 2000) or “outcome” and “contextual” vulnerability (O’Brien et al., 2007). The outcome or end-point perspective considers vulnerability to be a measure of the predicted detrimental impact that a system will suffer as a result of exposure to projected climate change hazards (IPCC, 2014b). The contextual or starting-point perspective considers vulnerability to be a present inability to cope with external pressures or changes including, but not limited to, changing climate

conditions (IPCC, 2014b). Oftentimes, research using either of these interpretations is collectively grouped as vulnerability research (Adger, 2006; Engle, 2011; Miller et al., 2010). However, in this this thesis I distinguish between research that follows an outcome or end-point interpretation as risk-hazard research[6], and research that follows a contextual or starting-point interpretation as vulnerability research. As I demonstrate in the following sections describing each approach, they are sufficiently different to be considered distinct approaches and the risk-hazard and vulnerability labels help to avoid confusion over terminology.

Resilience has been conceptualised in numerous disciplines, including engineering, psychology, social sciences, disaster management, ecology, and others. The various disciplines focus on different units of analysis and utilise a variety of methods for researching resilience (Brand and Jax, 2007; Downes et al., 2013; Martin-Breen and Anderies, 2011; Quinlan et al., 2016). However, in the field of climate change research, the resilience of SESs to climate impacts has gained particular prominence (Bahadur et al., 2013; Eakin et al., 2009; Tanner et al., 2015). In this thesis, I focus on SES resilience because of its prevalence in climate change research, the suitability of representing water services as SESs, and the limited existing knowledge of how it applies to water services (as I demonstrate in Chapter 4). Other forms of resilience (e.g. psychological resilience) may have useful lessons in a water management context, but are outside the scope of this research. I henceforth refer to SES resilience as simply "resilience".

The rest of this section is structured with an individual discussion of each approach. The discussions cover key concepts and theory of each approach to understanding how systems are affected by and respond to disturbances, how each approach is used to form assessments of climate impacts, recommended adaptation actions that commonly follow the assessments, and key strengths and drawbacks of each approach for guiding climate impact assessments. I then provide a summary of the approaches and concluding remarks on using them jointly.

[6] Others sometimes refer to it as "adaptation" (Bunce and Ford, 2015; Eakin et al., 2009; Janssen and Ostrom, 2006) or "impacts-driven" (Burton et al., 2002; Ford et al., 2010) research.

2.2.1 Risk-hazard

The risk-hazard approach stems largely from natural hazards research in the field of geography that focuses on the physical elements of hazards (Adger, 2006; Eakin and Luers, 2006). Hazards are akin to the definition of disturbances that I provided earlier. I use the term hazard when I refer to a specific type of disturbance (e.g. a drought) rather than disturbances in general (e.g. climate change disturbances). Risk-hazard assessments typically focus on identifying where and when biophysical hazards may appear, the extent to which they can cause losses (e.g. in terms of lives or property), and how impacts of hazards may be offset by adaptation actions (Cutter, 1996; Smit and Wandel, 2006). With respect to climate change research, the biophysical hazards of interest are climate hazards (Eakin et al., 2009).

The risk-hazard approach usually begins with the formulation of a future climate scenario. Future climate scenarios (i.e. predictions of the regional or global climate in the future) are typically generated using models based on prospective analyses of future economic activity and highly sophisticated simulations of the interactions between climate drivers (e.g. the atmosphere, oceans, land, and ice). Models aim to predict global development and greenhouse gas emission trends and consequently how these trends will alter climate drivers, thus creating significant changes in climate features (e.g. temperatures, rainfall variation, frequency of cyclones, etc.) over various spatial and temporal scales (Dessai et al., 2004). Large-scale climate models may be downscaled to more local levels through more sophisticated modelling or statistical analysis. Due to uncertainties associated with modelling future climate, models using divergent assumptions predict different climate scenarios (Füssel and Klein, 2006). These uncertainties come from incomplete knowledge of the physical processes that influence climate events (e.g. the rate of heat uptake by the deep ocean), the indeterminacy of human systems and behaviours (e.g. how the reactions of future societies to climate change will alter greenhouse gas emission rates), and inherent randomness of variables due to the chaotic nature of the climate system (Dessai and Hulme, 2004). Uncertainties in predicting changes in the future climate are often managed by generating multiple climate models holding different assumptions (known as an ensemble) and taking the average of their results (Dai et al., 2001).

Once future climate scenarios have been generated, the potential for climate change to strengthen or create new climate hazards may be identified for a given location and time. Climate hazards that can directly harm water supplies include drought, decreased inter-annual precipitation, flooding from intense or prolonged rainfall, wind damage from cyclones or storms, and saline intrusion from storm surges and sea-level rise (Luh et al., 2017). Projections of future climate scenarios may indicate that these climate hazards will become more intense, frequent, or widespread depending on the location and timeframe of reference.

The risk that the climate hazard poses to the system of analysis is a function of the system's exposure and sensitivity to the hazard (Turner et al., 2003a). Exposure is defined in general as the degree, duration, and/or extent to which a system is in contact with, or subject to, a hazard while sensitivity is the degree to which a system is modified or affected by a hazard (Adger 2006; Gallopín 2006). The projections of future climate scenarios are typically used to assess how climate change may increase or decrease levels of system exposure to a particular climate hazard. For example, climate models project that water supplies in Vanuatu will be exposed to decreased dry season rainfall over the course of the 21st century (Australian Bureau of Meteorology and CSIRO, 2011). Methods for assessing a system's sensitivity to a climate hazard can range from complex, computerised models to simpler dose-response functions (observing the change in effect on a system as levels of exposure to a hazard change) based on past and present experiences and understanding of system behaviour. For example, Nijssen *et al.* (2001) utilise a sophisticated hydrologic model that solves water and energy balances to demonstrate how quickly and substantially certain parameters of different rivers change when exposed to increased temperatures. Meanwhile, Turner *et al.* (2003b) demonstrate the sensitivity of the productivity of chili farmers in Mexico to drought through a review of case studies of how chili productivity was affected by droughts in the past.Risk-hazard assessments may or may not also investigate the capacity of systems to take action to mitigate climate risks (Smit and Wandel, 2006). This involves examining conditions or characteristics that enable a system to cope with a particular climate-related hazard (Lemos et al., 2013). One way to assess this capacity is through indicators. For example, survey data on the varieties of maize that are available to farmers in Chiapas, Mexico have been used to indicate their

capacity to reduce their sensitivity to drought (Eakin et al., 2014). Interviews can also be used. For example, interviews with policy-makers were used to assess the capacity of agricultural householders in Brazil to reduce their sensitivity to drought (Lemos et al., 2016).

Community knowledge contributes to risk-hazard assessments, but there is a need to bring in external, scientific data and knowledge to complete the assessments. Although communities are knowledgeable about their current and past exposure to climate hazards, they do not have the resources to characterise their future exposure to climate change-driven hazards. However, communities have detailed knowledge about the sensitivity of their water supplies to hazards they have experienced. This knowledge can be useful for understanding the types of consequences that communities will experience if a particular hazard becomes more frequent, intense or longer. On the other hand, communities may have limited knowledge of potential climate change-related hazards that they have never experienced before (e.g. effects of bushfires on water supplies).

The risk-hazard approach normally follows a positivist epistemology (Füssel, 2007). Risk is usually interpreted as something that can be mapped and measured with predictable impacts and increments of damage that can be estimated (Ribot, 2014). Although constructivist analytics could be applied using a risk-hazard approach (Ribot, 2014) it is most associated with a scientific, framing and understanding of climate change as a biophysical phenomenon (O'Brien et al., 2007).

Recommended adaptation actions following risk-hazard assessments aim to directly reduce the system's exposure or sensitivity to identified climate hazards, or enhance the capacity of the system to alter its exposure and sensitivity itself, usually through technocratic means (O'Brien et al., 2007; Tschakert and Dietrich, 2010). An adaptation to reduce a water supply's exposure to saline intrusion from sea-level rise may be to re-locate it away from the coast. The practice of designing or modifying technologies to reduce their sensitivity to climate hazards is sometimes called "climate-proofing". For example, raised aprons can be used to elevate handpumps to reduce their sensitivity to flooding (Elliot et al., 2011, p. 34). A suite of possible adaptation options may be considered and are often ranked

using cost-benefit, cost effectiveness, or multiple criteria analyses (Smit and Wandel 2006), although there is increasing recognition that social and environmental "costs" also need to be considered.

The risk-hazard approach to assessing the impacts of climate change has a few key strengths. First, the linear cause-and-effect logic behind risk-hazard assessments is intuitive. Although accurately projecting how future climate change will alter climate hazards can be highly challenging, the physical impacts of those climate hazards on systems like infrastructure are often easy for experts to analyse. Thus, precise solutions can potentially be developed to address specific tractable problems (Dessai and Hulme, 2004). Second, and as an extension of the first strength, identifying a well-defined risk can lead to more expedient and economically efficient policy responses (Eakin et al., 2009). Third, risk-hazard assessments are useful for understanding the magnitude of the threat of climate change (Ford et al., 2010). An assessment of the potential damage that a climate hazard can cause to a system can clarify how the severity of climate change impacts compare with other stresses on the system. Indeed, without risk-hazard assessments, the world would likely be unaware there is any climate change threat in the first place.

The risk-hazard approach has a few key drawbacks as well. Even with the ensemble technique described above, there are significant uncertainties surrounding the future rate of global greenhouse gas emissions, how this will affect the climate, and what the resulting impacts will be, which inhibits the accuracy of climate projections (Dessai et al., 2009). The accuracy of climate projections are particularly limited at local scales (Knutti and Sedláček, 2012) which makes it difficult to determine if and how a system at a rural community level will be exposed to a certain climate change hazard. Next, the risk-hazard approach tends to overlook other non-biophysical (e.g. political, institutional, cognitive) factors that contribute to why climate hazards affect certain groups of people more than others (O'Brien and Wolf, 2010; Turner et al., 2003a). This is especially noteworthy in the context of developing countries where a focus on the biophysical dimension of future climate change may disregard the current day-to-day hardships that communities already face (Gaillard, 2012). Finally, risk-hazard assessments require substantial technological resources and expertise to develop and interpret

climate change projections. Developing countries, especially at the community level, are often dependent on developed countries for producing and interpreting climate data (Barnett and Campbell, 2010, pp. 68, 82–83). Consequently, the risk-hazard approach may reinforce a relationship in which people of developing countries are disempowered from acting to help themselves without external assistance.

2.2.2 Vulnerability

Vulnerability refers to the ability (or lack thereof) of individuals or groups to respond to environmental stressors and changing conditions in general (O'Brien et al., 2007). It is determined by a range of contextual conditions (e.g. institutional, biophysical, socio-economic, technological) that are influenced by social and political structures and the environment at wider scales (O'Brien et al., 2007). While the vulnerability approach considers how environmental systems influence the ability of people to respond to stressors and change, the focus is largely on social systems, consistent with its origins in social and critical theory (Turner 2010).The vulnerability approach largely emerged from political economy and political ecology traditions in part because of a perceived lack of focus from risk-hazard approaches on the political and structural reasons for why some populations were more susceptible to harm from environmental disturbances than others (Adger, 2006; Eakin and Luers, 2006). Research by Blaikie et al. (1994), which viewed vulnerability as both a product of exposure to environmental hazards as well as a social predisposition to be harmed by environmental impacts, was seminal in understanding the political ecology of disasters. Vulnerability assessments do not necessarily require an evaluation of specific climate hazards because they focus on the ability of people to deal with environmental disturbances in general (O'Brien and Wolf, 2010). Thus, vulnerability assessments pertain to how people respond to all types of environmental disturbances, not just specific ones driven by climate change. For example, in the context of water, water stress that people experience can be a complex product of climate change, existing climate variability, water resource management, and available water infrastructure (Ziervogel et al., 2006). However, assessments of climate change vulnerability often do examine how people interact with current climate variability to gather data on how contextual conditions affect a system's ability to cope with disturbances (O'Brien et al., 2007).

The vulnerability approach tends to take a constructivist epistemology (McLaughlin and Dietz, 2008). The ontology of vulnerability is the differential capacities of people to deal with changes in the environment and the ability to develop those capacities as desired, and emphasises social-political dimensions (Ford et al., 2010; Miller et al., 2010; O'Brien et al., 2007; O'Brien and Wolf, 2010). Although, some aspects of how resources are accessed and mobilised may be measured objectively (Ribot, 2014), the vulnerability approach tends to focus on the qualitative interpretation of complex social relationships and institutions.

To assess vulnerability, researchers frequently draws on the concept of adaptive capacity. Adaptive capacity may be generally understood as "the ability of systems, institutions, humans, and other organisms to adjust to potential damage, to take advantage of opportunities, or to respond to consequences" (IPCC, 2014b). Although this definition allows for adaptive capacity to be applied to non-human entities, adaptive capacity is commonly associated with social systems. Recent literature reviews demonstrate that authors have suggested a wide array of social determinants of adaptive capacity. These determinants relate to access to numerous natural, financial, physical, human, and social capitals (e.g. water resources, financial savings, infrastructure, literacy, social networks, etc.), the presence of institutions and governance systems that mediate resource access and use and decision-making power (e.g. cultural norms, laws, formal and informal rules), and various cognitive or psycho-social elements (e.g. perception of risk, attachment to place, belief systems) (Mortreux and Barnett, 2016; Warrick et al., 2017). Researchers and practitioners seek to operationalise vulnerability assessments by measuring or evaluating some combination of these determinants in the field.

Importantly, the vulnerability approach also explicitly seeks to identify who is more or less capable of adapting to environmental disturbances and why this differentiation in capacity exists (Ford et al., 2010; O'Brien and Wolf, 2010). As a result, vulnerability approaches draw attention to concepts such as agency and empowerment, and emphasise the potential for climate change to exacerbate the social conditions that create poverty and inequality (Miller et al. 2010; Leichenko and Silva 2014). Differentiation of people's ability to adapt to environmental disturbances could be assessed from many different angles. For example, one could

assess the existing differential distribution of various resources for adaptation; the differential ability, power, or desire of people to accumulate or mobilise resources for adaptation; how resource access and power used for adaptation are related to gender, ethnicity, race, or socio-economic status; how broader social and institutional structures create or sustain these arrangements; or how environmental changes interact with any of these dimensions.

There are two common ways in which the vulnerability approach is used to assess climate change impacts. One way is to select a set number of determinants of adaptive capacity, establish standard parameters to measure the determinants and collect data on those parameters (often collected through aggregated secondary data), then process or aggregate the measures in some way to determine an overall measure of adaptive capacity or vulnerability (Smit and Wandel, 2006). For example, Grasso *et al.* (2014) developed an index for measuring the vulnerability of regions in Samoa based on indicators that quantitatively measure economic welfare (e.g. household weekly expenditure), social wellbeing (e.g. distance of households from the nearest hospital), access to infrastructure and technology (e.g. percentage of households owning a mobile telephone), and the local structure of the economy (e.g. percentage of households engaged in the tourism industry).

An advantage of this approach is that it allows a vulnerability assessment to be conducted at large scales, may only require collection of secondary data, and facilitates the direct comparison of vulnerability across different areas which can be used to guide decisions on where to allocate resources for adaptation (Smit and Wandel, 2006). However, the use of generic indicators to measure determinants of adaptive capacity or vulnerability at scale are criticised for over-simplifying the complex processes that construct vulnerability to the point that the resultant information is insufficient on its own for designing appropriate adaptation activities (Barnett et al., 2008; Hinkel, 2011).

A second common way to use the vulnerability approach is to conduct place-based assessments that aim to document the ways in which people experience changes in climate and their decision-making processes (Smit and Wandel, 2006). Case study methodologies are frequently used to examine in depth, in one location, how climate disturbances interact with local drivers of vulnerability (e.g. lack of access

to resources or inequitable institutions) (O'Brien et al., 2007). This method is suitable for generating knowledge that can be used to inform locally appropriate adaptation activities (Ford et al., 2010). For example, McCubbin *et al.* (2015) examined the vulnerability of communities in Tuvalu through interviews and participant observations carried out over a three month period that qualitatively assessed how people coped with combined climatic and non-climatic (e.g. overcrowding, changing land use, shifting cultural norms) forces. It is this form of the vulnerability approach that I draw on in my research because the overall purpose of my research is to improve understanding of climate change impacts in order to inform adaptation activities rather than for comparing different geographic areas.

Community knowledge plays a critical role in vulnerability assessments. The socio-political environment of a given community is complex and highly context-specific. Although generic indicators may offer some level of insight, sustained engagement with community members is likely needed to develop an understanding of power and politics. Issues relating to social difference in water access can be subtle and difficult for outsiders to detect, so local knowledge is important to draw on.

Recommended adaptation activities following vulnerability assessments usually aim to enhance the adaptive capacity of people, particularly those who are believed to have the lowest capacity. The range of recommended adaptation strategies is broad because vulnerability assessments take into account context-specific non-climatic factors (Ford et al., 2010). However, recommendations typically aim to address local constraints to adaptation, reduce inequities, and challenge fundamental socio-political processes that make people vulnerable (Eriksen et al., 2015; O'Brien et al., 2007). Furthermore, recommended adaptations are typically aimed at groups of people that are believed to be disproportionally at risk of loss or harm due to climate change (Eakin et al., 2009). For example, Kelly and Adger (2000) write that the poor in developing countries have higher vulnerability to climate change than wealthier people and that their vulnerability can be reduced through poverty alleviation, risk-spreading via income diversification, preservation of common property management rights, and strengthened collective action and investment by communities.

The vulnerability approach has a few key strengths for assessing climate impacts. Authors emphasise that how people are affected by and respond to climate change is influenced by a wide breadth of variables across different domains and scales (Adger, 2006; Engle, 2011; Leichenko and Silva, 2014; Smit and Wandel, 2006). The vulnerability approach aims to capture this breadth of variables in its assessments rather than limiting its scope to specific areas. This helps to ensure that important factors related to climate change adaptation are not neglected. Next, vulnerability assessments can reveal issues that affect the day-to-day lives of people and that should be addressed even if climate change is not considered (e.g. discriminatory practices) (Eakin and Luers, 2006). Finally, the vulnerability approach can promote social justice through demonstrating how systemic inequalities cause some people to be more adversely affected by climate change than others (Adger et al., 2006; O'Brien and Wolf, 2010). Promotion of a social justice angle can create a compelling moral imperative to act on the findings of the assessment. It may also be argued that, ethically, disadvantaged groups should be identified and prioritised for assistance.

The vulnerability approach to assessing climate change impacts has drawbacks as well. One such drawback is that place-based assessments of contextual variables that influence vulnerability may have limited generalisability (Vogel, 1998). If assessment findings come from information about structures and processes that are specific to a single site, it can be difficult to transfer these findings to other settings. Vulnerability assessments also tend to focus on how people presently experience climate variability, or how they have in the past, in order to make assumptions about how they will experience future climate change (Eakin et al., 2009). Past and present experiences with climate variability may provide limited insight on how people will react to future climate change if climate change effects are unprecedented (Adger et al., 2003). Lastly, vulnerability assessments in practice tend to be anthropocentric and overlook how human responses to climate impacts affect the natural environment (Miller et al., 2010). Consequently, environmental degradation that does not immediately impact the social system of focus could go unnoticed.

2.2.3 Resilience

The SES resilience perspective emerged from the field of ecology in the 1960s and 1970s and has evolved to take on different meanings (Folke 2006). In its initial conceptualisation, resilience was measured in terms of a system's resistance to disturbance (i.e. the amount of force needed to displace a system from its equilibrium or stable state) and its speed of return to equilibrium after being displaced (Holling 1996). Over time, this linear understanding of resilience fell out of favour with researchers studying SESs as being too simplistic when applied to complex and adaptive environmental and human systems (Folke et al. 2010). More specifically, researchers studying SESs argued that conceptualising resilience in terms of resistance and return time to equilibrium ignored that complex SESs exist in a constant state of dynamic change rather than persisting at some stable equilibrium, and that there are limits to which an SES can be disturbed before it fundamentally changes (Carpenter et al., 2001; Walker et al., 2004). With this understanding, resilience came to be generally understood by SES researchers as "the capacity of a system to absorb disturbance and reorganize so as to retain essentially the same function, structure, and feedbacks—to have the same identity" (Walker and Salt, 2012, p. 3). This is the definition of resilience that I employ in this thesis.

The resilience approach that I describe in this section mostly relates to how systems maintain their overall structure and functions against disturbances in general. This is sometimes referred to in the SES literature as "general resilience" as opposed to "specified resilience" which is "resilience of some particular part of a system, related to a particular control variable, to one or more identified kinds of shocks" (Folke et al., 2010). Specified resilience may be used as a concept to guide assessments of system resilience to specific hazards. However, specified resilience is relatively weakly theorised in the literature compared to general resilience.

It should also be noted that some authors consider "transformability" to be a part of resilience while others consider it to be a separate concept (Béné et al., 2014; Hahn and Nykvist, 2017; Wilson et al., 2013). Transformability is "the capacity to create a fundamentally new system when ecological, economic, or social (including political) conditions make the existing system untenable" (Walker et al., 2004). In this thesis, I consider transformability to be a related, but separate, concept to

resilience because the definition of resilience with which I work relates to a capacity to maintain structure and function rather than to change. The SES characteristics that enable a system to transform are distinct from those that enable it to maintain its state (Wilson et al., 2013), thus I consider transformability to be outside the scope of my research.

The resilience approach tends to follow a positivist tradition (Miller et al., 2010). The ontology of resilience is the SES comprising observable social and ecological components (e.g. see McGinnis and Ostrom (2014)) and emphasises ecological-biophysical dimensions (Brown, 2014; Cote and Nightingale, 2012; Miller et al., 2010). Although social aspects, such as management practices, feature in resilience analyses, the focus tends to be naturalistic (i.e. a belief that all outcomes arise from natural properties and causes) (Miller et al., 2010).

Resilience assessments aim to deepen understanding of system dynamics (Quinlan et al., 2016). Five key concepts that are frequently used to guide understanding of SES dynamics are self-organisation, thresholds, linked domains, the adaptive cycle, and linked scales (Walker and Salt 2012).

Self-organisation refers to the ability of interacting components within an SES to organise themselves without the need for external forces (Carpenter et al. 2001). This means that if one component of a system changes (on its own or because it was disturbed by an external force), other components of the systems can adjust themselves in response (Walker and Salt, 2012, p. 4). For example, users of a shared natural resource may self-organise rules for harvesting the resource, such as practicing conservation during certain seasons, to avoid depleting it (Ostrom, 2009). Systems that have a higher capacity for self-organisation tend to have higher resilience (Berkes, 2007).

Thresholds represent breakpoints between alternative stability domains in which a system can exist (Resilience Alliance 2010). Although resilience theory rejects the notion that SESs stabilise at a precise equilibrium, it posits that that SESs can exist in stability domains (or basins of attraction) where variables of the SES can change but the SES retains the same overall functions and structure. However, if a disturbance causes one or more of the variables to reach a certain limit (a threshold), the SES enters a new stability domain where the SES has fundamentally

different functions or structure (Folke et al., 2010). A commonly used example of a threshold being breached resulting in a change in stability domains pertains to lake ecosystems. A lake may continue to stay in a clear-water state (i.e. one stability domain) while being polluted by human activities (i.e. being affected by a disturbance) until phosphorous content in the lake (i.e. a variable) reaches a certain concentration (i.e. reaches a threshold) at which point the lake shifts to a turbid-water state (i.e. another stability domain) (Carpenter et al., 1999). Resilience is thus influenced by how close key variables are to crossing a threshold or to what degree they can be altered before crossing a threshold.

The concept of linked domains refers to the interplay between the social and ecological domains. In particular, the focus is on how the structure and function of ecosystems influence services delivered to society and vice versa (Turner 2010). Resilience theory posits that social and ecological systems cannot be conceived in isolation and a change in one system shapes changes in the other (Cote and Nightingale, 2012). Therefore, both social and ecological/environmental system components are critical in influencing resilience.

The adaptive cycle represents an analytical framework for the dynamics of an SES which postulates that complex systems pass cyclically through four phases (Gunderson and Holling 2001): rapid growth and exploitation characterised by accumulation of capital, conservation characterised by stability, collapse characterised by uncertainty and breaking of linkages between system sub-components, and renewal characterised by reforming of the same or new linkages between sub-components. A key feature of this concept is that opportunities for change within an SES usually happen during the collapse and renewal phases (Carpenter et al. 2001). Changes that occur during the collapse and renewal phases can make a system more or less resilient.

The concept of linked scales points to the fact that complex systems influence and are influenced by other systems in which they are nested or other systems that they encompass, and have a dynamic, long-term temporal dimension (Adger et al. 2005). Importantly, this concept emphasises the concern of climate change maladaptation – climate change adaptation actions on one system that negatively

affect other systems now or in the future (IPCC, 2014b). Thus, activities that build resilience at one scale can degrade it at another.

The characteristics, determinants, or features of a system that reflect these concepts to build resilience have long been deliberated, but it appears some consensus has begun to emerge. Reviews of SES resilience theory and practice have identified several characteristics of resilient SESs and management or governance structures and processes that promote resilience (Bahadur et al., 2013; Biggs et al., 2015; Walker and Salt, 2012). These resilience characteristics are categorised in varied ways by different authors but appear generally consistent. Biggs *et al.* (2015) propose "principles" for building characteristics of resilience in SESs (Table 1).

Table 1. Principles for building resilience

Principle	Definition
Maintain diversity and redundancy	Optimise levels of diversity and redundancy of SES components such that there are multiple options and insurance for responding to disturbances
Manage connectivity	Understand the way and degree in which SES components are connected to one another, and strengthen connections that spread useful material or information while weakening connections that propagate disturbances
Manage slow variables and feedbacks	Identify slow-changing variables that are key to keeping a system stable and prevent the variables from crossing thresholds that would cause system collapse. Strengthen feedback loops that keep key variables within thresholds and weaken feedback loops that do the opposite.
Foster complex adaptive systems thinking	Promote a worldview or mental model that views the world as comprising dynamic and interacting systems.
Encourage learning	Encourage learning through experimentation and monitoring. Promote adaptive co-management and adaptive governance.
Broaden participation	Actively engage all stakeholders in management and governance processes

Promote polycentric governance systems	Implement multi-scalar, nested, and collaborative governance systems that are matched to the scale of the problem

Adapted from Biggs *et al.* (2015)

Resilience assessments are carried out in multiple ways. They can be conducted at a global level or across multiple scales (Eakin and Luers, 2006; Miller et al., 2010), but localised assessments using case studies are especially common (Anderies et al., 2006; Ingalls and Stedman, 2016). Methods ranging from modelling to participatory and action research feature in resilience assessments, and a mix of quantitative and qualitative methods is often employed (Miller et al., 2010). For example, Linstädter *et al.* (2016) assessed resilience of a pastoral system in South Africa that spans across pasture, farm, and landscape scales using scientific quantitative methods to collect data on soil, vegetation, and water flows, and questionnaires and qualitative interviews to collect data on livestock owners.

Information gathered on system dynamics and SES resilience principles from a resilience assessment is used to guide recommended adaptation activities. These adaptations often, implicitly or explicitly, aim to enhance or manage the resilience principles in Table 1. For example, Berkes and Jolly (2002) emphasise the importance of institutions that coordinate local indigenous communities in Canada's western Arctic region with government authorities on land and environment in order to facilitate adaptive responses to climate change (reflective of the resilience principle of polycentric governance systems). They also state these institutions give communities access to scientific information on fisheries which may help them adapt (reflective of the resilience principle of learning) (Berkes and Jolly, 2002).

Community knowledge can play in an important role in resilience assessments. The role of Traditional Ecological Knowledge in making communities adaptive natural resource managers, including against climate change, is often noted (Berkes et al., 2000; Lebel, 2013). More specifically, it is noted that communities often have in-depth knowledge of the complex interactions between environmental resources and their use of them. Drawing on this experiential knowledge is useful because the interactions can be difficult to measure scientifically. However, communities may have limited understanding of physical processes that are hidden (e.g.

underground hydrology) or how future climate change could alter environmental processes, and insufficient scientific knowledge and tools for water assessment.

The resilience approach also has key strengths for assessing climate impacts. First, it aims to take a holistic approach to understanding the complex and dynamic interactions between human and environmental systems (Cote and Nightingale, 2012). This is useful because, historically, research on climate change adaptation has often concentrated on social or environmental systems with little consideration for the others (Eakin and Luers, 2006). Second, like vulnerability assessments, resilience assessments are able to capture a wide breadth of variables beyond those pertaining to direct biophysical impacts of climate change on physical systems (Engle et al., 2014). Third, the resilience approach has been described as a boundary object, that is, the concepts that it utilises are fuzzy or imprecise enough that it enables the coordination of different groups with different aims and interests by providing a common discourse (Brand and Jax, 2007; Gillard, 2016). This is helpful for facilitating interdisciplinary dialogue on making sense of the impacts of climate change.

However, the resilience approach has key drawbacks as well. Social scientists have been especially critical of resilience thinking, arguing that it underplays political issues, human agency, and normative issues while assuming that ecological concepts can be transferred to social contexts (Brown, 2014; Stone-Jovicich, 2015).. This can lead to important social dimensions of climate impacts being left out of assessments. Additionally, notwithstanding the benefit of resilience acting as a boundary object as discussed above, the imprecision of resilience concepts makes them difficult to operationalise (Gillard, 2016). Difficulties with operationalisation pose an obstacle to translating resilience ideas into practical assessments. It has also been argued that a shift in thinking from vulnerability reduction to increasing resilience in a development context can be problematic because it leads to recommendations that do not prioritise the needs of the poor and vulnerable groups (Cannon and Müller-Mahn, 2010).

2.2.4 Summary of three approaches

Each of the three approaches that I have reviewed in this chapter is concerned with how systems experience disturbances and their capacity to respond to them (Adger, 2006). However, the ways in which each approach conceptualises the interactions

between systems and disturbances (in the case of this research, climate disturbances) differ significantly in terms of the events or processes on which they focus, the types of systems on which they focus, and their analytical objectives. As a result, climate change impact assessments using each approach have different key strengths and drawbacks and tend to recommend different adaptation actions. A summary of important characteristics of each approach is shown in Table 2.

Table 2. Summary of risk-hazard, vulnerability, and resilience approaches

Characteristics	Risk-hazard	Vulnerability	Resilience
Key concepts	Exposure; sensitivity; hazards	Adaptive capacity; equality; agency; empowerment	Self-organisation; thresholds; linked domains; adaptive cycle; linked scales
Primary systems of interest	Physical	Social	Ecological; social-ecological
Common analytical objectives	Identify hazards and consider likelihood and severity of their impacts	Understand who is least and most likely to cope with environmental disturbances and why	Understand interactions within and between systems and how these sustain overall system functions and structure against disturbances
Commonly recommended adaptation options	Implement technologies; climate-proof infrastructure; improve management of technology	Reduce inequalities; empower people to cope with external stresses in general; poverty alleviation	Optimise or manage resilience properties; develop resilient governance structures and processes
Strengths for climate impact assessments	Intuitive logic; precise bounding of problem; evaluates magnitude of climate change problem	Captures a wide breadth of variables; considers non-climate related issues; promotes social justice	Aims to consider both social and environmental domains; captures a wide breadth of variables; resilience as a concept is a boundary object for multiple disciplines
Drawbacks for climate impact assessments	Significant uncertainty at local levels; tends to overlook non-biophysical factors; partially reliant on Western science	Limited generalisability of findings; assumes people will act in the future similarly to how they act now; tends to overlook effects on the natural environment	Tends to overlook political and normative issues; some concepts remain difficult to operationalise

2.2.5 Concluding remarks

Although I have presented the risk-hazard, vulnerability, and resilience approaches to assessing climate change impacts discretely, they may be used together jointly. Many authors note that the approaches are largely complementary (Eakin and Luers, 2006; Miller et al., 2010; Nelson et al., 2007; O'Brien et al., 2007; Turner,

2010). One way in which they are complementary is that certain characteristics of one approach sometimes fill a gap in another. This is clear from looking at the characteristics listed in Table 2. For example, the approaches focus on different types of systems such that using them all together would help to ensure that a climate change impacts assessment is holistic.

Another way in which the approaches are complementary is that they contribute thinking to one another on areas where they overlap. For example, the topics of governance, institutions, and management are common areas of interest (Engle, 2011). Vulnerability thinking contributes ideas around power relations to the management space while resilience thinking contributes ideas on experimentation and innovation.

I discuss how the different approaches can be drawn on in a climate change impact assessment in relation to community-managed water services in Vanuatu further in Chapter 4.

2.3 The Vanuatu context

In this section, I provide details about the context in which I conducted the fieldwork for my research. I first give a broad overview of the country of Vanuatu. I then give an overview of government bodies that are directly related to the delivery of water services or climate change adaptation. Later, in Chapter 6, I refer to these government bodies to discuss how the findings of my research are relevant for different stakeholders in Vanuatu. I provide details about the specific case study sites in my research in section 3.7.

2.3.1 The country of Vanuatu

Vanuatu is a sovereign archipelago nation located approximately 1,750 km east of Australia in a region of the South Pacific Ocean known as Melanesia (Figure 1). Vanuatu comprises 81 islands, averaging 167 km^2 in area and 330 m in maximum elevation, that collectively cover 13,526 km^2 of land area (Nunn et al., 2016) (Figure 2). Geologically, the islands are primarily volcanic or limestone (Falkland, 2002), the former of which are characterised by a topography of peaks and valleys and the latter by flat tabular surfaces (Nunn et al., 2016).

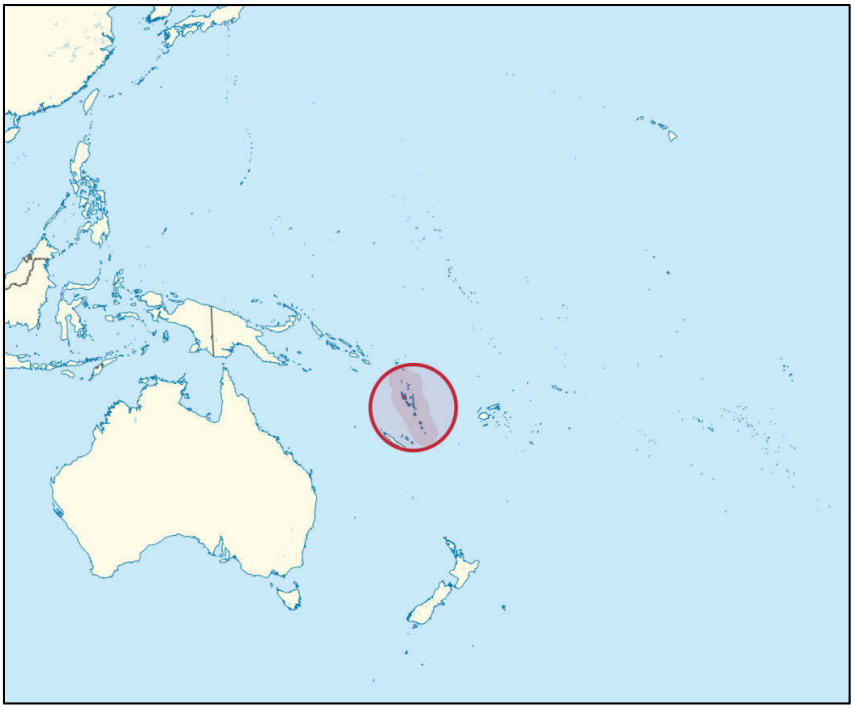


Figure 1. Location of Vanuatu relative to Australia (Source: commons.wikimedia.org)

Figure 2. Map of Vanuatu (Source: commons.wikimedia.org)

Vanuatu has a tropical climate that follows a distinct seasonal cycle influenced by local topography and regional climatic phenomena. The country generally experiences its highest average monthly temperatures and rainfall from January to March (25°C and 333-346 mm) and lowest from July to September (22-23°C and 156-159 mm) (World Bank 2017). However, the climate can vary considerably depending on the phase of the El Niño-Southern Oscillation and the presence of mountains influences rainfall variation on some islands (VMGD et al., 2011).

Vanuatu is also highly exposed to climate-driven extreme events. Historically, the country experiences two to three cyclones per season (cyclone season being November to April) on average and incidences of drought and flooding are prevalent (Australian Bureau of Meteorology and CSIRO, 2011; VMGD et al., 2011). A recent World Risk report identified Vanuatu as the most exposed country in the world to natural hazards, calculated as a function of the proportion of the national population exposed to particular hazards (although earthquakes, which are non-climate driven, are included in the calculation) (UNU-EHS, 2016).

Socio-economically, Vanuatu is classified by the United Nations as a Least-Developed Country (UN, 2017a). The total population is estimated to be 276,000 (UN, 2017b) with 74% of people living in rural areas (WHO and UNICEF, 2017). Populations in rural areas primarily make a living through subsistence work (Government of Vanuatu, 2009, p. 103) and, in 2010, 10% of rural dwellers lived underneath the Basic Needs Poverty Line (VNSO and UNDP, 2012).

The culture of the ni-Vanuatu reflects a noticeable blend of their indigenous past and more recent Western influences. The population of Vanuatu is made up of 99% indigenous people, ethnically referred to as Melanesians (Government of Vanuatu, 2016b, p. 115), who first migrated from the Guinean and East Asian regions to settle on the islands around 3,000 years ago (Skoglund et al., 2017). Today, Vanuatu is renowned for its cultural diversity which, in part, is represented by the estimated 138 indigenous languages spoken throughout the country (Francois et al., 2015). Bislama (an English creole), English, and French are the national languages as a result of the joint colonisation and rule of the country by Great Britain and France from 1906 to 1980. Although forces of globalisation, development, colonialism, and Christian proselytisation have heavily shaped beliefs and values in modern-day

Vanuatu (Campbell, 2009), there is still deep reverence for *kastom* – indigenous values and mores (e.g. the sanctity of the *nakamal* where ceremonies and other gatherings are held) that have persisted since pre-colonial times (Goddard and Otto, 2013, p. 4).

Water services in rural areas of Vanuatu are typical of those in many low- and middle-income countries. National level statistics indicate that 87% of the rural population has access to at least basic water services[7] and 43% has water accessible on premises (WHO and UNICEF, 2017). This is a modest increase from 78% of the rural population with access to at least basic water service and 38% with water accessible on premises in 2000 (WHO and UNICEF, 2017). In 2013, approximately 12% of 1,103 children in rural areas were reported to have had diarrhoea, a potentially fatal condition associated with water-related diseases, (VNSO and SPC, 2014) and diarrhoeal diseases account roughly 6% of deaths of children under the age of 4 in Vanuatu (Carter et al., 2016). The most common water supplies in rural Vanuatu are shared piped supplies and rainwater collection systems (Government of Vanuatu, 2016b). Installation of rural water supplies is frequently financed through government, civil society, or NGOs (Mommen et al., 2017). Meanwhile, their ongoing operation and maintenance, in theory, are undertaken by community-based water committees and financed through user fees (Mommen et al., 2017). In contrast, urban areas in Vanuatu typically receive water services from government or private utilities and 99% of the urban population has access to at least basic water service (WHO and UNICEF, 2017). The total national expenditure on non-utility based WASH services in Vanuatu in 2016 was estimated to be just 0.26% of the national GDP, the lowest of 25 developing countries surveyed in a recent World Health Organization report (WHO, 2017).

2.3.2 Climate change and society in Vanuatu

Vanuatu has already begun to experience some measurable effects of climate change and will likely continue to for the foreseeable future. Specifically, a significant warming trend in air temperature and a rise in mean sea-level has been measured (Australian Bureau of Meteorology and CSIRO, 2011). Climate change

[7] Drinking water from an improved source, provided collection time is not more than 30 minutes for a round trip, including queuing (WHO and UNICEF, 2017)

projections and their potential direct impacts on water supplies is discussed later in this thesis in section 4.2.2.

While the Government of Vanuatu has recently taken a proactive stance to addressing climate change impacts, as detailed in section 1.1, other forces have already long shaped how society in Vanuatu interacts with climate. In some ways, globalisation, the process of international institutions influencing and integrating markets and lifestyles across national borders, has made Vanuatu and other Pacific island countries more susceptible to harm from climate change through reducing agro-ecological biodiversity, settlement security, and inter- and intra-community cooperate (Campbell, 2009). In other ways, globalisation has strengthened small island developing states like Vanuatu through institutionalised cooperation at a global scale, increased foreign investment, and identity politics (Pelling and Uitto, 2001).

At a more local scale, communities in Vanuatu have long coped with substantial climatic variability and natural disasters. Community members in Vanuatu have been documented to follow traditional practices for building temporary evacuation centres when cyclones are incoming and helping one another move to secure places (McNamara and Prasad, 2014). During droughts, communities use local knowledge of the land to grow drought-resistant crops and locate alternative water sources (McNamara and Prasad). Such knowledge is developed experientially in Vanuatu and is often handed down across generations through oral traditions such as storytelling (Walshe and Nunn, 2012). In addition to informing coping and adaptation actions, experiences with environmental change have likely shaped the way Pacific island communities in Vanuatu and elsewhere form relationships with one another (e.g. adversarial or cooperative) (Nunn, 2003).

Presently, the threat of climate change does not strongly influence the behaviours of rural-dwelling Ni-Vanuatu people who typically enjoy the stability of familiar lifestyles. Many rural communities are still unaware of climate change and its effects, and opt for natural resource management strategies that have worked in the past but may not be sustainable under future climatic changes (Nunn et al., 2014). Where awareness of climate change does exist, communities in Vanuatu may prioritise maintaining their way of life and view conformity to traditional

values and practices as preferred strategies for responding to climate impacts (Granderson, 2017). While some of these traditional practices, like the ones noted above, help communities cope with extreme weather, others may be counterproductive. For example, many Ni-Vanuatu strongly support customary land governance which excludes women from being land owners (Naupa, 2017). If natural resources, including clean water, become more scarce, traditional customs such as this can cause disproportional harm to women.

2.3.3 Government bodies related to water and climate change

There are three government bodies directly related to the delivery of water services or climate change adaptation to rural communities in Vanuatu: the Department of Water[8] (DoW), the Department of Local Authorities (DLA), and the National Advisory Board for Climate Change and Disaster Risk Reduction (NAB). In this section, I give a brief overview of the structure and responsibilities of these departments to introduce them to the reader. In Chapter 6, I discuss how these departments can use the findings from my research to improve their support for sustaining community-managed water services against climate change.

The DoW, which sits within the Ministry of Lands and Natural Resources, is the primary government body responsible for supporting the delivery of water services to rural populations in Vanuatu (Connolly, 2016). More specifically, the DoW is responsible for responding to community requests pertaining to water supply development, the technical design of new water supplies, water quality surveillance, and coordination of WASH NGO activities (Connolly, 2016; Government of Vanuatu, 2017a, 2008). As recently as 2011, the DoW was severely understaffed with a total of nine permanent staff members (ISF-UTS, 2011). However, the number of DoW staff members has since grown to 18 with plans to eventually expand to 63 (Gregor, 2016). Per the recommendation of the 2008 – 2018 National Water Strategy (Government of Vanuatu, 2008), the DoW is also undergoing a restructure that facilitates the decentralisation of resources and decision-making from a national to provincial level (Government of Vanuatu, 2017a). Per the draft National Water Policy (Government of Vanuatu, 2017b), decentralisation of decision-making includes giving provincial government greater authority to create local water by-laws. Details on how the allocation of resources

[8] Formerly the Department of Geology, Mines and Water Resources

will be decentralised have not been publicly released. Figure 3 shows an organogram of the current DoW structure with some positions yet to be filled.

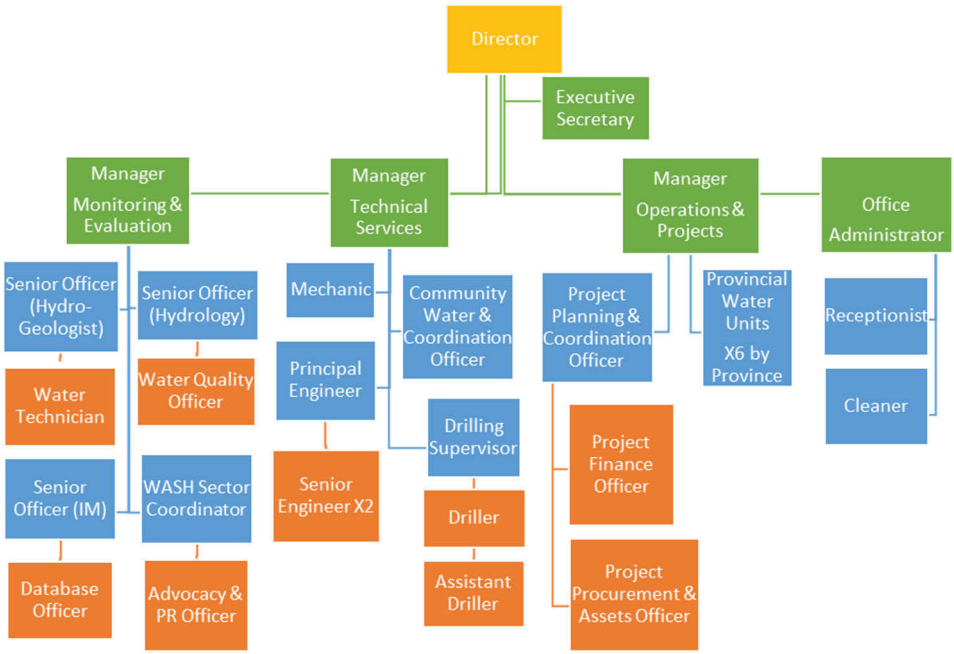


Figure 3. Department of Water organisational structure (Source: Government of Vanuatu, 2016c)

At the time of my visit, each of the provincial water units had only one staff member that was responsible for providing support for rural water services in each province. This staff member was called the Community Development Officer. The responsibilities of the Community Development Officer included receiving community requests for water supply projects, providing technical and managerial training to community water committees, assisting with the implementation of water supply projects, and monitoring the activities and work plans of community water committees (Government of Vanuatu, 2016c). However, as part of the ongoing decentralisation strategy, more positions at a sub-national level for providing support for rural water services were planned to be added in the future.

The DoW's intent to decentralise government support for the delivery of water services reflects a wider trend in rural water service delivery throughout the developing world. Many authors note that, even with substantial investment in

appropriate technologies, consultations on community preferences, and community training, community-managed water services frequently fail without ongoing external support (Carter et al., 1999; Chowns, 2015; Harvey and Reed, 2007; Hutchings et al., 2015; Schouten and Moriarty, 2003). The WASH sector increasingly sees local government authorities as the best positioned entity to provide external support (Cairncross et al., 2010; Hucks, 2008; Moriarty et al., 2013). In particular, local government is viewed as a *service authority* whereby it is not responsible for providing water services to communities, but instead is responsible for supportive functions such as planning, monitoring, regulation, and post-construction advice (Lockwood and Smits, 2011, p. 88).

Another government department that is relevant to rural water service delivery in Vanuatu is the DLA which sits within the Ministry of Internal Affairs. Vanuatu's constitution provides for decentralisation through the administration of local government regions by councils (Sansom, 2013). Urban areas are overseen by municipal councils while rural areas are overseen by provincial councils, both of which are a part of the DLA. Six provincial councils exist (one for each province of Vanuatu) and comprise a mix of elected and appointed members which must include representatives of chiefs, women, youth, and churches (Sansom, 2013). Each provincial council is headed by an elected Secretary General. Provincial councils are responsible for ensuring that national policy and legislative directives are enacted in their provinces (Hassall and Tipu, 2008). Area Secretaries, one for each area[9] in the country, monitor activity in their area and report to the provincial council (Hassall and Tipu, 2008). The provincial councils are expected to work jointly with the DoW to ensure that water services are being delivered to communities (CLGF, 2014).

In 2013, an amendment to the Vanuatu *Decentralisation Act* was made to form and recognise area councils under the supervision of the provincial councils (Government of Vanuatu, 2013). These area councils are intended to provide a more immediate presence of government amongst rural communities and ensure that service delivery is more equitably distributed throughout rural Vanuatu (GEF,

[9] An area is a geographic region at a sub-provincial level. There are 72 areas total in Vanuatu.

2014). The overall functions of area councils are newly established for local government and are as follows (Government of Vanuatu, 2013):

- *"Review and consolidate community action plans for each community within that area council division or district;"*
- *"Develop an area council Strategic Development Plan for the relevant area council division or district;"*
- *"Coordinate, monitor and report to the relevant Provincial Government Council on the implementation of the relevant area council Strategic Development Plan."*

Under the *Decentralisation Act*, area councils and Area Secretaries together identify community development needs and document them under community action plans and strategic development plans. Area Secretaries report these plans to the provincial councils, sometimes through an Area Council Development Officer if one is appointed to oversee the province's area councils. Community development needs can pertain to any sector, including water service. Once development needs are communicated to the provincial council, the provincial council can choose to disburse funds for community development projects such as water supply. A diagram showing the structure for reporting community needs through the DLA is shown in Figure 4.

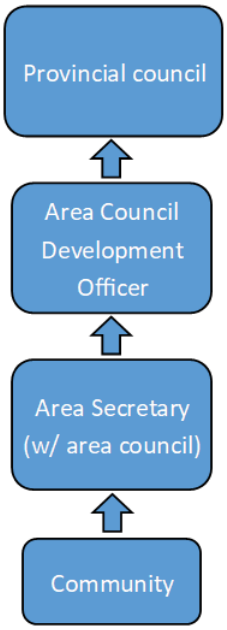


Figure 4. Structure for reporting community needs within the DLA

The NAB is the primary entity that oversees climate change adaptation activities in Vanuatu. The NAB is led by the government with co-chairs from the Vanuatu Meteorology and Geo-hazards Department and the National Disaster Management Office and includes members from various line ministries and civil society organisations (Nalau et al., 2015). The purpose of the NAB is to supervise the consistency and appropriateness of government and NGO climate change and disaster risk policies, agendas, strategies, projects and decision-making in the country (Nalau et al., 2015; Vachette, 2017). The NAB seeks to achieve its animus by advising government agencies on the priorities of the Vanuatu Climate Change and Disaster Risk Reduction Policy, coordinating climate change activities and projects across government departments, NGOs, and donors, and facilitating the implementation of projects through a programme of small grants (Government of Vanuatu, 2015). The auspices of the NAB reach across all sectors of government, including water service delivery.

In this section, I have provided details on the geographic context of Vanuatu where I conducted my fieldwork for this research. In Chapter 3, I describe the methodology for that fieldwork.

2.4 Summary

In this chapter, I have introduced three approaches to understanding how systems are affected by and respond to impacts of climate change, and described the context in which my fieldwork took place. I first described the risk-hazard, vulnerability, and resilience approaches, each of which are prominent bodies of theory-practice in the general climate change and global environmental change spaces, that the WASH sector could usefully draw on to understand climate change impacts on water services. I described how the approaches can be used to guide assessments of climate impacts on systems and discussed strengths and drawbacks of each. Discussing these approaches sets the stage for Chapter 4 where I use them to demonstrate how climate change impacts on community-managed water services in Vanuatu can be assessed. I also provided an overview of the country and administrative contexts in which my fieldwork took place. This provides needed background for Chapter 6 in which I discuss how the findings from Chapters 4 and 5 inform stakeholders in Vanuatu in order to strengthen their assessments of the capacity of community-managed water services to sustain water access against climate change disturbances.

Chapter 3. Methodology

Chapter preface

This chapter contains re-formatted and adapted portions of co-authored journal submissions. The details of these submissions are:

Kohlitz, J.P., Chong, J., Willetts, J., 2017. Climate change vulnerability and resilience of water, sanitation, and hygiene services: a theoretical perspective. J. Water Sanit. Hyg. Dev. 7, 181–195. doi:10.2166/washdev.2017.134

Statement of contribution

In the study that generated this journal submission, I led the research design, data collection, and data analysis. Joanne Chong and Juliet Willetts provided substantial feedback and advice on these activities. I wrote the journal submission and Joanne Chong and Juliet Willetts reviewed and provided substantial feedback on and approval of the manuscript.

3.1 Introduction

In this chapter, I describe the research methodology undertaken to answer my three research questions:

Research question #1: What contributions do the risk-hazard, vulnerability, and resilience approaches make to understanding how community-managed water services are affected by and sustained against climate change disturbances?

Research question #2: How can climate change risk-hazard, vulnerability, and resilience assessments be conceptually integrated with respect to community-managed water services?

Research question #3: How can the findings from research questions #1 and #2 be drawn on to develop recommendations for policy-makers, practitioners, and researchers in Vanuatu to better assess the capacity of community-managed water services to sustain water access against climate change disturbances?

Before describing my methodology, it is useful to provide a prelude to orient that reader that summarises how I answered my research questions. I answered research question #1 through a literature review and the collection of data from two rural community case study sites. I reviewed WASH literature with a climate change focus to determine whether the studies most closely aligned with the risk-hazard, vulnerability, or resilience approach and to describe how the studies problematise climate change. I also conducted individual risk-hazard, vulnerability, and resilience assessments of the community-managed water service in two rural communities using interviews, surveys, and observations, and compared and critiqued the outcomes of each assessment. The resulting comparison/critique analysis answers the research question.

I answered research question #2 through a combined analysis of existing literature and my findings on research question #1. In particular, I synthesised existing theories from the literature on the risk-hazard, vulnerability, and resilience approaches using a conceptual integration technique that focuses on building a framework around nexus concepts – concepts that are shared by different theories. I reflected on my emerging framework with regard to my findings from research question #1 to refine it further. Since the conceptual framework emerged as a

product of my engagement with the different conceptual approaches in the field, the framework was not available for me to use until after I had collected from the field. However, I apply the framework retrospectively to my case study findings to show it may be used to assess various elements of the capacity to respond to climate change disturbances. The conceptual framework that I developed from this process serves to answer research question #2.

I answered research question #3 through the collection of data from local government authorities, a review of government policy, and a review of an NGO framework. Initially, I aimed to make research question #3 especially relevant for local government authorities (area and provincial councils from the DLA and Community Development Officers from the DoW) in Vanuatu. In particular, I intended to co-produce solutions with local government authorities using strengths-based approaches to build on their successes to address challenges that they encountered. I initially checked with provincial government authorities to see if active area councils had been established in the case study sites. However, after I began data collection, I found that the area councils that had agreed to participate in my research were, in fact, mostly inactive. Furthermore, throughout the duration of my time in the field, I was unable to meet in person with Community Development Officers from the DoW (although I was able to speak with one briefly over the phone). Due to these difficulties, I changed the scope of research question #3 to focus on a wider range of stakeholders. In this chapter, I describe the methodology I followed for collecting data with government participants because it still yielded a few useful insights. I also describe how I collected and analysed relevant government and NGO documents. In Chapter 6, I answer research question #3 through a discussion of how the findings of research questions #1 and #2 are useful to local and central government, NGOs, and researchers by drawing on the data I was able to collect from government authorities and from available policy documents. With respect to research question #3, a methodology for investigating how the findings are relevant to community stakeholders is not included in the scope of this research. Although this is an important area, translating academic and scientific knowledge into locally understandable and relevant information is challenging and requires further time and resources beyond what was available to me in this research project.

The structure of this chapter roughly follows the chronological order in which the steps occurred. First, I describe why I chose Vanuatu as the main country of reference for my research. I then explain why I chose a case study methodology to answer my research questions. Next, I describe the practical activities I undertook to prepare for data collection in the field and how I selected the case study sites. I then describe the ethical considerations I took in the planning and implementation of the data collection activities. After, I describe the case study sites in which I collected data and the methods I used. Finally, I describe how I processed, analysed, and wrote up the collected data and discuss the limitations of the methodology that I followed.

3.2 Country selection

I decided to focus my research on the context of a single developing country for two reasons. First, reaching my research aim through an investigation in a single country allowed me to achieve the depth I needed to answer my research questions. An investigation of multiple country contexts would not have allowed me to achieve this depth due to the time and resource constraints of my doctoral programme. Second, situating my research in a specific country context increases the likelihood that the research findings are relevant and stimulate real-world improvements.

I chose to focus my research on Vanuatu because of my previous experience working in the Pacific island region[10] and its suitability for the scope of my research. Prior to my doctoral programme, I served as a Peace Corps Volunteer in Fiji for three years. During this time, I worked with the Secretariat of the Pacific Community where I provided research and programmatic support to WASH projects all around the Pacific island region. I gained valuable knowledge and a keen interest in WASH issues in Pacific islands from this experience, which I could beneficially leverage for my thesis by researching in a Pacific island context.

Within the Pacific island region, I chose Vanuatu based on a set of selection criteria and a process of elimination that I used to identify countries with suitable characteristics for this research. My selection criteria included countries with

[10] The Pacific island region comprises 22 countries and territories: American Samoa, Cook Islands, Federated States of Micronesia, Fiji, French Polynesia, Guam, Kiribati, Marshall Islands, Nauru, New Caledonia, Niue, Northern Mariana Islands, Palau, Papua New Guinea, Pitcairn Islands, Samoa, Solomon Islands, Tokelau, Tonga, Tuvalu, Vanuatu, and Wallis and Futuna

geographic diversity, large proportions of the population relying on community-managed water services, and governments that have indicated that water and climate change are national priorities to address. I also made pragmatic considerations including the cost of transport to the country, my existing network of contacts, language barriers, and my personal career aspirations. Vanuatu is geographically diverse with 81 separate volcanic, limestone, and atoll islands that rely on surface water, groundwater, and collected rainwater to meet water needs (Duncan, 2011). The majority of Vanuatu's population lives in rural areas where communities manage their own water supplies (VNSO and SPC, 2014). Finally, the Government of Vanuatu has recently been highly active in addressing climate change (Nalau et al., 2015) and colleagues informed me that the delivery of water services was to be featured in the country's new National Sustainable Development Plan.

In addition to the suitability criteria above, I removed other Pacific island countries and territories from consideration using a process of elimination. Eight states in the Pacific island region are territories of developed nations and have limited autonomy compared to the independent Pacific island countries (Levine, 2009). I did not choose these territories because their development contexts (e.g. current standards of living and development trajectories) are dissimilar to most developing countries which would affect transferability of my research findings. A large proportion of the populations of Nauru, Niue, Samoa, and Palau (86% or more) are serviced by water utilities (PWWA, 2013) leaving only a small segment of the population that would fit within the scope of the research. Researcher fatigue on the topic of climate change has been noted to be problematic in Tuvalu (Mortreux and Barnett, 2009) and Kiribati (Conway and Mustelin, 2014) and transportation costs to these countries from my base in Australia are relatively high. Lastly, Papua New Guinea is included in the Pacific island region, but its population and land mass are much greater than what one would normally associate with an island setting and there were potential safety and security issues. All of these issues were not present in Vanuatu which, along with the criteria described above, made it a suitable country in which to employ a case study methodology to investigate my research questions.

3.3 A case study methodology

I employed a case study methodology for collecting data from the field because it was especially suitable for answering the research questions. With respect to research questions #1 and #2, the case study methodology was especially suitable for collecting data pertaining to vulnerability and resilience. Case studies are appropriate where in-depth and detailed understanding of a situation is desirable (Creswell, 1998). There is much to be gained from an in-depth investigation of vulnerability and resilience in a specific place because the processes and factors that influence vulnerability and resilience are highly complex and context-specific (Armitage et al., 2012; Hinkel, 2011). As such, case studies are a common methodology in both vulnerability and resilience research (Anderies et al., 2006; Ford et al., 2010; Miller et al., 2010).

Case studies are relatively less common in risk-hazard research, which instead generally opts for methodologies that can be used at broad scales (Eakin and Luers, 2006; O'Brien et al., 2007). Risk-hazard research can be and has been conducted at a community level (Hay and Mimura, 2013). Yet, if research question #1 is meant to demonstrate the contributions that the risk-hazard approach makes to understanding climate change impacts on water services, would this aim have been better accomplished by using a methodology that leverages the risk-hazard approach's strength of doing assessments at broad scales? There are a few reasons why I used a case study methodology for the risk-hazard approach. First, using a consistent methodology across the three theoretical approaches facilitates a direct comparison between them to discuss their relative merits. Indeed, new insights can be gained when different epistemological approaches are employed and contradictory results are probed (Nightingale, 2016). Second, the risk-hazard approach can still generate useful insights at local scales. Third, I show examples from elsewhere in the WASH literature of the contributions of broad-scale risk-hazard assessments in section 4.2.1 which demonstrates the utility of the approach at broader scales.

The case study methodology was also appropriate for gathering local information on government authorities in order to address research question #3. Although information on the operations of local government can be collected through documents such as job descriptions and policies, the actual operations that

authorities carry out day-to-day can be different. Case studies allowed me to gather context-specific data on the daily working environment of local government authorities.

Another reason that the case study methodology was advantageous was because it gave detailed insight into a place that the outside world seldom sees. Rural areas of Vanuatu are challenging for outsiders to access for a variety of reasons, including difficult terrain to cross to reach rural areas, health and safety concerns, limited communication and transport infrastructure, language and other cultural barriers, and ethical considerations. Consequently, there is little in-depth place-based research in rural Vanuatu relative to other places in the Western world. These barriers also make it challenging for rural communities in Vanuatu to voice their thoughts and concerns to the outside world. The case study methodology allowed me to observe and document interesting dimensions of local life that are often unseen by outsiders and to give visibility to some of the issues raised by the research participants.

I decided to collect data from two case study sites to allow for comparison between sites and to gather a wide breadth of data. Comparison between multiple case studies allows researchers to confirm emerging propositions by observing them in independent sites (Santos and Eisenhardt, 2004). With respect to my research, this meant confirmation of the applicability of risk-hazard, vulnerability, or resilience concepts to community-managed water services (Chapter 4), confirmation of propositions that I was considering to include in my conceptual framework (Chapter 5), and confirmation of the circumstances under which local government authorities in Vanuatu operate (Chapter 6). Multiple case studies also allow researchers to extend their analyses, that is, reveal more complementary aspects of a phenomenon (Santos and Eisenhardt, 2004). With respect to my research, this meant extending my analyses to different geographic and social contexts (I discuss my purposive selection of different contexts further in section 3.5 below).

One key disadvantage to the case study methodology is that it is often criticised for a perceived lack of generalisability of findings (Denscombe, 2014). That is, how does one know if a finding is specific to the case study site(s) or likely to be found elsewhere? This point is especially salient in the context of Vanuatu where there is

immense cultural diversity and variance in local government processes across different islands (R. McNaught, personal communication, 10 December 2015). In qualitative case study research, it is normally not possible to prove that findings from one study can be applied to other situations, so researchers instead aim to provide sufficient contextual information such that readers can relate the findings to their own situations (Shenton, 2004). With respect to research question #1, I provide this contextual information in section 3.7 and throughout Chapter 4. With respect to research question #2, I compare my case study findings to theory developed over the course of many years from different sectors to develop a framework that has wide applicability. With respect to research question #3, I complement my local case study methods with document analyses and interviews of central government authorities (discussed further in section 3.8) to understand the prevalence of the aspects that I examined locally.

Once I decided on a case study methodology, I needed to arrange resources, make contacts, and gather information to prepare for my data collection activities in the field.

3.4 Preparation for data collection in Vanuatu

Before entering the field to collect data, I needed to do a substantial amount of planning and preparation. First, I made contacts on the ground in Vanuatu via professional networking. I had never been to Vanuatu before my doctoral research and my research was not tied to any existing project or programme. Therefore, I needed to establish new contacts that could help me situate my fieldwork. I began networking by contacting practitioners and researchers who were currently working or had worked in Vanuatu through phone or email. I initially identified and was introduced to these individuals through people in my immediate professional network. These individuals introduced me to other people, including central government authorities, working in Vanuatu in areas relevant to my research (WASH or climate change adaptation).

Next, I arranged a scoping visit to Vanuatu in order to meet my newly established contacts on the ground, familiarise myself with the country, assess the feasibility and appropriateness of my proposed research design, collect information about potential case study sites, and gain any necessary approvals or permissions to do

research in-country. The scoping visit lasted three weeks from 6 to 25 March 2016. During this time, I met with government authorities at the DoW, DLA, and the National Disaster Management Office who expressed support for my research, provided feedback on my research design, and suggested potential case study sites. I visited the areas where my contacts suggested I might conduct the case studies to assess their suitability and to meet local contacts who could introduce me to individuals and communities that could potentially participate in my research. I also met with NGO representatives to discuss and obtain feedback on my research design. Finally, I visited the Vanuatu Cultural Centre, the Ministry of Internal Affairs, and the Department of Immigration and Passport Services to acquire the necessary approvals and visa to conduct research in Vanuatu.

Before commencing data collection activities, I also arranged for someone to act as a research assistant and interpreter. I identified and hired a capable ni-Vanuatu female for this role via a local contact that I established through the networking process. Although I eventually learned to speak Bislama[11] conversationally over the course of my fieldwork, I initially relied on the services of my assistant for language interpretation during interviews and for help working out logistics. My assistant also acted as a cultural adviser by counselling me on our interactions with local individuals and communities.

Finally, I raised money to fund my data collection activities. Because my PhD research was not connected to any existing project or programme, I worked part-time to secure funding whilst making preparations for the data collection field trip.

After I had become more familiar with Vanuatu and obtained input from my newly established local contacts, I could go about selecting two case study sites.

3.5 Selection of case study sites

I aimed to collect data for each of the research questions across two case study sites. I selected the two case study sites in which I collected data based on considerations of practicality and which sites would yield the richest data. First, I decided that each case study site would include a rural community, an area council, and relevant provincial government authorities. Each rural community was to be located in the

[11] Bislama is the most widely-spoken language in Vanuatu

"area" that the area council oversaw. Likewise, the relevant provincial government authorities were those that operated in the same province in which the studied rural community and area council were located. Each of these community/area council/provincial government sets formed a case study site (Figure 5).

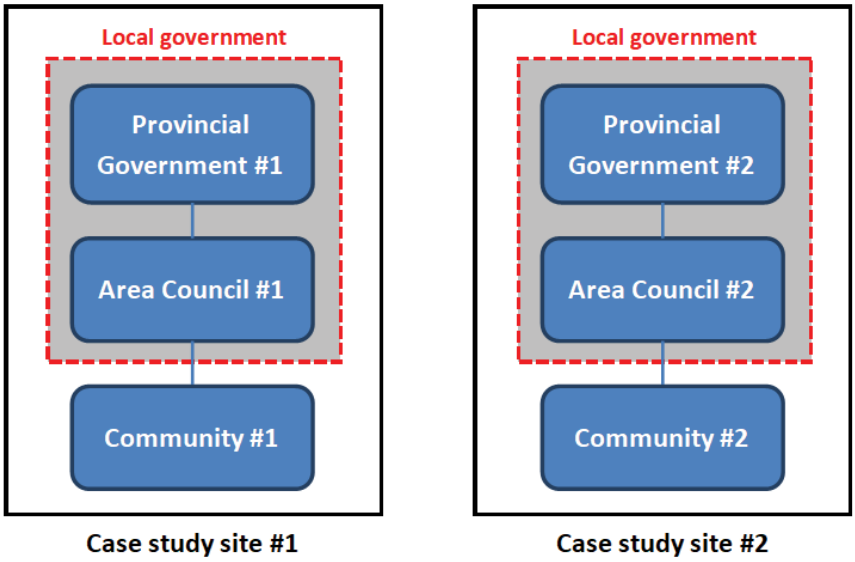


Figure 5. Structure of research case study sites

I was initially open to selecting case study sites in any rural area of Vanuatu, but narrowed down my selection to two provinces following advice from my contacts in Vanuatu. I was advised to avoid areas that were still recovering from Tropical Cyclone Pam which devastated large parts of Vanuatu in March 2015, and areas that were, as of early 2016, suffering from a drought induced by an El Niño event. This is because my data collection activities could have potentially added burden to communities that were already struggling to cope with day-to-day hardships created by the disasters. Most of Vanuatu had been affected severely by Tropical Cyclone Pam or the drought, so my selection of eligible communities was limited to those in the provinces of Sanma and Malampa.

I purposively selected two rural communities, named Namoru and Uripiv, that had different geographic and social characteristics. One of my government contacts advised that I should include a community on a small low-lying island (Uripiv) in one of the case studies because the government believed they were threatened most by climate change. Thus, to complement this geographic context, I sought another

community located away from the coast on a larger island (Namoru). I also looked for communities that relied on different types of water supplies and water resources. Next, I sought communities of different socio-economic standing. In lieu of income data that could indicate the wealth of communities, I looked for one community (Namoru) that was within driving distance of one of Vanuatu's two biggest towns where most of the country's industrial and commercial activities were located, and another community (Uripiv) that was in an area remote from Vanuatu's two largest towns. Finally, given that my assistant and I were travelling alone with no in-country support, I sought communities that were accessible from urban areas should health or safety concerns arise. Before finalising my selection of these two communities, I checked with my government contacts to ensure that area councils had been established for the areas in which these two communities were located. The locations of these communities within Vanuatu are shown in Figure 6.

Figure 6. Locations of rural community study sites (Source: modified from commons.wikimedia.org)

Before I could travel to the case study sites to begin data collection, I undertook an extensive review of the ethical implications of my proposed research design.

3.6 Ethics

I took several major steps to ensure that I conducted my research ethically. Below, I describe ethics consultations that I undertook, the primary risks of my research that I sought to manage, necessary approvals that I acquired, how I planned to bring tangible benefits to my research participants, and how I practised reflexivity to manage the ways in which I may impose my worldview on others.

3.6.1 Consultations

In order to ensure an ethical research design, I undertook numerous consultations, reviewed relevant guidelines and policies, and attended ethics seminars. The in-person consultations that I undertook were with various relevant staff members at the University of Technology Sydney (UTS). Relevant guidelines and policies that I reviewed included the UTS Research Ethics and Integrity Policy (UTS, 2018), the Guidelines for Ethical Research and Evaluation in Development prepared by Australian Council for International Development (ACFID) (ACFID, 2015), the Guidelines for Ethical Research in Australian Indigenous Studies prepared by the Australian Institute of Aboriginal and Torres Strait Islander Studies (AIATSIS, 2012), and the Vanuatu Cultural Research Policy (Vanuatu Cultural Centre, n.d.). I also attended ethics seminars led by the Graduate Research School at UTS and the ACFID University Linkage Network[12].

3.6.2 Managing potential risks

In this section, I describe some of the potential risks or harm that could have occurred to people as a result of my research and how I minimised or managed them. Risks primarily pertained to people directly participating in my research but also extended to other community members, government departments, my assistant, and myself.

One risk was that asking research participants to recall their experiences with natural disasters could have induced emotional distress if participants recalled especially stressful or traumatic memories. Before commencing interviews, I reminded participants of their right to end an interview at any time they wished. I also discussed this risk with my assistant and we agreed to offer to end the interview if either of us observed that the participant was distressed. Fortunately, we did not observe a concerning level of distress during any of the interviews.

Another risk to all research participants was that data collection activities could have caused inconvenience or disruptions to participants' daily routines. I sought to mitigate this risk in the field by being flexible and offering to talk to participants at times and places of their choosing. I also sought to limit my interviews to one hour or less (confirming with participants beforehand that this length of time was

[12] Now named Research Development Impact (RDI) Network

acceptable) to avoid taking too much of the participants' time. Per the advice of one of my local contacts, I did not provide financial compensation to participants because of the potential for it to create competition or discord within communities and government departments.

A risk that was particular to the rural community participants was that certain interview questions could potentially instigate community or household disputes. These questions mainly pertained to the vulnerability analysis in which I asked questions on the participants' satisfaction with the performance of the water committee and their perceptions of how fairly water was managed in the community. I sought to mitigate the risk of instigating a community dispute by maintaining confidentiality of the interviews and reminding the participants that their personal responses would not be shared with others in the community. I managed the risk of instigating a household dispute by avoiding questions that were potentially contentious within the household (e.g. questions about whether participants felt water management decision-making within their own family was fair).

Another risk for rural community participants related to their expectations of what would be the outcomes of my research. Having experienced carrying out research fieldwork in other rural Pacific island contexts, I was aware that community members could sometimes come to expect that a research project would culminate in a physical development project for the community (e.g. installation of a new water supply). I sought to manage the risk of disappointing community members by preceding each interview with an explanation of the intent and planned outcomes of the research. I also discussed the intent and outcomes of the research with traditional leadership in the communities before gaining their permission to collect data.

One ethical issue that I encountered in the rural communities that I had not planned for pertained to the signing of consent forms. I initially requested each participant to sign a form to signify their consent to participating in the research after I explained the purpose of the research and their rights as participants[13].

[13] Information sheets were also provided in written Bislama to explain the research and participant rights. See Appendix A for consent forms and information sheets.

Although participants were willing to sign the form, I noticed that producing the form and requesting signatures made participants visibly uncomfortable. I also sensed that, for many of the participants, the act of signing the consent form may have not been meaningful for them, thus defeating its purpose. After discussing this issue with my research supervisors, I opted to explain the research and participant rights and obtain consent verbally in subsequent interviews. I also provided information sheets with details on the research at the conclusion of the interview.

Another risk that I managed pertained to the health and safety of my research assistant and myself. Before traveling to Vanuatu, I considered potential risks, such as disasters or illness, and made plans for how I would respond if they occurred. I also discussed these plans with my supervisors who have extensive experience researching in developing countries. While I was in Vanuatu, I drew on my years of experience living in rural communities in another Melanesian country, Fiji, to act safely and in a culturally appropriate manner. Before staying in rural communities, I discussed potential risks with my interpreter and how we would respond if she felt threatened or unsafe. Over the course of the fieldwork, we regularly checked up on each other to ensure that we felt safe. We did not experience any safety or security incidents while in the field.

3.6.3 Approvals acquired

I acquired approval to conduct this research from multiple bodies. Permission to enter communities for data collection was granted verbally by traditional leadership within the communities. Permission to interview government staff members was granted in writing by the Directors of their respective departments. Approval to do climate change-related research was granted by the NAB. Approval to do research related to cultural matters in Vanuatu was granted by the Vanuatu Cultural Centre. Finally, ethical approval was granted by UTS Human Research Ethics Committee (Ref no. 2015000306).

3.6.4 Benefit to research participants

I have taken a number of steps to ensure that research participants directly benefit from my research. At the end of my fieldwork in the rural communities, I prepared a short document with my preliminary findings. I wrote this document in simple terms, had it translated into Bislama, and handed it to the leadership in the

communities along with a verbal presentation and discussion of the findings. I am currently making plans to re-visit the communities in the future to update them with further findings. At the end of my fieldwork with local government authorities, I held workshops to provide training to them on climate change impacts on water services. I also delivered a report with preliminary findings to the DoW and DLA at the conclusions of my fieldwork. I am currently making plans to develop an updated research report intended for the Government of Vanuatu that provides practical recommendations based on the findings of my research.

3.6.5 Practising reflexivity

Given that my research is largely in the space of international development, it is noteworthy that critics of development (sometimes referred to as post-development commentators) have raised legitimate concerns about the fundamental purpose of development. While many development researchers view development as a means to achieve desirable changes and outcomes, some post-development commentators view development as a dominant discourse of Western modernity that has mostly precipitated "bad" changes and outcomes from the vantage of the people ostensibly meant to benefit (Sumner and Tribe, 2008, p. 14). Although there is much nuance to the points of view of post-development commentators, one of their major arguments may be summarised as "the development discourse is itself based on Western ideas of progress and therefore cannot help but take the form of an imposition of those ideas on the South, thus repressing local cultures and interests" (Parfitt, 2002, p. 7). Although some post-development positions have been criticised as focusing narrowly on an outdated form of development (Kiely, 1999; Pieterse, 2000), they do raise an important point about the extent to which researchers' beliefs and values can potentially usurp those of research participants.

Practising reflexivity is perhaps the best way to address the potential of my own viewpoints to influence how I interpret and represent the viewpoints of others in my research. The practice of reflexivity can be understood as the researcher continuously examining the ways in which (s)he influences the research project (Dowling, 2008). Practising reflexivity is particularly important in development research because development research is normative, engaged, and seeks to make a difference (Mehta et al., 2006). Although it is not possible for qualitative

researchers to entirely disentangle their own worldviews from those of the people they are aiming to represent, researchers can aim to be transparent about how they influence their research through open reflection on their positionality and the real-world impact of their research on people's lives (Sumner, 2007).

I practised reflexivity throughout my research in multiple ways. Prior to traveling to Vanuatu for data collection, I had weekly conversations with my supervisors to think critically about and question the assumptions of my emerging research design. Also, during my scoping visit to Vanuatu prior to data collection, I discussed my research design with Government of Vanuatu authorities to gain their critical feedback and listen to what they felt were important dimensions that I should include. While I was in-country collecting data, I kept a diary (separate from my journal of observations described in section 3.8.3) in which I recorded observations of how my experiences in the field challenged my research approach and assumptions I had made. For example, I noted in my diary when I noticed that some of the participants appeared to be intimidated by the act of signing a consent form rather than assured by it. Throughout my time in Vanuatu and beyond, I also continued to have reflexive discussions with my supervisors. Diary-keeping and discussions with my supervisors helped me recognise my own assumptions and avoid interpreting them as objective facts.

I present the outcomes of some of my reflexive practices throughout this thesis. In Chapter 1, I described my own background, how I approached this research, and the possible effect this had on my research outcomes. In this chapter, I described some of the potential risks that my research posed to people in the case study sites. Finally, in Chapter 7, I reflect on my research as a whole.

Having undertaken a rigorous ethics review, I was ready to enter the case study sites.

3.7 Description of case study sites

The first case study site was Namoru community (15°36'26" S, 166°55'10" E), with a population of approximately 400, located on the southern end of the island of Espiritu Santo in the province of Sanma. The community is located along a dirt road approximately a 1.5 hour drive from the provincial capital, and Vanuatu's

second largest town, Luganville. It is also located in the southwest corner of the Wailapa River watershed near the downstream end of the river. Most community members live in the main village, although some live in houses that were built on plantations a few hundred metres away from the village. Most homes in the community are constructed out of locally sourced materials such as bamboo and palm leaves, although communal buildings like a church and school are built from cement blocks. Most families use individual or shared pit latrines built from local materials with wooden floors, although a few more affluent families use pour-flush latrines.

Namoru community was settled by indigenous islanders, but grew with migrants when Espiritu Santo was colonised by France in the 20th century. Colonial authorities constructed a feeder road that connected the community to markets in Luganville, and built a Protestant church and francophone primary school in the village. The opportunities that these developments brought, along with Christian proselytization that compelled islanders to worship at a church, led many people from the interior of Espiritu Santo to migrate to Namoru. In the present day, families that originally settled the community hold larger land claims than those that migrated later who claimed what little land was still available. All families attend the same Protestant church. In the last two decades, population growth has continued to accelerate as health services improve in the area. Economic opportunities have also increased as result of increased foreign investments in nearby Luganville and a growing tourism industry. Currently, most working community members are farmers that earn income selling surplus produce in markets in Luganville or by producing and selling copra to agricultural export companies. A minority of community members have entirely subsistence-oriented livelihoods or generate income via other market-based methods such as raising and selling cattle or operating local kava bars.

The primary water supply for Namoru is a gravity-fed branched-main piped system which is accessed via 24 separate standpipes spread throughout the community. Water for this supply is sourced from an unprotected spring in the hills behind the village. Spring water is stored in a metal storage tank and then fed to the standpipes. All standpipes are located outdoors and are shared by the households living in their proximity. The standpipes are developed to different degrees, for

example, some have platforms and drainage ditches while others do not. The water supply was constructed by the government in the 1980s and is managed by a community-based water committee. Prior to the construction of the piped water supply, household collected water from the neighbouring stream and river or hand-dug wells. Community members aspired to expand and improve the piped water supply in the future to have piped water to every house and 24 hour continuity. Water is primarily used for domestic purposes such as bathing, cleaning, and drinking. The water supply is typically not used for irrigation or agriculture because gardens are primarily rain-fed.

The water committee consists of six elected volunteers from the community that are changed irregularly (i.e. not at regularly scheduled intervals). The committee members comprise a president, a secretary, a treasurer, and one alternate for each of those positions. Committee members are elected by the community through a process of nomination and blind vote (community members attending are instructed to close their eyes and raise their hand to vote). All community members are allowed to vote. The committee is responsible for the collection of user fees, infrastructure inspections, arrangement of repairs to be made, and formation of a mid- or long-term plan for developing the supply.

The community also retrieves water from two secondary sources: a spring-fed stream that runs along the northeast corner of the village and the Wailapa River located approximately 700 m east of the main entrance of the village. Community members retrieve water from both of these sources via scooping with containers. Figure 7 shows the community and approximate locations of water supply features (not all standpipes appear in the figure).

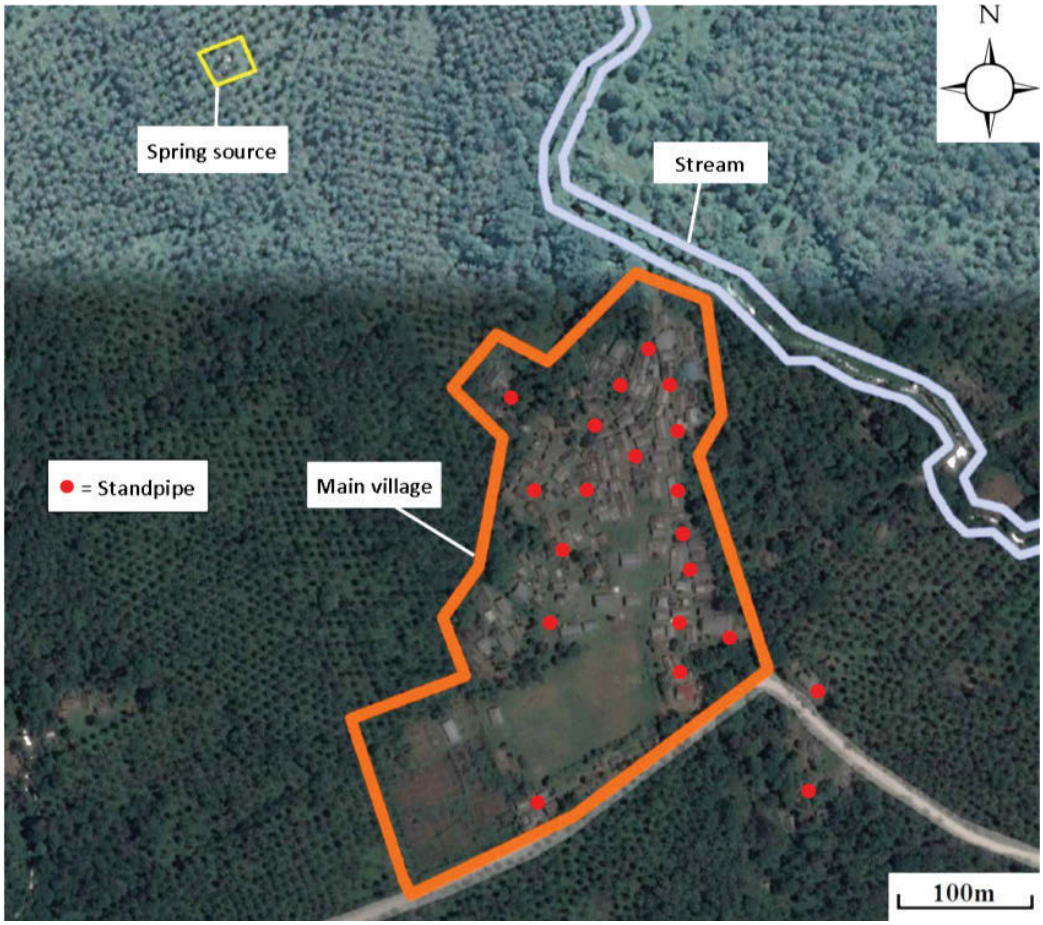


Figure 7. Namoru community (Source: ©2017 CNES/Airbus, DigitalGlobe)

The second case study site was the low-lying limestone island of Uripiv (16°4'26" S, 167°26'54" E) located approximately 3.5 km offshore of Lakatoro – the capital of neighbouring Malekula in the province of Malampa. The land area of the island is approximately 1.1 km^2. Seven villages, comprising a combined population of approximately 700, exist on Uripiv. I treated the villages as a single community in this study because they share resources, are in close proximity to one another, and jointly address development issues. Most homes on the island are built out of locally sourced materials, although some more affluent families have homes built from purchased wooden boards or cement blocks. Most households use individual or shared pit latrines with wooden floors although some households have pour flush latrines.

Uripiv was jointly settled by several indigenous tribes many centuries ago, the descendants of which continue to occupy the island. Archaeological evidence indicates that the island was settled some 2500 – 3000 years ago (Kinaston, 2014).

Oral history on the island, according to current inhabitants, holds that groundwater that naturally pooled in a depression on the surface alerted the first settlers that freshwater could be found underground, thus making the island hospitable for settlement. A council of chiefs was formed to govern the island, one chief from each of the seven tribes. Although each tribe established its own village on the island, the villages have lived in peace with one another and have governed themselves as a collective community.

Over time, the community received aid from national and international authorities to build a school, a health clinic and dispensary, rainwater storage tanks, a community hall, and a general store. The community has also been heavily proselytised leading to the development of several Christian churches representing different denominations. Economic development that has been experienced in other parts of Vanuatu has been slow to reach Uripiv, but the population of the community is growing as health services in the area improve. In the past, traditional beliefs that homes could not be built on certain parts of the island due to demons restricted expansion. However, these beliefs are diminishing and families are beginning to clear more trees and vegetation to build new homes.

Presently, most working community members are farmers or fishers that earn income via selling surplus produce and fish in local markets. A minority of community members practices subsistence-based livelihoods or engage in other market-based livelihoods such as renting out boats, operating local kava bars, or working at local government offices in the nearby town.

Water needs in Uripiv are primarily met through the joint use of eight shallow hand-dug wells and several dozen domestic rainwater harvesting systems spread throughout the community. No surface water bodies exist on the island. The hand-dug wells vary in levels of development (e.g. parapets or concrete platforms). Water is retrieved from each well using rope and buckets, except for one well that is fitted with a solar pump. Groundwater on small low-lying islands like Uripiv typically exists as a shallow freshwater lens that sits above seawater (White and Falkland, 2010). Freshwater was first discovered on the island when it was noticed to pool within depressions in the ground. Over several decades, the community the

different wells by hand. The wells are informally managed collectively by the householders that use them. Figure 8 shows the layout of the community and approximate location of wells.

Most rainwater harvesting systems are attached to domiciles and were built by homeowners. Storage receptacles for these systems include pre-fabricated plastic tanks, in-situ underground cement tanks, and other locally sourced materials such as drums or barrels. Homeowners manage their own private domestic rainwater harvesting systems. At the time of my field a visit, several rainwater harvesting systems had recently been installed on communal buildings such as churches and a community hall by NGOs. All community members are allowed to extract water from these communal rainwater harvesting systems. It did not appear that any individuals or groups were responsible for the management and maintenance of the communal rainwater harvesting systems.

Figure 8. Uripiv community (Source: ©2017 CNES/Airbus, DigitalGlobe)

Community members had different aspirations for developing water sources on the island. Some community members requested the government to install a piped supply originating from the nearby town, traversing the ocean, and servicing the town. Other community members were interested in decentralised desalination plants on the island, solar pumps installed at each and feeding piped water to each

household, or an individual rainwater harvesting systems for each house on the island. The water supplies are currently used for domestic purposes such as bathing, cleaning, and drinking. Neither the wells nor rainwater systems are typically used for plantations or gardens which are primarily rain-fed.

The provincial government authorities in the Namoru and Uripiv case study sites are located in offices in the towns of Luganville and Lakatoro, respectively. The offices are equipped with basic IT equipment (computers with internet access; printers with a limited supply of ink). Area council members work out of their own homes and use communal buildings in villages when a meeting is needed. The primary meeting point for the area council serving Namoru community is in Namoru village. The primary meeting point for the area council serving Uripiv is located in Lakatoro.

Once I had situated myself within the case study sites, I was able to commence data collection.

3.8 Methods

In this section, I describe the methods that I used to collect data for answering each research question. I describe each method discretely and specify with which research question(s) it is associated. For research question #1, I used the semi-structured interviews, sanitary surveys, and participant observations together to conduct my own risk-hazard, vulnerability, and resilience analyses of the community-managed water services. I also conducted a literature review. For research question #2, I drew on my findings from research question #1 and the literature to carry out a conceptual blending technique. For research question #3, I used semi-structured interviews, observations, document analyses, and workshops to gather information on how my research findings are useful to stakeholders in Vanuatu.

3.8.1 Semi-structured interviews

I primarily collected qualitative data for answering research question #1 through semi-structured interviews. Semi-structured interviews are a method where the interviewer asks open-ended questions about a list of issues to address, but is flexible in allowing interviewees to talk about other issues (Denscombe, 2014, p. 175). Semi-structured interviews were an appropriate method for collecting data

on the application of the risk-hazard, vulnerability, and resilience approaches to community-managed water services because they allowed me to purposively ask questions related to key concepts of the approaches while also giving me flexibility to explore interesting, context-specific leads.

Prior to entering the communities, I developed an interview guide that contained questions pertaining to risk-hazard, vulnerability, and resilience concepts listed in Tables 1 and 2 in Chapter 2 (e.g. hazards, equality, diversity, etc.), as well as more general community issues (Appendix B). However, I took an iterative approach to interviews in that I frequently changed my planned questions in order to explore newly emerging themes. Also, after each day of interviewing, I referred to a list on concepts that I had developed beforehand (Appendix C) and reflected on whether I felt I was collecting enough data on each. If I felt I was lacking data on a particular set of concepts, I would devise new questions to target them. As such, I seldom planned to ask the same questions to all participants.

I conducted the semi-structured interviews for research question #1 with a cross-section of households from the two rural community case study sites. Due to resource limitations, it was not possible for me to interview every household in each community, so I aimed to sample a representative cross-section of each community. Interviewing a cross-section of a community is common in community-based climate change adaptation research (Dumaru, 2010; Ford et al., 2008; Kuruppu, 2009; McCubbin et al., 2015). I identified potential households to participate in two ways: transect walks whereby I walked with a community member in parts of the villages to see who was home and willing to be interviewed, and via snowballing whereby participants recommended other families with whom I could speak. I aimed to include households from different spatial areas within the community in my sample. I also aimed to interview an equal number of men and women. However, due to cultural norms, it was sometimes a challenge to find families comfortable with a female member speaking on their behalf or women willing to speak to me on their own. Consequently, the sample was gender biased with 31 male participants, 19 females, and three interviews where men and women took turns answering questions.

I determined the number of households to interview in each community using the concept of saturation. Saturation is the idea that a sample size should continue to increase until no new information or themes are observed in the data (Guest et al., 2006). It is a legitimate and commonly used concept in qualitative doctoral research (Fusch and Ness, 2015; Mason, 2010). In my research, I aimed to detect my saturation point by judging when I was no longer able to find questions that would generate significantly new data on the concepts that I was investigating, and no new major themes were emerging. Following this approach, I conducted 24 interviews in Namoru and 29 interviews in Uripiv with a total of 53 interviews.

After obtaining consent from rural community participants, I conducted all interviews face-to-face in Bislama. My assistant aided in interpreting and I recorded all interviews on a voice recorder. I conducted interviews at the choice location of the participants, usually the home. Frequently one family member answered questions on behalf of other present family members, although in a few cases multiple members took equal turns answering questions. The interviews typically lasted between 30 and 60 minutes in length with an average of 40 minutes.

Although my approach to conducting semi-structured interviews was suitable and yielded rich data for research questions #1 and #2, it did have a drawback. I mostly took a deductive approach that focused on investigating concepts as described in existing theory. Focusing on a pre-determined list of concepts may have made it more difficult for me to recognise other relevant themes not captured in the existing theory. I aimed to counter this by including questions about general community development issues that I prepared beforehand or developed based on casual conversations that I had with community members. For example, after I learned from casual conversations that some families recently migrated to Namoru from other parts of the island in order to gain better access to schools and roads, I asked questions regarding how those families were integrated into the community.

Another limitation of the semi-structured interview was that many of the strategies for accessing water, experiences with climatic hazards, and relationships between people described in this thesis were recounted by research participants rather than being directly observed by me. Thus, I am reliant on reporting of events which runs

the risk of important factors being left out due to the imperfect memories of participants. However, a reporting of events without my own direct observations also has the benefit of allowing the views of what the participants deem important to surface without being influenced by my own perceptions of an event.

Semi-structured interviews were also one of my primary methods for collecting data from government authorities to answer research question #3. Similar to the rural community interviews, I designed an interview guide prior to the fieldwork that I refined after each interview (Appendix D). Questions from my interviews mainly centred on the roles and responsibilities of relevant government authorities, the participants' past experiences working in their position, and challenges and opportunities for government in supporting rural communities.

Based on my scoping visit and discussions with my local contacts, I identified relevant government authorities to participate in my research from two government departments. From the DLA, I interviewed one national level staff member, two provincial level staff members (one from each case study site), and 12 area council members (seven from the Namoru case study site and five from the Uripiv case study site). Each of the participants from the DLA had responsibilities or key knowledge directly pertaining to the support of general service delivery to the rural community case study sites. From the DoW, I interviewed one national level staff member and one provincial level staff member from the Uripiv case study site (the equivalent staff member from the Namoru case study site was unavailable for the duration of my fieldwork). At the time of the visit, the provincial staff member held the only DoW position that provided support for rural water service delivery in the province in which Uripiv was located. The national level DoW staff member held key knowledge on the responsibilities of provincial level staff.

After obtaining consent, I conducted all interviews with government participants face-to-face at the choice location of the participant, except for one interview that I conducted with a provincial DoW staff member over the phone. I recorded all interviews on a voice recorder. Some interviews were conducted in English where the participant was comfortable doing so. Other interviews were conducted in Bislama with my assistant acting as an interpreter. The total number of government interviews that I conducted was 17, typically between 30 and 60

minutes in length with an average length of 41 minutes. Only three of the government research participants were women.

3.8.2 Sanitary surveys

Another method that I used to collect data related to research question #1, primarily with respect to conducting the risk-hazard assessment, was the sanitary survey. Water supply sanitary surveys are a method for systematically assessing contamination risks to water supplies (WHO, 2012). They make use of standardised inspection forms that typically contain yes or no questions pertaining to whether a particular water contamination risk is present or not (see Appendix E for the inspection forms that I used). The inspection form is specific to the type of water supply being examined (e.g. a piped water supply or a dug well) and the pre-determined list of questions is based on contamination risks that are known to be common issues (e.g. animal excreta near water collection points). If other contamination risks not included in the pre-determined list are present, they can be added. I conducted sanitary surveys of the water supplies in the rural community case study sites by visually inspecting the water supplies and noting what contamination risks were present. This method helped to determine how climate hazards could disrupt the quality of the community-managed water services.

As an add-on to the sanitary survey, I also visually inspected the water catchment area immediately surrounding the water source. In particular, I noted if the natural vegetation and soil had been altered by human activities. I also asked communities about the history of land development in the water catchment (e.g. if and when land within the catchment was cleared for coconut plantations). This provided information that I used for assessing climate hazards and the resilience of the water supply system.

A limitation to the sanitary surveys was that my visual inspections could have missed sanitary risks that were not clearly visible. For example, I could not see leaks in pipes underground or know exactly where negative pressure in the pipes might have been occurring. I similarly may have not detected risks to the health of the natural environment in the water catchment. Sanitary surveys of rural water supplies using visual inspections, however, often are effective at capturing particularly worrying sanitary risks.

3.8.3 Participant observations and cultural immersion

Another data collection method that I used to answer each research question was participant observation. Participant observation differs from systematic observation in that the researcher participates in social events to gather primarily qualitative data about them instead of independently observing the events and quantitatively noting characteristics about them (Denscombe, 2014, p. 196). I conducted the fieldwork for this research in a single trip to Vanuatu that spanned from 11 July to 19 December 2016. During this time, I stayed in Port Vila, Luganville, Lakatoro, and spent a total of two months living in the rural communities that participated in my research (one month in Namoru and one month in Uripiv). I kept a journal throughout my stay where I recorded my observations of life around me that were relevant to my research questions (e.g. observing how access to water supplies was affected on rainy days versus sunny days). I referred to my journal entries when I refined my interview questions and after I began the data analysis phase.

A limitation to the participant observations was that my access to social life in Vanuatu was restricted by my role as an outsider. I did not develop a deeply intimate understanding of everyday life in Vanuatu over a prolonged time as an anthropologist might, which limited the depth of data that I could obtain. I also was open with the communities that I visited about being a researcher that was documenting his experiences which could have disrupted the "naturalness" of the social events in which I participated (i.e. caused the participants to behave differently than if I was not there). However, I used participant observations to provide complementary insights on what participants told me during interviews rather than to develop a deeply detailed picture of real-life events.

My time in Vanuatu was also valuable for familiarising myself with local cultures and lifestyles more generally. I socialised with people, made genuine friends, became conversational in Bislama, and participated in community activities and events. Although these experiences were not directly tied to some purposive collection of data, they were beneficial for understanding the context in which I was researching.

3.8.4 Workshops

In order to learn more about the experiences of local government authorities to collect data for research question #3, and to provide training on climate change and water services to the participants, I hosted a workshop-style event in each of the Namoru and Uripiv case study sites. The workshops were attended by Area Secretaries and area council staff members. I also invited provincial DoW staff members, but they were unable to attend.

During the workshops, I presented information on climate change and its impacts on water services, and facilitated activities to discuss what area council members could do to support water service delivery in communities against climate change. My presentation included two short videos in Bislama created by NGOs about climate change[14], and Powerpoint slides that I created about links between climate change and water services. I used the videos and the presentation to stimulate discussions on the role of the area councils and to provide a level of training to the council members. Activities to facilitate discussion on the role of area councils in supporting communities included small group discussions, followed by open plenary discussion, on the participants' thoughts on the videos and the presentation, and what government could do to help communities. Another activity involved the use of a tree as a metaphor whereby participants identified the fruits of their work (i.e. the desired outcomes of their work) and the roots (i.e. the enabling factors or conditions that helped them achieve outcomes) (Figure 9). I approached these activities in a strengths-based way where, at the beginning of the event, I requested that participants focus on positive experiences and aspirations. During the interview portions of my research, I had already collected many of the negative experiences. I recorded the events on a voice recorder and took notes on my reflections afterward.

[14] Available at https://www.youtube.com/watch?v=EGyV-BdoNdI and https://www.youtube.com/watch?v=7pE5-RBSiK8

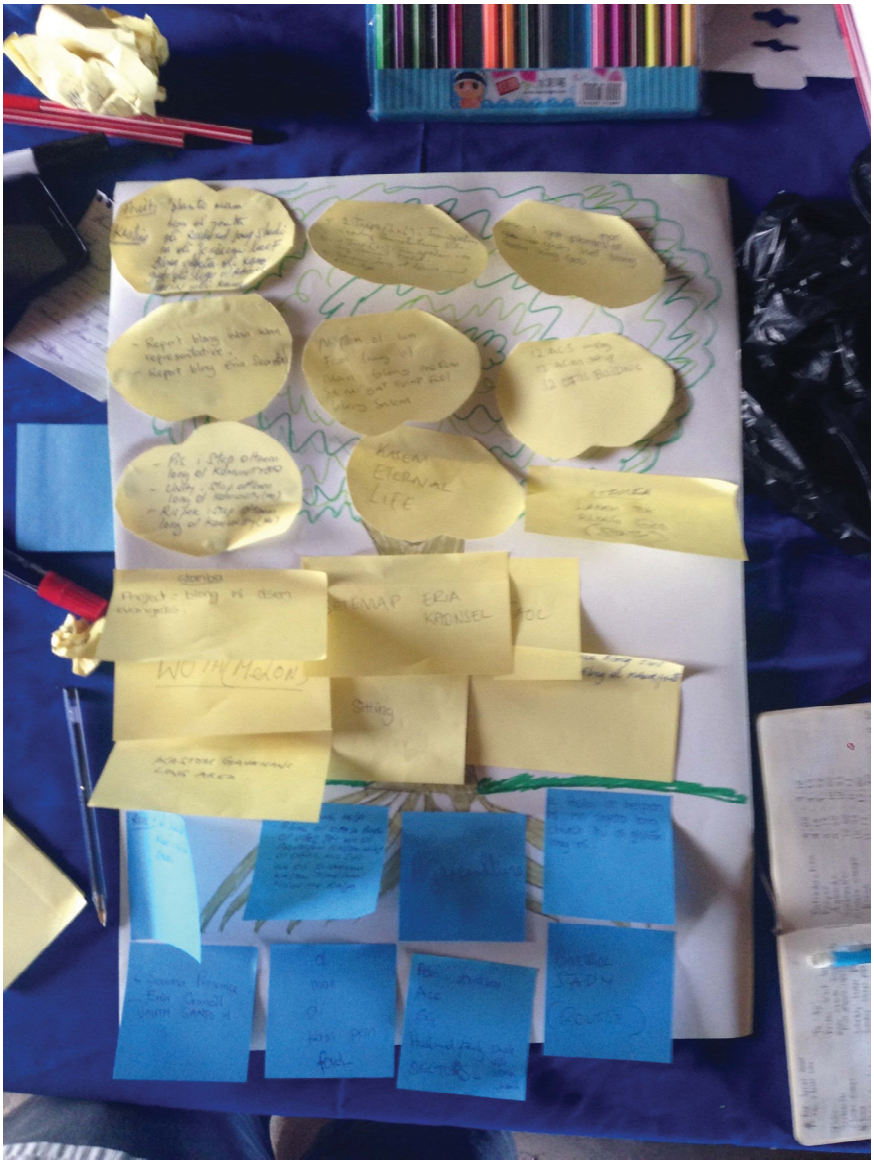


Figure 9. Tree metaphor activity during area council workshop

3.8.5 Document analyses

I also conducted desk-based document analyses to address research questions #1 and #3. I describe the processes I followed for each below.

In order to help answer research question #1, I reviewed and analysed scholarly WASH literature with a climate change focus to determine if the studies implicitly aligned with the risk-hazard, vulnerability, or resilience approaches and consequently how they problematised climate change. The purpose of this review was to gather examples from the literature on how the risk-hazard, vulnerability, and resilience approaches can be applied in a community-managed water service

or wider WASH context, the results of which I present in Chapter 4. I focused on peer-reviewed literature, although I also included non-peer-reviewed reports that were rigorous, fully referenced, and well-argued. WASH and climate change are not fields of scholarship with clearly delineated boundaries, so it was necessary to delimit this literature review in several ways.

First, I reviewed literature that primarily focused on access to WASH services. Thus, I did not review the expansive body of literature on climate change impacts on water resources management, or the growing epidemiological body of literature on WASH-related diseases driven by climate change. Not all literature falls clearly between these categories, so at times I had to make a judgement on whether a particular paper had enough of a service delivery focus to be included in my review. Second, I sought literature that included a focus on the delivery of WASH services for small-scale domestic and productive uses. Thus, I did not include literature focused on large-scale industries or large cities. Third, I sought literature that has an explicit focus on developing countries. Finally, the literature needed to include the impacts of or adaptation to climate change for WASH services as one of its primary areas of analysis to be a part of my review. I did not review literature pertaining to WASH and disaster risk reduction if there was no focus on climate change, or literature pertaining to WASH and climate change mitigation.

I obtained relevant scholarly literature through searches on ProQuest, Web of Science databases, and Google Scholar databases. I used numerous search strings containing the terms “climate change”, “water service”, “water access”, “water supply”, “water supplies”, “drinking water”, “household water”, “domestic water”, “sanitation”, “hygiene”, and “WASH”. To these terms, I also added a custom-made search string containing over 100 country names and related terms to identify studies that focused on developing countries. I initially screened papers by reviewing titles and abstracts for relevance. I reviewed the contents of 59 papers using the delimitations described above, and selected 33 to be included in this study.

I reviewed each of the 33 papers to identify to which theoretical approach (risk-hazard, vulnerability, or resilience) they were most closely aligned. I did this by drawing on a diagnostic tool developed by O’Brien *et al.* (2007) for identifying

different interpretations of vulnerability through an examination of research questions, methods, results, and recommendations, a list of analytical focal points provided by Miller *et al.* (2010) that distinguish vulnerability and resilience studies, and my own knowledge of the approaches.

A limitation to the literature review was that there was a level of subjectivity in how I judged what qualified as "scholarly WASH literature" and what implicit theories were used by the authors. I described my strategy for identifying relevant WASH literature, but it is possible that other researchers would include more, or exclude some that I have used, based on their own interpretations. Other researchers may also interpret the implicit theories behind some of the literature differently than I did. I provide a summary of the points of each study that I refer to in Chapter 4 to give the reader an idea of why I interpreted it as aligning with a particular approach.

For research question #3, I collected documents pertaining to the operations of government departments and NGOs working in the areas of water services and climate change in Vanuatu. The purpose of collecting these documents was to understand how my research findings from research questions #1 and #2 related to the operations described in the documents. To locate relevant government documents, I searched for government policies, legislation, strategies, plans, notes, guidelines, and reports that were freely available online. I also obtained copies of relevant documents by inquiring with colleagues through my professional network. I conducted a qualitative content analysis of these documents wherein I identified and organised relevant passages of text in relation to my research questions (Bowen, 2009). Although I found many government documents relating to either water services or climate change, few covered the overlap between the two. I present the relevant government documents and how I organised relevant passages of text in section 6.2. I followed a similar process for identifying and analysing relevant documents pertaining to NGOs based in Vanuatu. I found few relevant documents for NGOs so I focused on doing a qualitative content analysis on a shared framework for NGOs collectively working in the space of community-based climate change adaptation in Vanuatu. I present this analysis in section 6.3.

After I collected a sufficient quantity and depth of data, I could begin to process, analyse, and write about it.

3.9 Data processing, analysis, and write-up

In this section, I describe how I transcribed the audio data, coded the transcriptions, documented my emerging ideas, and presented the data throughout my thesis. I also describe the steps that I took to conceptually integrate the risk-hazard, vulnerability, and resilience approaches into the conceptual framework that I present in Chapter 5.

Transcription of the audio that I recorded during interviews and workshops was my primary data processing task. I used Nvivo software for all transcriptions. The majority of the audio was spoken Bislama, but I transcribed it into English so that it would be easier and quicker to refer to later. By the time I began the transcription process, I understood Bislama well enough that I could translate it into English. However, my audio recording also included the English interpretations by my assistant. My assistant's interpretations thus helped to confirm my own translations. I personally transcribed every audio file that I created – a total of approximately 49 hours of audio.

For research question #1, I coded the transcripts from my interviews with rural community participants in order to organise the data and describe it (Patton, 2002, p. 465). After reading through the transcripts multiple times, I first coded them using deductive and inductive techniques. I used a deductive coding technique called provisional coding whereby I used a predetermined list of codes (Appendix C) and assigned them to corresponding portions of the transcripts (Saldaña, 2009). The list of codes that I used was derived from concepts in risk-hazard, vulnerability, and resilience theories. Through this coding technique, I was able to aggregate substantial amounts of empirical evidence of risk-hazard, vulnerability, and resilience concepts in the context of community-managed water services. I then used an inductive coding technique called descriptive coding (Saldaña, 2009) whereby I identified themes from rural community interviews that were not captured by the provisional coding technique.

After this first round of coding, I did a second round of coding and began to document my ideas. In the second round of coding, I examined my aggregated data and grouped some codes into "parent codes" and broke other codes into separate sub-codes (Gibson and Brown, 2009, p. 142). Meanwhile, I reviewed the data collected from my other activities (sanitary surveys and observation notes) and compared them to the data I was iteratively coding. Throughout the coding process, I recorded my thoughts and ideas about how the data provided evidence of the risk-hazard, vulnerability, and resilience theories and about the usefulness of the evidence. I recorded these thoughts and ideas initially as brief jottings and then later in a more detailed freestyle narrative form (Miles et al., 2013, p. 97).

In order to answer research question #2, I used a model-based synthesis technique for blending concepts of risk-hazard, vulnerability, and resilience theories in the context of community-managed water services into a single conceptual framework. Bammer (2013, pp. 45–48) describes three broad ways in which disciplinary knowledge can be synthesised and integrated. Dialogue-based synthesis creates shared meaning and understanding of an issue through methods such as the Delphi technique or appreciative inquiry that prompt different stakeholders to explicitly articulate their thoughts on the issue with the aim of coming to a consensus. Model-, product-, and vision-based synthesis aims to develop a shared, discrete model, product, or vision that is created with inputs from different disciplinary-based perspectives. Common metric-based synthesis uses a single measure for different disciplinary concepts so that they can be directly related to one another (e.g. assigning a monetary value to ecosystems, homes, farmland, etc. in order to analyse the encroachment of housing and farms on bushland). I chose to do a model-based[15] synthesis because I wanted to create a tangible tool for stakeholders to use to ultimately inform climate change adaptation activities. Also, dialogue-based synthesis would have required significant time commitment and coordination from a range of experts that was beyond what was feasible within the constraints of my doctoral research. Common-metric based synthesis would not have achieved my

[15] A model constitutes a detailed manifestation of a theoretical explanation whereas a framework is a more abstract set of linked concepts and terms (McGinnis and Ostrom, 2014), but the model-based synthesis works all the same for frameworks.

aim of providing guidance to stakeholders on the ways in which community-managed water services sustain water access against climate change disturbances.

I went about conducting a model-based synthesis by constructing a conceptual framework based on grouping and linking risk-hazard, vulnerability, and resilience concepts in the context of community-managed water services. A synthesis, such as the conceptual framework I developed, can be represented as a hierarchy of constituents (Defila and Di Giulio, 2015). These constituents can be theories, concepts, empirical evidence, tools, etc., that link up or combine with one another to form higher-order constituents which, in turn, link up to culminate in the synthesis (Defila and Di Giulio, 2015). The constituents that I dealt with in this research were risk-hazard, vulnerability, and resilience concepts that I identified from the literature. I went about combining or blending the different concepts in two ways. One way I did this was by identifying "nexus concepts" – concepts that are shared or nearly synonymous across different disciplines or theories (Newell et al., 2005). For example, as I explain in section 5.3.3, vulnerability and resilience theories make a similar conceptual distinction between specific and generic adaptive capacity and between specified and general resilience respectively. Another way I combined concepts was by reconstituting lower-order concepts into new higher order ones (Bergmann et al., 2012, p. 63). For example, as I explain in section 5.3.4, I group the concepts of climate-proofing and thresholds into the concept of biophysical specific capacity. I continued this process of linking concepts by studying the literature and reflecting on my findings from research question #1 until I arrived at a draft framework. I then diagrammed my framework in multiple ways, presented drafts to my supervisors and colleagues, sought their feedback and critiques, and refined the drafts until I reached the final product.

I further analysed my proposed conceptual framework by retrospectively applying it to the findings from one of my rural community case study sites. I did this by reflecting on the findings that I had written in a freestyle narrative in order to analyse the data for research question #1. In particular, I looked for evidence of different elements of my conceptual framework in my writings and present them in section 5.6.

A limitation of the way I constructed the conceptual framework was that it was done mostly on my own. Although I drew on academic literature to create the synthesis, I did not include other academics to articulate and discuss their interpretations of concepts. Nor did I include practitioners or rural community members of Vanuatu in its construction. I tried to be as open as possible to a range of ideas, but the framework may be limited by own worldview and values. Therefore, including a wider range of inputs is important for the future evolution of the framework. However, delegating the task of integration to a single person is not uncommon in interdisciplinary and transdisciplinary research (Defila and Di Giulio, 2015) and has the advantage of being more expedient than doing integration in a group setting.

For research question #3, I conducted document analyses as I described in section 3.8.5 and present in Chapter 6, and reviewed the transcripts of my interviews and workshops with government officials, and reviewed my observation notes in relation to these analyses. In particular, I looked for passages in the transcripts where the participants commented on operational challenges that were relevant to the results of my document analyses. I then reflected on relevant portions of the transcripts and observations notes, and on my experiences in the country, to guide the conclusions and recommendations that I make regarding policy documents in Chapter 6.

I present data from the semi-structured interviews and workshops in this thesis through quoting, references to participant comments, and counting of responses to particular questions. I provide quotes that succinctly capture an opinion, sentiment, or perception that I found to be especially salient or prevalent amongst the participants. I also present counts of how frequently I received a particular response to provide a sense of how prevalent an idea was, but totals vary because all participants were not asked the same questions.

I present data from the sanitary surveys through my own personal comments on water supply infrastructure and water resources in the communities that I visited. Similarly, I present data from participant observations through my own comments on social behaviours in the communities.

Finally, I present data from the document analyses by quoting passages from documents or paraphrasing their contents.

Having described how I analysed and presented the data, it is necessary to point out some of the limitations that were associated with my approach and thus influence the impact of my findings.

3.10 Limitations

In addition to the limitations that I described for the particular methods above, there were several more general limitations to my methodology. First, researching cross-culturally and across language barriers presents additional opportunities for loss of meaning between participants and the researcher (Camfield, 2014). Immersing myself in the field for an extended period of time, learning to speak Bislama, and consulting my assistant on cultural matters helped to mitigate this effect. Furthermore, for transparency, whenever I present the English translation of a quote from a research participant, I also present the quote as it was originally spoken in Bislama in the footnotes.

Second, the perspectives of women may be underrepresented in the findings of this research. As mentioned earlier, cultural norms in the rural communities made it difficult as a male researcher to get a balanced inclusion of perspectives from men and women. The research participants from government were also disproportionally male due to the small number of women working in the relevant government departments. Due to the gender imbalance, reporting of events should be regarded as being more strongly influenced by a male perspective. This could have potentially resulted in important issues facing women in relation to water service and climate change not being raised.

Third, the case studies that I present in my research only capture a snapshot in time. The climate in Vanuatu will continuously change over time and the processes that influence vulnerability and resilience are dynamic. Therefore, the issues that are presented in this thesis may worsen or alleviate and new ones may arise in the future. Although the exact nature of the issues presented in Chapter 4 may change over time, the key findings of my research will remain relevant because they pertain

to how we think about these issues rather than what the specific issues are that a community is facing.

Fourth, my research has primarily taken a deductive approach that may limit the inclusion of novel, grounded contributions from the case study sites. I have kept an open mind about critiquing and building on the theories with which I worked, but future research that engages more deeply with the lived experiences of rural communities accessing water under climate change could significantly complement my findings.

Another limitation of the deductive approach, and the associated methods that I have chosen, is that they limit the number of in-depth insights I could gain on socio-political factors influencing water access and climate adaptation in the communities. Researching social-political factors cross-culturally requires sustained engagement (i.e. an ethnographic methodological approach) and social science research skills for collection, analysis, and interpretation of data. My research design, which incorporated two case study sites with community and government participants limited the amount of insights I could gather on social-political dimensions within the two communities. Research that focused on only the vulnerability approach (i.e. sacrificing a broader lens that includes the risk-hazard and resilience approaches) using more ethnographic-oriented methods would have gained deeper insights on how social-political factors influence water access in the communities.

3.11 Summary

This chapter has outlined the research methodology that I employed to answer my three research questions. I first described how I chose Vanuatu as the country in which to situate my research because of my previous experience in the Pacific region and geographic characteristics of Vanuatu that made it a suitable study site with respect to my research questions. I then explained why a case study methodology was appropriate for investigating each of the research questions. After, I described the networking and planning activities that I undertook to prepare for data collection in the field. Next, I explained how I selected the case study sites based on advice from my local contacts and a number of geographic and social criteria. I also discussed a number of ethical considerations related to my

research including consultations that I undertook, risks that I managed, providing tangible benefits to the research participants, and practising reflexivity to recognise when I am taking my own assumptions as facts of my participants' lives. I then described the two case study sites in which I collected data and the methods (semi-structured interviews, sanitary surveys, observations and immersion, workshops, and document analyses) I used. Finally, I described how I transcribed, coded, and wrote about my data, and discussed the limitations of my research approach. Table 3 shows a summary of my data collection methods and data analysis techniques for each research question for ease of reference later when I present my findings to research questions #1, #2, and #3 in Chapters 4, 5, and 6 respectively.

Table 3. Summary of data collection methods and data analysis techniques

	Research Question #1	**Research Question #2**	**Research Question #3**
Data collection methods and data analysis techniques	Semi-structured interviews w/ rural community members	Conceptual blending (based on RQ1 findings and literature)	Semi-structured interviews w/ government officials
	Sanitary surveys		Workshops
	Participant observation and cultural immersion		Participant observation and cultural immersion
	Transcript coding		Document analyses
	Document analyses		Transcript review

In the next chapter, I present and discuss my findings pertaining to research question #1.

Chapter 4. Making sense of climate impacts on water services: Contributions of different approaches

Chapter preface

This chapter contains re-formatted and adapted portions of co-authored journal submissions. The details of these submissions are:

Kohlitz, J.P., Chong, J., Willetts, J., 2017. Climate change vulnerability and resilience of water, sanitation, and hygiene services: a theoretical perspective. J. Water Sanit. Hyg. Dev. 7, 181–195. doi:10.2166/washdev.2017.134

Kohlitz, J., Chong, J., Willetts, J., [under review]How are climate change vulnerability and resilience analyses related? An investigation of their application to community-managed water services, submitted manuscript to *Climate and Development on 12 December 2017*

Statement of contribution

In both of the studies that generated these journal submissions, I led the research design, data collection, and data analysis. Joanne Chong and Juliet Willetts provided substantial feedback and advice on these activities. I wrote both of the journal submissions and Joanne Chong and Juliet Willetts reviewed and provided substantial feedback on and approval of the manuscripts.

4.1 Introduction

The purpose of this chapter is to address research question #1: What contributions do the risk-hazard, vulnerability, and resilience approaches make to understanding how community-managed water services are affected by and sustained against climate change disturbances? In Chapter 2, I reviewed the risk-hazard, vulnerability, and resilience bodies of theory-practice and described how each conceptualises how systems experience and respond to disturbances. I noted that, although these three approaches have been highly influential in informing climate policy in other sectors, the WASH sector has not yet fully engaged with the breadth of their knowledge bases. In this chapter, I contribute to filling this gap through a review of existing WASH literature and a presentation of empirical evidence of community-managed water services in rural Vanuatu.

This chapter is structured into five sections. In section 4.2, I demonstrate how the risk-hazard approach can be applied to community-managed water services. I do this through first presenting analyses from scholarly literature that have implicitly used this approach to problematise the effects of climate change on WASH services. This literature includes examples of sanitation services but I still refer to them because there are many similarities between the delivery of water and sanitation services. I then present empirical evidence from my fieldwork in Vanuatu to further illustrate the application of the risk-hazard approach. In sections 4.3 and 4.4, I repeat this process for the vulnerability and resilience approaches respectively. In section 4.5, I discuss the implications of using different approaches for conceptualising how community-managed water services are affected by and sustained against climate change disturbances. Finally, in section 4.6, I summarise the key findings of the chapter.

In applying the three approaches to the case study sites, I focus on the potential problems that climate disturbances cause for water access in the communities to illustrate the different interpretations that each approach takes to climate change impacts on water services. I primarily do this by drawing on present and past community experiences with climate variability to understand how they may be impacted by future climate change. Although the effects of climate change are likely being presently felt in some way in Vanuatu, it is difficult to discern the magnitude and areas of impact, and thus I do not assert that the issues being faced by the

communities are, in fact, being driven by climate change. Further, even when discussing the impacts of present and past climate disturbances, it can be difficult to attribute the extent to which water access problems are caused by climate effects versus other drivers such as poor operation and maintenance. All climate change impacts will be intertwined with other forces of change and it is difficult, and perhaps not even meaningful, to attempt to separate them.

In my application of the three approaches to the case study sites, I do not necessarily utilise every concept discussed in Chapter 2. The vulnerability and resilience theories in particular encompass a wide range of concepts that can be usefully drawn on to interpret climate change impacts and responses to them. I drew on concepts that I felt were most applicable to community-managed water services. My analyses are influenced by my own subjective observations, questions, and interpretations of the data and others may find a different combination of concepts is useful in other settings.

4.2 Risk-hazard analyses of water services: Managing increasing risks from physical hazards

The risk-hazard approach follows an outcome interpretation of vulnerability. This interpretation views vulnerability as a function of a system's exposure and sensitivity (i.e. the risk whereby risk is the product of exposure and sensitivity) to identified climate hazards and the system's capacity to alter that exposure and sensitivity through adaptations (section 2.2.1). In this section, I illustrate ways in which the climate change problem can be conceptualised as the risks that projected climate hazards pose to WASH services, and how the capacity to respond to these risks can be created.

4.2.1 Risk-hazard analyses from existing literature

One of the most common focal points that the reviewed literature covers is the direct physical impact of certain projected climate change hazards on WASH technologies. How specific climate hazards can cause physical damage to or directly disrupt functionality of an array of technologies, and which technologies are most likely to resist hazards under a range of climate change scenarios, has been described in detail (Bonsor et al., 2010; Howard et al., 2010; Luh et al., 2017; Sherpa et al., 2014). For example, Luh *et al.* (2017) include discussion in their

paper on how manually dug wells are more likely to be disrupted by changes in precipitation than drilled boreholes due to the relative depths from which each extracts groundwater.

Some studies focus on WASH technologies that are commonly used in a particular geographic region and consider only climate hazards that are projected for their region. The impacts of specific projected climate change hazards on wells and latrines in Mauritania (Cissé et al. 2016), spring-fed water systems in Bolivia (Fry et al. 2012), groundwater supplies in southeast Asia (Hoque et al. 2016), small-scale sand dams in Ethiopia (Lasage et al. 2015), various small-scale water supplies in Bangladesh (Rajib et al. 2012), mountain spring-fed water systems in India (Tambe et al. 2012), and rural groundwater supplies in Africa (MacDonald et al. 2009; Bonsor et al. 2010) have been the subject of in-depth studies. These studies tend to be place-based and sometimes consider other local non-climate factors. For example, Fry *et al.* (2012) discuss how projected changes in rainfall over the course of the 21st century, combined with local population growth and changing water use practices in the Alto Beni region of Bolivia, are likely to cause water shortages in existing spring-fed supplies.

These above types of studies typically make recommendations that promote technologies, or modifications to existing technologies, that will resist disruption when exposed to particular climate change driven hazards. For instance, Howard *et al.* (2010) write "few [drinking-water supply and sanitation] technologies are resilient to most climate change scenarios. These should be prioritised in future investments".

Investigation of the risks that climate change poses to the *management* of technologies is also an area of attention. A couple of studies have investigated the capacity of utilities and communities, in general, to make repairs and modifications to water infrastructure affected by climate hazards (Howard et al., 2010; Luh et al., 2017). Other studies are place-based. For instance, the financial costs of abstracting and delivering water for small towns under changing rainfall conditions in South Africa (Mukheibir 2010a) and the development of strategies for the management of water service infrastructure and resources threatened by climate change in the Caribbean (Cashman 2014) have been studied.

Guides and tools have also been developed to assist WASH service implementers and providers in managing climate change risks to WASH infrastructure. Elliot *et al.* (2011) present a catalogue of technologies and managerial practices with guidance on how they can be applied to offset the impact of climate change hazards. Heath *et al.* (2012) field test a tool for downscaling regional climate models and generating recommendations for climate-proofing water and sanitation infrastructure. Oates *et al.* (2014) present a three-step process of assessing the risks of climate change hazards against other large-scale stressors on WASH, evaluating the extent to which adaptation options can reduce these risks, and prioritising the options using cost-benefit analysis. Lastly, Doczi (2013) reviews 137 practitioner tools designed for, or that could be reappropriated for, managing climate risks to WASH services.

The literature and guides on management of climate risks to WASH infrastructure often aim to optimise technical and financial efficiency and effectiveness in managing the identified risks. For example, the Rapid Climate Change Assessment tool developed by Heath *et al.* (2012) generates recommendations to water service providers on the most cost-efficient and effective technological adaptations for mitigating the impacts of specific climate hazards.

How community-managed WASH system adaptations to climate change can be maladaptive (i.e. cause unintended negative consequences) was little explored in the existing WASH literature. One such example is the potential of water storage and rainwater harvesting, promoted as an adaptation to increased rainfall variability driven by climate change, to transmit disease (Boelee et al. 2013). The authors recommend assessing different forms of water storage and their relative health risks.

Overall, the WASH literature contains many studies that examine a wide range of climate change hazards and WASH infrastructure. Some studies are generalised and some are place-based. An area of further research needed under this approach is the potential for technological WASH adaptations to be maladaptive. Research on how projected effects of climate change can be beneficial for WASH services, and thus offset some of the deleterious effects, would also be useful for developing a more comprehensive evaluation of the impacts of climate change.

In the following section, I contribute to the body of knowledge on climate change risks and hazards for water services through evidence from my case studies in two rural communities in Vanuatu.

4.2.2 Risk-hazard analyses from fieldwork in Vanuatu

In order to apply the risk-hazard approach to my own case studies, I first characterise the climate change hazards to which the communities are exposed. Then, based on data I collected from the field, I discuss ways in which the climate hazards pose risks to levels of water services in the communities.

Climate models suggest that Vanuatu's climate will change significantly over the course of the 21st century. Climate change projections over the 21st century and the potential for the changes to directly impact water access in rural communities in Vanuatu are listed in Table 4. Climate change projections for Vanuatu are derived from multiple models of the global climate from 2010 to 2110 developed under the Coupled Model Intercomparison Project (Australian Bureau of Meteorology and CSIRO, 2011). Projected climate change effects for Vanuatu and their associated confidence levels are produced by climate experts based on their judgements of the consistency between the different models, physical plausibility, and the simulation ability of the models (Australian Bureau of Meteorology and CSIRO, 2011). Due to limitations in the resolutions of the models, projections are not available at a sub-national level. Because of the unavailability of sub-national climate projections, there is a significant degree of uncertainty on which climate change effects will manifest locally at the community level.

Table 4. Projected climate change effects and direct impacts on rural water access in Vanuatu

Projections of climate change effects	Confidence level	Potential direct impact on rural water access?
Surface air temperature and sea-surface temperature are projected to continue to increase	Very high	Limited
Wet season rainfall is projected to increase	Moderate	Yes
Dry season rainfall is projected to decrease	Moderate	Yes

Little change is projected in annual mean rainfall	Low	Limited
The intensity and frequency of days of extreme heat are projected to increase	Very high	Yes
The intensity and frequency of days of extreme rainfall are projected to increase	High	Yes
Little change is projected in the incidence of drought	Low	Limited
Tropical cyclone numbers are projected to decline in the south-west Pacific Ocean basin (0–40°S, 130°E –170°E)	Moderate	Yes
Ocean acidification is projected to continue	Very high	No
Mean sea-level rise is projected to continue	Very high	Yes

Source for projections and confidence levels: Australian Bureau of Meteorology and CSIRO, 2011. Source for levels of direct impact: Author.

In the following analyses, I focus on the hazards that I judge, based on the data I collected from the field, as having the most potential to directly impact water access detrimentally in the studied communities. With respect to Table 4, these are decreased rainfall in the dry season, increased intensity and frequency of days of extreme heat and days of extreme rainfall, and continued sea-level rise. Climate change potentially can also affect water services in many indirect ways (Batchelor et al., 2009). However, indirect impacts are usually complex and difficult to predict. Since the purpose of this chapter is to demonstrate different conceptualisations of how community-managed water services are affected by and sustained against climate change disturbances, and not an attempt to exhaustively describe the ways in which the communities can interact with climate hazards, I focus primarily on direct impacts of projected hazards.

4.2.2.1 Namoru community

In Namoru community, the climate hazards that are potentially most severe for the community-managed water service are an increase in intensity and frequency of

days with extreme rainfall and a decrease in dry season rainfall. A major reason for this was the nature of the spring source from which the primary piped water supply extracts water (Figure 10).

Figure 10. Spring source of Namoru water supply

The spring source was not protected with a spring box and thus was exposed to surface runoff. Participants remarked that heavy rainfall, which occurs frequently in the wet season, often caused water from the taps to appear turbid and flowrate to be diminished or halted due to blockage by debris at the spring intake. For instance, one participant stated "*The water runs, the water does not dry out. But sometimes it is stuck because there is too much mud inside* [the intake]. *That is why sometimes we do not receive water*[16]". An increase in frequency and intensity of days with extreme rainfall has significant potential to increasingly disrupt water quality and continuity in the piped water supply.

A decrease in dry season rainfall is also likely to increasingly disrupt water service. Participants reported that extended periods of dry weather reduced flowrates, sometimes to the point that flow at standpipes was cut off entirely: "*Sometimes in the dry season, sometimes the water no longer runs. Just slowly*[17]". Since springs

[16] Wota i stap ron, wota i no stap drae. Be samtaem, em i stap fas from se i gat tumas sofmad insaed. Mekem se samtaem mifala no risivim wota.
[17] Samtaem lo drae sisen, samtaem wota nomo ron. Jes slo nomo.

typically arise from shallow groundwater, their productivity is sensitive to changes in precipitation (Luh et al., 2017). Thus, a decrease in dry season rainfall, coupled with a reported growing water demand from an increase in the community's population, would likely result in more frequent water shortages in the dry season.

The precarious state of the community's water supply infrastructure also put water access at risk to climate hazards. Piped water supplies, in general, have heightened exposure to contamination hazards due to their relatively large spatial spread and numerous points for contaminant ingress (Howard et al., 2010). Since most of the infrastructure was built in the 1980s, assets showed advanced deterioration such as rusting of the steel storage tank, which makes it more likely to leak (Figure 11). I also frequently observed leaks in the water main (Figure 12) and secondary pipes. The observed leaks and the likelihood of negative pressure in the system when flowrate is stopped indicated that contaminant ingress was a substantial risk. Increased intensity of rainfall due to climate change raises the exposure of piped water networks to the ingress of contaminated water (Charles et al., 2010). The risk of contamination of the piped water supply in the wet season is therefore heightened by a projected increase in intense rainfall.

Figure 11. Namoru community water storage tank

Figure 12. Namoru community water main

The most direct way to respond to these risks would be to make changes to the water supply system but the community was constrained in its capacity to manage these risks. For example, a spring box could be constructed to protect the spring source, pumping technology could be used to exploit deeper groundwater, and deteriorated assets could be renewed to control leakage. However, the community had limited financial resources and technical expertise to make these adjustments. This supports the assertion of Howard *et al.* (2010) that community-managed piped water supplies are especially likely to be negatively affected by climate change due to limited human resources and restricted ability to raise capital for adaptations. Thus, technological responses would need to be accompanied by financial and technical support from external sources.

4.2.2.2 Uripiv community

An increase in intensity and frequency of days with extreme rainfall and a decrease in dry season rainfall also posed the greatest climate change risks to water services in Uripiv. Additionally, mean sea-level rise and increase in the frequency of days of extreme heat also posed risks.

The wells in Uripiv were highly sensitive to heavy rainfall. Participants described incidents of surface water runoff carrying debris into wells and degrading water quality: "*When we sleep during the night, if it rains too much, it will go inside the*

well. So we must clean the well again[18]". I also observed substantial pooling around the wells on rainy days which could allow for ingress underneath the well parapets since none of the wells had platforms or lining (Figure 13). Furthermore, participants recounted that wells could become difficult to reach for elderly members of the community during rainy days due to muddy or slippery conditions around the well: "*Sometimes it is slippery, especially for elderly women. Sometimes they cannot get water because it is slippery*[19]". An increase in days with heavy rainfall could heighten contamination risks to the wells and reduce their physical accessibility.

Figure 13. Pooling around well in Uripiv

Future salinisation of the wells due to climate change was also a concern. None of the participants reported that climate-related events affected the salinity of the water in the wells. However, research indicates that groundwater lenses on small islands becomes thinner and more susceptible to saline intrusion during dry periods (White et al., 2007). Further, it is widely accepted that rising sea levels seriously threaten to make more permanent changes to the salinity of groundwater resources on low-lying islands (Chui and Terry, 2013; White and Falkland, 2010). Reduced rainfall in the dry season and increasing sea-level rise, therefore, threaten the water quality of the wells.

[18] Taem mifala slip lo naet, spos i ren tumas, bae i go insaed lo wel. So mifala mas klinim wel bakaken.
[19] Samtaem i glis, speseli lo oldfala woman. Samtaem bae oli no save kasem wota from i glis.

The rainwater harvesting systems in Uripiv are highly sensitive to decreased rainfall. Participants reported that rainwater storage tanks commonly became empty during dry periods: "*When the sun is strong for a long time, we use up* [the water in the tank] *I think after one, two, or three months*[20]". The risk of water shortages in rainwater tanks will increase if rainfall in the dry season decreases as projected. An increase in wet season rainfall, on the other hand, could provide additional benefit to rainwater harvesting systems which households could carry over into the dry season if storage capacities were sufficient.

An increase in the number of days of extreme heat could be problematic for a couple of reasons. Partially underground rainwater tanks, locally called *lasiterns*, were usually constructed in-situ by pouring concrete into moulds or by binding cement blocks with mortar (Figure 14). Three participants mentioned that their *lasiterns* were prone to leakage. High temperatures can adversely affect the mechanical properties and serviceability of hardened concrete (Soudki et al., 2001) which could increase the tendency for the *lasiterns* to leak. Extreme heat can also pose a health risk to people who have to carry water from off-site water sources back to their homes.

Figure 14. Underground rainwater storage tank (lasitern) in Uripiv

[20] Taem san i strong longtaem, mifala yusumap ating wan, tu, tri manis.

As in Namoru, changes to the water supplies are the most apparent way to address these risks. Wells could be protected by building platforms, higher parapets, and covers. Rainwater tanks could be constructed to have higher storage capacities, have more robust designs (e.g. cylindrical rather than cubic shapes), and be placed closer to more homes. However, Uripiv also was limited in implementing these changes due to limited financial resources and technical expertise, which would need to be augmented by external sources.

4.2.3 Summary

In summary, projected climate change hazards for Vanuatu pose numerous direct risks to disrupting water services in the case study sites. The risks mostly exist because the design of the water supplies makes them sensitive to variable rainfall, extreme weather, or sea-level rise. Potential responses to these risks involve changes to the water supply systems. However, the capacity of the communities to implement these changes is limited due to a lack of financial resources and technical expertise. Climate change hazards and their risks for the community-managed water services in the case study sites are summarised in Table 5.

Table 5. Climate change hazards and risks to water services in case study sites

Climate change hazard	Risk to water services
Namoru	
Increase in intensity and frequency of days of extreme rainfall	Contamination of spring source and blockage of intake due to surface runoff; contaminated ingress at faulty points in the distribution system
Decrease in dry season rainfall	Water shortages due to decreased spring productivity
Uripiv	
Increase in intensity and frequency of days of extreme rainfall	Contamination of wells due to surface runoff spillage and ingress
Decrease in dry season rainfall	Water shortages due to rainwater storage tanks becoming dry; well water more susceptible to salinisation
Continued rise in mean sea level	Salinisation of well water
Increase in intensity and frequency of days of extreme heat	Compromised structural integrity of *lasiterns*; heat stress for people carrying water from off-site sources

4.3 Vulnerability analyses of water services: Mitigating deepening inequalities in water access

The vulnerability approach is based on the contextual interpretation of vulnerability. This conceptualisation views vulnerability as an inability to cope with external pressures and changes in general that is differentiated amongst people (O'Brien et al., 2007) (section 2.2.2). In this section, I illustrate ways in which WASH users and managers have differentiated capacity to respond to disturbances from climate change in general.

4.3.1 Vulnerability analyses from existing literature

WASH literature that implicitly takes a vulnerability approach varies widely in regard to what dimension of the capacity to respond to climate change in general is examined and along what lines it is differentiated. One study investigates how people in Kiribati draw on a range of assets that are mediated through institutions, such as religion and cultural values, to secure freshwater (Kuruppu 2009). The study finds that differential access between communities to different types of water

supplies, the exploitation of church patrons by relatively powerful church elites, and perceptions of self-efficacy influence the ability of people to take climate change adaptation actions to secure water access (Kuruppu 2009; Kuruppu and Liverman 2011). Another study examines how differing perceptions between female- and male-headed households in South Africa on future water access may influence their decisions to respond to climate change (Mudombi and Muchie 2013). A third study investigates how unequal access to land rights and tenure in Nepal affects people's capacity to adapt to climate change impacts to maintain water access (Khatri and Shrestha 2014). In the context of a water utility in a city in South Africa, the authors explore how processes for improving water management to meet day-to-day development needs can also address climate change risks (Ziervogel et al. 2010). Lastly, a study focused at the national policy level in Ethiopia makes an argument in favour of addressing climate change through securing long-term livelihoods and strengthening government coordination and decision-making processes in general (Oates et al. 2011).

The recommendations from these studies mostly centre on enabling people to respond to climate shocks and stresses in general. These recommendations include addressing power structures within influential organisations (Kuruppu 2009), improving or managing feelings of self-efficacy (Kuruppu and Liverman 2011), empowering individuals to overcome local barriers to adaptation action (Kuruppu 2009; Mudombi and Muchie 2013), poverty alleviation (Khatri and Shrestha 2014), strengthening technical and human resource capacity (Ziervogel et al. 2010), and maintaining attention on existing development issues at the core of climate change adaptation work (Oates et al. 2011). One specific example is the recommendation of Kuruppu (2009) to change the role of the powerful church in certain communities in Kiribati from not only providing spiritual guidance in return for financial contributions, but also facilitating climate awareness and financially backing adaptation needs in the communities.

Overall, relatively few studies from the WASH literature use a vulnerability lens to study the climate change problem. There is a need for further research, in particular in-depth qualitative case studies, on the contextual conditions that enable or inhibit different groups of people from sustaining water access under

changing climate effects. In these following section, I contribute to this space with evidence I collected from Vanuatu.

4.3.2 Vulnerability analyses from fieldwork in Vanuatu

In contrast to the risk-hazard approach, which begins with the characterisation of climate hazards, the vulnerability approach begins with a characterisation of the community. In this section, I present analyses of water access inequality and power relations in water management for each community, and relate them to their capacity to respond to climate disturbances in general.

4.3.2.1 Namoru community

In Namoru, participants indicated inequalities in water access due to unequal levels of service that different households receive from the primary piped supply. Eleven out of 19 participants responded "no" when asked if the piped water supply was fair in their community. Participants remarked that households that relied on standpipes further away from the spring source received poorer reliability due to drops in pressure, especially during dry periods: "*When the tank is empty, those of us here and there no longer receive water. Only those on top close to where the pipe comes from*[21]". Since land in Namoru is traditionally inherited and owned through paternal lineage, there is no opportunity for families far away to move closer to the source and technological fixes are beyond the capacity of the community. Moreover, as the population has grown over time, families nearer to the source have increasingly taken advantage of the relatively good water reliability to the detriment of those living downstream: "*This standpipe has problems. When the people on top use their standpipes too much…there are problems here. It will not run, it runs only a little. Sometimes it will not run at all*[22]".

Rights to land with favourable water service are further complicated by a decline in the available space within the village to build more houses. As a result, some families inheriting smaller tracts of land within the village were forced to build homes on their plantations, far removed from the village centre. Over time, these homes clustered into small settlements that were locally referred to as *stesens* (stations). The *stesens* are considered a part of the Namoru community and engage

[21] Taem tang i emti mifala lo ples ia mo lowei nomo kasem wota. Olgeta antap nomo klosap lo paep we i kam.
[22] Paep ia i stap gat problem. Taem olgeta antap yusum tumas paep…lo ples ia i gat problem. Bae i no save ron, i ron smol nomo. Samtaem bae i no save ron nomo.

in community activities but generally receive poorer reliability of water service due to being located downstream and far from the source. Thus, a family's land rights are a strong determinant of the reliability of the water services that they receive.

This is significant with respect to climate change because climate disturbances, be they dry spells or intense rainfall, frequently degrade water access provided by the piped supply. Householders typically deal with water shortages at their standpipe by walking to the nearest functioning standpipe or to a stream which is also in the direction of the spring source (Figure 7). As a result, householders that live furthest downstream of the spring source experience more climate-driven disruptions to service and have to walk longer distances to find water when their service is cut. Rights to land with better physical access to more robust water assets, therefore, contribute to the ability of householders to sustain water access when climate stress is experienced.

I observed that people living in the *stesens* sometimes felt estranged from the community centre. For example, during casual conversations with families there, one husband and wife explained that they do not like their children to socialise with children in the main village for fear that they would take up bad practices like smoking. Another man from a *stesen* stated that he would suggest to his children that they move away from the community when they are older. This contrasted with my observations in the main village that people there enjoyed each other's company and felt pride in where they came from. It is possible that tension between people living in the *stesens* and people living in the main village, who generally control more resources and have more power, contributes to lack of resource allocation to ensuring water access is sustained in the *stesens*.

On the other hand, there were also signs of tension between community members living in the village centre over the payment of user fees. At times households refused to pay user fees as agreed by the community due to poor service from the committee. Four participants accused the owner of the land where the spring was located of sabotaging or blocking water supply development over personal disputes. Finally, for better or worse, a village elder claimed he was in contact with a member of parliament about funding a new community water supply but had not informed the rest of the community for fear they would meddle his plan. These

issues highlight limitations to the cohesiveness of the community which impacts its ability to work together to achieve sustainable water outcomes.

Gender inequality in water management and governance decision-making is also present in Namoru. None of the water committee members were women and some participants did not feel that women's voices are listened to on matters of water. Although nine out of 11 participants responded "yes" when asked if it would be a good idea to have a woman on the water committee, one female dissenter explained: "*No, it will not be good because when it is men it is a little good, but when these women talk about water, they will not listen*[23]". When asked if the water committee listens to complaints from women, female participants expressed uncertainty: "*I do not know because when women talk, the men will not believe them*[24]".

Women are the primary users of water in Namoru and are thus likely to be affected the most by disruptions to water service from climate disturbances. During fieldwork, I observed women carrying water in containers and using it for numerous domestic purposes more frequently than men. When asked which social group faces the most problems with water in the community, eight out of 12 participants named women. For example, a woman answered: "*Mothers, because when there is no more water in the house, we cannot send the children because they are playing. The fathers cannot go out, they are drinking kava and walking around. Now mothers must get water*[25]". Thus, if a standpipe stops functioning due to a climate disturbance, it is primarily women who must work to find other ways to maintain water access on behalf of the family.

Consequently, despite suffering the effects of climate-driven disruptions to water service more than men, women have relatively less influence on community decisions on how to respond to climate disturbances due to their exclusion from decision-making processes. This exclusion detracts from the capacity of women to

[23] No, bae i no gud from se taem ol man i gud smol, be taem ol woman hemia bae oli go toktok from wota, bae oli no save lisin.
[24] Mi no save from ol woman taem oli toktok, ol man bae oli no save bilivim olgeta.
[25] Mama from taem wota i finis lo haos, mifala no save sendem pikinini from ol pikinini olegta i pleiplei. Ol papa oli no save stap go aot, olgeta dring kava, wokbaot wantaem. Nao mama wantaem oli kasem wota.

respond to climate disturbances and by extension detracts from the capacity of the whole community to secure water against climate change.

Throughout my stay in Namoru, as a male researcher from another country, I found it difficult to engage with women. During formal visits in homes for interviews, women were often present but spoke little. Oftentimes when I addressed a question specifically toward a woman, a man would answer on her behalf. When I socialised on a personal level with the community, women were often segregated from men and I had few opportunities to converse casually with women one-on-one. However, I did observe women freely socialising with one another such as during games of volleyball or whilst cooking. It appeared that the gender norms that drove the aforementioned exclusion of women from water management decision-making were deeply-seated in the social fabric of the community.

Addressing these above issues would involve making changes to governance processes and institutions. For example, the community could establish rules around water usage so that water continuity to households further away from the source is not cut off during dry periods. However, this would require a significant degree of cohesion and cooperation across many different families. Another option would be to change the community's current water governance position of maintaining a centralised water system that inherently favours people living on one side of the village to a decentralised approach that makes water access more equitable. Improved inclusion of women in water decision-making process would involve challenging patriarchal cultural norms (for example, through strengths-based approaches (Willetts et al., 2013)) which can be a slow-changing and contentious process.

4.3.2.2 Uripiv community

In Uripiv, households that own domestic rainwater harvesting systems typically have better water access than those that do not. The rainwater systems were clearly popular during my field visit. I observed dozens of domestically owned systems and multiple families were in the process of constructing new ones during my stay. Owning a rainwater system is advantageous because it provides an additional layer of water security by complementing the wells with an on-site source of potable water. Yet, not all households own a rainwater system. These households instead

often meet their water needs by accessing the wells, which can be located more than 100 metres away, depending on the location of the home. Further, the quality of the wells is degraded when they are contaminated by surface runoff during intense rainfall or by debris blown in during storms.

Whether or not a household owns a rainwater system is a matter of affordability and those that can afford one have increased flexibility for accessing water. Participants remarked that the costs of materials for constructing a rainwater system are simply too much for some families: "*Sometimes it costs too much. Like the cost of a tank, to make blocks, buy cement*[26]*"*. During dry periods, all households rely on the wells when the rainwater tanks run empty. However, during times of intense rainfall when wells are contaminated, rainwater system owners can often rely on water stored in their tanks. Poorer households without a rainwater system, meanwhile, often have no choice but to use the degraded wells. Thus, having financial resources to diversify water sources contributes to a higher capacity to respond to climate disturbances through the development of multiple options for water access.

Income inequality was visible in the community, although it was difficult to discern its causes. There is little economic development in the region in which Uripiv is located with most non-agricultural jobs being provided the government. When I asked participants why some people were richer than others in the community, the response was typically that richer families had members who were employed. These households were the ones that could typically afford homes with metal roofing and storage tanks that made domestic rainwater harvesting possible. When I asked why some households were able to secure lucrative jobs while others were not, participants usually answered that it was a matter of how educated a person was. However, to the extent to which this was even true, it was not clear why some families could secure better education for their children than others. This is also a matter of financing because the nearest secondary school was away in the capital Lakatoro so transport by boat needed to be paid for each day. Traditionally, resources are shared amongst community members in Ni-Vanuatu culture. However, this appears to be less true for financial resources which are a more

[26] Samtaem em i kos tumas. Olsem kos blo wan tang, blo mekem bloks, pem simen.

recent addition to rural communities. It seems likely that income inequality in Uripiv will accelerate as the country continues to develop economically. Social welfare mechanisms will need to be put in place to ensure that poorer households are able to pursue adaptation options to secure water access. In addition to providing better water access, owning a domestic rainwater harvesting system puts a household in a position of power in relation to non-owners. For non-owners of rainwater systems, an alternative to the wells is to collect water from a rainwater system that belongs to a nearby neighbour. In these cases, the authority of the owner to grant permission to use their system is respected. As one participant described: "*If you want to get [water] someplace, you must ask. If the owner is not there, you must wait. When he returns, you ask if he can allow it or not*[27]". Another participant conveyed discomfort with using another household's rainwater system: "*Sometimes you will feel that you are going too often, you will feel embarrassed to go*[28]". During interviews, some owners described rules that they set for use of their stored water such as that water could be collected for drinking only during dry periods. Thus, rainwater system owners were at times in a position to dictate the terms of water access for non-owners because ownership granted them authority.

The authority granted by ownership of a rainwater system (which itself is attained through access to financial resources) gives owners more capacity to respond to disturbances. Owners can freely use or ration their own stored water as they deem necessary depending on climate conditions. Non-owners who get water access through a neighbour's system do not have this level of control, which relatively diminishes their capacity to make choices about water use in the face of climate disturbances.

The development of individual domestic rainwater harvesting systems that serve individual families, as opposed to communal wells that serve an entire village, reflects increasingly individualistic lifestyles in the community. People in the community lamented that neighbours did not help one another as often as they did in the past. Two chiefs that I spoke with each felt that households were increasingly

[27] Spos yu wantem go kasem samples, yu mas askem. Spos ona i no gat, yu mas wet. Taem we em i kambak, yu askem spos bae em i save letem o no gat.
[28] Samtaem bae yu filim se yu gogo tumas, bae yu meksem blo go.

pursuing their own objectives and ideas for development which led to social discord. Both longed for a return to days when customary processes of traditional chiefs making the final decisions on development were followed and respected, although noticeably this implies putting power back into their own hands. Shifting values in the community indicates that solutions to address climate impacts on water services in this community may need to consider management models that are not dependent on substantial community cohesion, such as water committees that are selected to represent on behalf of everyone.

The above issues could be addressed through more equitable access to domestic rainwater harvesting systems. The introduction of pre-fabricated polyethene storage tanks in Vanuatu has made installation of domestic rainwater harvesting systems more convenient. However, the cost of the systems, particularly the storage tanks, is still unaffordable to many households. Increasing the incomes of poorer households, or reducing the costs of the system through the subsidisation of storage tanks could make access to rainwater systems more equitable. Economic instruments that assist the poor in this regard require political will and may be logistically difficult to implement.

4.3.3 Summary

In summary, inequalities in water access and unequal power to make decisions on water management influence the capacity of people to respond to climate disturbances at both sites. Addressing the relative lack of capacity involves developing more equitable institutions and water governance to give marginalised groups greater priority and control over how their water access is sustained. A summary of the examples is listed in Table 6.

Table 6. Inequalities and implications for responding to climate change in case study sites

Inequality in water access or decision-making power	Implications for responding to climate change
Namoru	
Households with rights to less favourable land receive relatively worse reliability of water services	Households on less favourable land experience more climate-driven disruptions to water service and travel further to access water when service is disrupted
Women are largely excluded from water decision-making processes	Women have less influence than men on community decisions about how to respond to climate change disturbances
Uripiv	
Poorer households cannot afford domestic rainwater harvesting systems	Poorer households have fewer options for accessing water against a range of climate disturbances
Owners of domestic rainwater harvesting systems in part dictate terms of water access for non-owners	Non-owners have less control than owners over how water is rationed under changing climate conditions

4.4 Resilience analyses of water services: Dealing with uncertainty through flexibility

The resilience approach is based on the definition of SES resilience: "the capacity of a system to absorb disturbance and reorganize so as to retain essentially the same function, structure, and feedbacks—to have the same identity" (Walker and Salt, 2012, p. 3) (section 2.2.3). Notably, resilience is not inherently positive since harmful or undesirable systems can also be resilient. This is significant in the context of development in which people are often stuck in highly resilient states of poverty (Béné et al., 2014). However, there is a greater foundation of theoretical literature on building resilience in desirable systems than on weakening resilience in undesirable systems. Consequently, my analysis primarily focuses on resilience as a means of sustaining basic water services. This section illustrates how the interactions between WASH service sub-systems and the application of resilience principles to WASH services enhances their capacity to respond to climate disturbances.

4.4.1 Resilience analyses from existing literature

Existing WASH-climate change literature has engaged little with the resilience approach to climate change. Adaptive co-management, claimed to be a successor to resilience thinking, is proposed as a potentially effective approach to adapting rural water services to climate change (FitzGibbon and Mensah 2012). This approach draws on complex and adaptive systems thinking to analyse cross-scale interconnections between water sectors and ecological resources, promote continuous learning amongst local water management institutions, emphasise involvement of local communities in water management, and build social capital between decentralised bodies that have a stake in water resources (FitzGibbon and Mensah 2012). IWRM is another approach based on a holistic understanding of how water-related systems interact with one another that is proposed for managing WASH services under climate change (Hadwen et al. 2015). Authors of both papers argue that their respective approach facilitates decision-making processes that account for the relationships between different water-related domains (e.g. social, environmental, and economic) which is needed to address the wide scope of the climate change threat.

Although resilience principles (Table 1, Chapter 2) are scarcely mentioned explicitly in the WASH-climate change literature, some authors make points that implicitly align with some of them. Some points relate to water management. For example, multiple authors recommend monitoring and information gathering on climate impacts, especially on water resources, to support continuous learning (Smits et al. 2009; Batchelor et al. 2011; Calow et al. 2011; Elliot et al. 2011). Mukheibir (2010b) emphasises that water managers need to plan adaptation for fast-changing variables like extreme events differently than slow-changing ones like gradual precipitation change.

Resilience principles have also been implicitly applied to biophysical aspects of WASH service delivery. Diversification of water supplies in order to “spread out” risk such that the likelihood of one perturbation disrupting all services is lessened (Calow et al., 2011; Elliot et al., 2011; Kuruppu, 2009) and increased redundancy through an expanded number of discrete water supplies (Boelee et al., 2013; MacDonald et al., 2009) are encouraged. Bonsor et al. (2010) state that boreholes or deep wells that reach 20 metres below the ground surface in rural Africa are

likely to avoid depletion under future climate scenarios. This could be considered an important threshold. However, along these same lines, MacDonald *et al.* (2009) note a possible feedback loop whereby users of shallow groundwater sources may abandon their failed systems and move to more robust deep groundwater supplies, which in turn could fail due to the increased mechanical stress on pumps from a rising number of users. Finally, Howard *et al.* (2010) recommend decentralising water infrastructure to reduce the spread of risk through highly connected water supplies but centralising water management to maximise the use of people with needed skillsets. This can be seen as management of the property of connectivity.

4.4.2 Resilience analyses from fieldwork in Vanuatu

As with the vulnerability approach, the resilience approach usually begins with a specific setting. For my research, it begins with a characterisation of the community and its water resources. In this section, I present an example of the interconnections between the community and its water resources and the implications for responding to climate disturbances for each case study site. I also give examples of the relevance of certain resilience principles (Table 1, Chapter 2) to the case study sites and discuss their relevance to climate change.

4.4.2.1 Namoru community

In Namoru, land development activities taken by the community threaten a secondary source of water which could feed back to reduce the level of water service available to the community. The stream on the northeast periphery of the main village is a vital backup water source for the community (Figure 15). It is frequently used for bathing, washing, and sometimes for drinking when the piped system fails. At the time of my field visit, the stream was surrounded by dense riparian vegetation which is known to protect streams from pollution (Narumalani et al., 1997). However, I noted from my field observations and casual conversations with residents that the community was growing and increasingly encroaching on the stream to build houses, dig pit latrines, and clear natural vegetation for plantations and livestock. Waste from these new houses and effluent that soaks from the pit latrines into the surrounding soil could threaten to pollute the stream. The clearing of natural vegetation could reduce the attenuation of surface runoff and associated pollutants before they enter the stream (Narumalani et al., 1997). If pollution of the

stream increases significantly enough, the stream could become unsuitable for its current uses.

Figure 15. Stream in Namoru community

This is relevant to climate change because these activities also diminish the capacity of the stream to absorb the effects of climate disturbances. Climate change is projected to reduce raw water quality through increases in pollutant loading during heavy rainfall events and reduced dilution of pollutants during droughts (Jiménez Cisneros et al., 2014). Surface water bodies have a capacity to self-purify to an extent that the water is still acceptable to users but this capacity can be exceeded when the pollutant load becomes too high (Newson, 1992). Thus, land use activities that increase the existing pollutant load on the stream make it more likely that future climate change effects will cause the self-purification capacity threshold to be crossed.

With respect to other resilience principles, the principle of polycentricity is reflected by management mechanisms in place for responding to extreme weather events. In Vanuatu, a network of government and non-government agencies have been established to, amongst other functions, communicate threats of extreme weather from a national to local level (Vachette, 2015). The network delineates management roles and responsibilities for responding to threats horizontally across sectors and vertically across geographic areas (Vachette, 2015). Namoru

community is nested within this network through a community disaster committee that was established with the assistance of an NGO. The community disaster committee is trained to advise the community on how to respond to a range of climate disturbances. When threats of extreme weather are detected by national authorities, responses are coordinated at national and provincial scales. Information about threats and responses will then be communicated by the authorities to the community disaster committee or directly to households through radio or mobile phone. Families then make water management decisions accordingly. For example, a participant explained how his family responded to cyclone alerts: "*Sometimes we fill up water in buckets…fill up water in plastic bottles. When the cyclone comes, it makes the water* [in the piped supply] *stop running but there will be water here already*[29]".

The polycentric network is helpful to the community for responding to climate change because it matches scales of management to the appropriate level of the problem. National authorities are better equipped to detect climate disturbances and how they may impact various sectors. Communities are better equipped to assess their water situations locally and make quick decisions about what is best for their families. By nesting community and household water management processes within broader decision-making processes on regional climate disturbances through lines of communication, the Namoru community benefits from the capacity of authorities to detect disturbances that they cannot, while maintaining the flexibility to make their own locally appropriate decisions on how to maintain water access.

The Namoru community can maintain or increase the resilience of its water services to climate change through management of the community's interactions with its water resources, and through strengthening their beneficial interactions with agencies at broader scales. The stream may be sustained as a viable secondary source for non-drinking uses if households are restricted from building or farming too close to it. However, maintaining this buffer zone may be a challenge given the rising population of the community. Lines of communication with authorities at broader scales are beneficial to the community for making water management

[29] Samtaem mifala filimap wota lo ol baket…filimap ol plastik. Taem hariken i kam, mekem se wota i nomo ron be wota i stap finis.

decisions locally and could be strengthened to include closer communication with the DoW.

4.4.2.2 Uripiv community

In Uripiv, increasing abstraction of groundwater has affected the quality of the freshwater lens. Research shows that on very small islands like Uripiv, groundwater pumping technology risks salinisation of the freshwater lens through a phenomenon known as upconing whereby brackish water in the "transition zone" (the zone where the freshwater lens and seawater meet underground) is pulled upward (White and Falkland, 2010). Participants remarked that this had been experienced at one well where a solar pump was installed: "*Now it is becoming salty. I think because the dry season is too strong, it is causing a lack of water. The solar pump is pulling it but it is becoming salty*[30]". Once the water in the well became saline, users began rejecting it for drinking which marks an important threshold. Although upconing is reversible by discontinuing or slowing pumping rates, repeated incidences of upconing can cause the thickness of the transition zone to permanently increase (Custodio, 1991). This means that the salinisation threshold can potentially move to become more restrictive if upconing repeatedly occurs.

The community also affects the groundwater through its activities on the surface. Vegetation and good soil structure promote infiltration of rainwater (Robinson and Ward, 2017) which is then purified as it percolates toward the water table (Balke and Zhu, 2008). However, in Uripiv, the development of living spaces has led to clearing of natural vegetation and compacting of the topsoil. As a result, the land's infiltration capacity has decreased and surface runoff has increased, which causes problems with spills of contaminated runoff into open wells. This, in turn, leads users to take up coping strategies such as treating the well water through boiling (often using firewood sourced by clearing more vegetation which continues the feedback loop).

The influence that the community has on the groundwater has implications for how the groundwater may be affected by climate change. In section 4.2.2.2, I noted that the groundwater is threatened by decreasing rainfall in the dry season, continuing

[30] Naoia em i kam olsem solti. Ating from draesisen tumas, afta mekem se i no gat inaf wota. Sola i stap pulum, be i kam solti.

sea-level rise, and intensification of rainfall in the wet season. This range of climate change pressures on the groundwater is amplified by the aforementioned activities of the community.

Resilience principles of diversity, redundancy, and connectivity are reflected in the structure of the water sources in Uripiv. The proliferation of discrete rainwater harvesting systems on Uripiv, in addition to the eight dug wells, means that community members have numerous options for accessing water. If rainwater systems are dry due to drought, water is still available from wells (participants remarked that the wells had never gone dry before). If intense rainfall contaminates the wells, water is available in rainwater tanks. Although most rainwater harvesting systems are privately owned by households, the water supplies are generally shared amongst the entire community. Furthermore, numerous, discrete water supplies means that disturbances like point contamination are generally quarantined to a single supply. In essence, limited connectivity between the water supplies helps to prevent contamination risks from propagating.

This structure of water supplies gives the community increased capacity to respond to climate change. Wells and rainwater harvesting systems are affected differently by different climate disturbances (Luh et al., 2017). The variety and decentralised arrangement of water supplies makes it less likely that any one climate disturbance would cut off water service for the whole community. Being afforded multiple options for accessing water thus gives community members increased flexibility for responding to climate disturbances.

As with Namoru, resilience in Uripiv can be maintained or increased through improved management of the community's interactions with their water resource. Moderating the amount of groundwater extracted and limiting the clearing of vegetation may contribute to enhancing the freshwater lens such that it is less likely to be compromised by effects of climate change. However, on a small island such as Uripiv, water and land are scarce and it is difficult for the community to moderate their use more than they do already. Having multiple options for accessing water is an advantage so maintenance of the wells should not be

neglected even though the domestic rainwater harvesting systems are the preferred option of the participants because of their convenience.

4.4.3 Summary

In summary, the interactions that the communities have with their water resources and the resultant feedbacks have implications for how water services will fare when climate change disturbances are experienced. Further, there is evidence that certain resilience principles can be applied to community-managed water services with respect to climate change. Improving capacity in these communities in the resilience sense involves managing interactions between the communities and their water resources, and upholding resilience principles. A summary of the examples in this section is listed in Table 7.

Table 7. Resilience principles and their implications for climate change

Community-water resource interaction or resilience principle	Implications for responding to climate change
Namoru	
Land use activities threaten to increase pollutant load on the secondary water resource	Pressures from land use activities can combine with pressures from climate change to make the secondary water source unsuitable for its current uses
A polycentric governance system nests community/household water management responses to extreme weather events within regional/national management processes for responding to extreme weather events	The community benefits from the capacity of broader authorities to detect climate disturbances while maintaining flexibility to make locally appropriate responses
Uripiv	
Increased groundwater abstraction and land use activities threaten the quality of the freshwater lens	Pressures from community activities can combine with pressures from climate change to make water abstracted from the freshwater lens unpotable
A variety of discrete water supplies gives community members multiple options for accessing water	It is less likely that any one disturbance from climate change will entirely cut water services for the community

In the cases of Namoru and Uripiv, some issues appeared to me, as an outside research expert, to be more salient than others. In Namoru, the resilience lens showed the water service to be rigid and poorly equipped to handle slow changing variables like the growing population and deterioration of assets which appeared

to be reaching critical thresholds. The vulnerability analysis revealed serious social sustainability issues regarding the exclusion of women from decision-making processes. In Uripiv, the resilience and risk-hazard assessments raised major issues with the integrity of the shallow groundwater lens that is needed to sustain life (both human and environmental) on the island. However, it is possible that community members would prioritise issues differently.

4.5 Discussion

All adaptation actions to sustain community-managed water services against climate change are based, implicitly or explicitly, on some analysis of how the services are affected by and sustained against climate change disturbances. The above analyses from Vanuatu demonstrate how the same situation can be problematised differently based on different theoretical approaches. Subsequent recommended adaptation actions to address the issues emphasised by the different approaches (listed in Table 5, Table 6, and Table 7) would have different outcomes for the communities. The significant link between the approach taken and the adaptation outcomes for communities points to a need to think critically about the ways in which climate change impacts on community-managed water services can be analysed.

In this section, I discuss the implications of the findings presented in this chapter. In particular, I discuss the limited explicit engagement that the existing WASH scholarly literature has with conceptualising climate change impacts, the limitations of each approach, and how the process of working across different approaches may be navigated.

4.5.1 Limited conceptual awareness in existing literature

Authors use the terms vulnerability and resilience frequently throughout the WASH literature but very few attempt to define or even characterise them. There is also little acknowledgement of the different ways of conceptualising how climate change affects WASH services. However, my research has found that the risk-hazard (or outcome vulnerability) approach is implicitly drawn on most frequently for analysing climate change impacts on WASH (Kohlitz et al., 2017). One possible explanation for this is that the WASH sector is reflecting the same tendency that the wider climate change scholarship and policy previously took to favour a

scientific framing of climate change as a biophysical problem (O'Brien et al. 2007). Another possible explanation is that when WASH authors without a strong grounding in climate change theory are met with the conflicting definitions and conceptualisations presented by the climate change literature, they default to definitions provided by the Intergovernmental Panel on Climate Change (IPCC), which is widely seen as the authoritative body on climate change. The IPCC definition of vulnerability aligned mostly with an outcome interpretation until the definition was changed in the 2014 Fifth Assessment Report to be more encompassing of different interpretations. Meanwhile, the resilience concept historically has had weaker links with climate change adaptation research than vulnerability (Janssen et al. 2006). Notably, a dominant focus on technologies over environmental and social dimensions is also present across many WASH sustainability initiatives (Mehta and Movik, 2014).

Regardless of the reason, the limited conceptual awareness exhibited in WASH-climate change nexus literature is cause for concern. Authors often seemingly take definitions of vulnerability and resilience as given (i.e. that the definitions must be so obvious that they require no discussion). However, as I have demonstrated in the review of theory in Chapter 2 and in the analyses in this chapter, there are multiple conceptualisations of vulnerability and resilience that lead to starkly different problematisations of the effects of climate change on water services. Failure to define key concepts is likely to lead to confusion, gaps in addressing adaptation needs, and adaptation approaches that are incongruous with one another in the WASH sector. Further, WASH climate change policy that overlooks the range of available perspectives could allow a narrow domain of solutions to dominate. This latter potential outcome requires attention due to inherent limitations or weaknesses of each approach for water services.

4.5.2 Limitations of each approach for analysing water services

In this section, I discuss key limitations of each of the three approaches in the context of community-managed water services. While this is not an exhaustive list, it demonstrates that no approach should be followed uncritically.

As shown in section 4.2, the risk-hazard approach tends to focus on technologies and how they will fare when exposed to specific climate hazards. This is problematic for a few reasons. Robust technology clearly is important for water

service provision. However, poor communities and households are least likely to be able to implement and maintain climate-proofed infrastructure, such as deep boreholes, due to their higher costs and expertise required to build and operate them safely. Thus, promotion of water technologies that are resistant to climate change hazards must be accompanied by strategies to make these technologies available to all social groups in order to avoid reinforcement of inequalities in water access. Second, a focus on climate-proofing existing water supplies may lock communities into a single option and leave them with less flexibility to explore alternatives. Communities may benefit from avoiding a "sunk-cost" effect whereby past investments in water supply infrastructure weigh more heavily in adaptation decisions than future opportunities (Nelson, 2011). Third, a dominant focus on climate hazards and their risks may overlook the everyday struggles of communities that inhibit them from responding effectively to environmental stresses (Gaillard, 2012). Finally, climate change projections have large uncertainty at the local scales where water services are managed by communities (Batchelor et al. 2011). Building capacity to respond to specific climate change hazards risks wasteful investment if hazards emerge differently than expected. This may be addressed in part by referring to the literature that has studied which water service technologies are most robust to the widest range of climate hazards.

The uncertainty of how climate change hazards will develop at local levels and how they will interact with other drivers of change is significant for water access for a few reasons. First, uncertainty affects planning on the development of water resources. Community members in both Namoru and Uripiv aspired to increasingly exploit shallow groundwater resources to meet community needs. However, the extent to which this is a viable solution for either community depends on a confluence of factors including climate-driven changes in future water recharge rates, water demand, changes in population growth and migration patterns, and land development activities amongst other known and unknown variables. This makes it difficult to determine whether shallow groundwater resources, or other water resources, are the most effective solutions for sustaining water access.

Next, climate change can create new vulnerabilities that affect water access, albeit in more indirect ways. For example, the majority of community members in

Namoru and Uripiv making a living from farming staple crops. Climate change threatens food production in Pacific island countries in multiple ways (Barnett, 2011). This could severely impact people's livelihoods which in turn could affect the amount of income they have to spend on accessing water, cause migration to urban areas with stressed water resources, or cause competition for securing water to sustain plantations (in the event of drying conditions). Indirect impacts like these and are likely, but difficult to predict and respond to due to the number of different variables involved.

Finally, other socioeconomic changes that are not necessarily related to the climate also can create vulnerabilities that are difficult to foresee. For example, four participants in Uripiv stated, without being prompted, that the community was becoming increasingly individualistic over time: "*Before the community's lifestyle was good. But now, they stay as individuals…Before there was no development coming. When development comes, everyone stays as individuals*[31] ". Shifts from communal lifestyles to more individualistic ones are occurring throughout the Pacific island region (Campbell, 2009). This gradual change in preference and values may indicate that climate change adaptation strategies that rely on the sharing of power and decision-making for management of water services, such as through water committees and voluntary payments on tariffs for communal water systems, could become increasingly difficult to implement equitably. Again, these interactions between socioeconomic and climate change are complex and difficult to foresee.

The examples from section 4.3 show that the vulnerability approach is highly focused on present, context-specific, and social issues. Addressing present issues of inequality in how people are affected by and respond to climate change may be akin to conventional development and poverty alleviation approaches (McGray et al., 2007, p. 18). However, poverty reduction policies and goals are unlikely to be sufficient for addressing specific climate risks (Adger et al., 2003; Nelson et al., 2016) such as the impact of sea-level rise on groundwater on very small islands. It is worthwhile to consider how conventional development approaches to water service delivery can be integrated with the management of new climate risks. Next,

[31] Bifo fasin blo komuniti i gud. Be nao, oli stap wanwan…bifo i no gat divelopmen i kam. Taem divelopmen i kam, ol man stap wanwan.

the context-specific nature of the vulnerability approach makes vulnerability of water services difficult to quickly and broadly assess. Generic indicators for assessing water service vulnerability can be developed based on socio-economic data (e.g. see Luh et al. (2015)) but vulnerability indicators for the purpose of comparison at large scales are roundly criticised for over-simplifying the complexity of contextual vulnerability (Barnett et al. 2008; Hinkel 2011). Complementing quantitative indicator-based approaches to assessing vulnerability with transferable lessons from in-depth place-based assessments would generate more meaningful insights (Ford et al., 2010). Finally, the focus of the vulnerability approach on social aspects of water service delivery may neglect environmental aspects. Traditionally, the WASH sector has paid relatively little attention to upstream (water source reliability) and downstream (sanitation pollution) effects of WASH service provision compared to improving access in the near-term (Carrard and Willetts, 2017). Given that climate change also adds stress to environmental systems on which water services depend and impact, it is worthwhile to consider environmental dimensions of sustaining water services under climate change in concert with social dimensions.

Examples in section 4.4 show that the resilience approach emphasises biophysical aspects of water service delivery, the relationships between different water-related systems, and investments to develop flexibility in the face of uncertainty. Like the risk-hazard approach, the emphasis of the resilience approach on biophysical aspects has a tendency to omit or underplay social-political dimensions such as power relations and cultural values (Cote and Nightingale 2012). Systemic discrimination is known to be a major barrier to water access (Van de Lande et al., 2015) and climate change has potential to exacerbate inequalities in water access (OHCHR, n.d.), so it is important that resilience approaches are not completely apolitical when applied to water services. In relation to this, the resilience approach's representation of water services as linked systems can overlook differences in levels of resilience between people within a social system (Béné et al., 2014). Therefore, examinations of the relationships between water-related systems may need to go deeper than a whole-of-system level to ensure that the most disadvantaged people are not being left behind. Finally, investments in building flexibility to deal with future uncertainty usually come at the expense of present

cost-efficiency (Eakin et al. 2009; Walker and Salt 2012). This can be difficult to encourage in resource-poor settings where people struggle to afford to pay for even basic water services. Equitable financial support should be made available where these types of investments are promoted.

Yet, with these limitations in mind, the analyses from the literature and from my fieldwork demonstrate that each approach can make valuable contributions to understanding how community-managed water services are affected by and sustained against climate change disturbances. Although the approaches tend to raise different types of issues, they are all valid and worthy of consideration. A valuable next step is to consider how these approaches can be drawn on to leverage their respective strengths.

4.5.3 Working across different approaches

When analysing how community-managed water services are affected by and sustained against climate change disturbances, it is advantageous to simultaneously draw on each approach to help minimise their inherent limitations. This is because the weaknesses of each often appear to be strengths of one of the others. However, there is still a question of how this should be done. Should one attempt to balance all three approaches equally or, in the context of water services, does it make sense to depart from one approach and bring in the others later? I argue that the answer to this question depends on why the analysis is being taken and what aspects related to water service are especially valued by stakeholders.

In instances where climate change is being addressed for a specific reason, it may make more logical sense to use one approach as a foundation and draw on the others to complement it. A risk-hazard approach may be most useful in the design of a rapid water service disaster response plan to expeditiously restore water access after a specific extreme event. If one is interested in studying how climate change will affect the achievement of the human right to water, the social focus of a vulnerability approach may be the most useful starting point. A resilience approach may work best for preparing water services for long-term climate change in an area where water resources are especially fragile. In all of the above scenarios, I strongly recommend that analysts also consider how the other approaches could contribute and what are the potential consequences of emphasising one approach over the others.

However, in many cases there will be no obvious rationale for emphasising one approach over the others and this is when approaches can become contested due to differing values. Values in the context of climate change relate to forming ideas about what is considered effective and legitimate adaptation, what is worth preserving and achieving, and what should be the goals of adaptation (O'Brien and Wolf 2010). Experience shows that the success of climate change adaptation efforts is often limited when the values of implementers are not aligned with those who are meant to benefit (Adger et al. 2009).

This has implications for how climate change adaptation should be mainstreamed into water service policy. It could be argued that adaptation actions should prioritise a reduction in inequalities and empowerment of people so that they are better able to maintain water access against the stresses of climate change. It could also be argued that a focus on climate-proofing or building resilience into water services gives enormous long-term benefits in terms of ensuring water security and reliable infrastructure. Ideally climate-resilient water services are developed without compromising near-term gains in access but decision-makers must choose how to allocate scarce resources. Making a decision on this requires debating the ethics of delaying basic water service provision to build in additional measures to prepare for climate change, beliefs about the extent to which society should invest in enabling future generations to meet their needs, and the value that should be placed on the natural environment amongst numerous other axiological considerations. Water service policy-makers interested in mainstreaming climate change adaptation into policy must consider who stands to benefit most from taking different orientations and whose values will be privileged.

Politics are likely to factor into deciding which approach to take because existing institutional structures create incentives or political will for how water services are delivered (Harris et al., 2011). Social groups that rely on expensive water infrastructure are more likely to advocate for an approach that manages climate risks to technologies than those who utilise inexpensive technologies. In some cases, politicians who want to improve embarrassingly low coverage figures may be less inclined to take an approach that invests in the distant future. Whether intentional or not, groups in powerful positions, like international donors, will have

unbalanced influence on how the WASH sector should incorporate climate change vulnerability and resilience into its agenda.

The best way to begin making choices about how to draw on different approaches to address the effects of climate change on water services is to be cognisant of them and their implications. In this chapter, I have begun an illustration of the different approaches in the context of water services to elucidate how they lead us to conceptualise the climate change problem differently and, consequently, lead us down different adaptation pathways. However, to this point, I have considered each approach in isolation. In the next chapter, I discuss the challenges and opportunities of jointly applying the approaches in analysing the capacity of community-managed water services to sustain water access against climate change disturbances.

4.6 Summary

In this chapter, I have examined the contributions of the risk-hazard, vulnerability, and resilience approaches to understanding how community-managed water services in Vanuatu are affected by and sustained against climate change disturbances. I have done this through a review of existing WASH-climate change literature and a presentation of empirical evidence from two rural communities in Vanuatu. I have demonstrated how the risk-hazard approach emphasises the implementation of management of water technologies, the vulnerability approach emphasises equitable water access and decision-making power, and the resilience approach emphasises interactions between social and environmental systems and flexibility. These are all valuable contributions that can be drawn on to sustain community-managed water services against climate change disturbances but each approach has limitations. I argue that, in most situations, it will be most beneficial to draw on all three approaches when conceptualising how community-managed water services are affected by and sustained against climate change disturbances. However, the degree to which each approach is drawn upon will depend on the specific situation and the values and preferences of stakeholders. I also argue that the best way to weigh the different choices for conceptualising the climate change problem for community-managed water services is to be cognisant of the choices,

how they are related to one another, and the implications of emphasising some options over others.

Chapter 5. Combining perspectives to more effectively address climate impacts: A proposed conceptual framework

Chapter preface

This chapter contains re-formatted and adapted portions of co-authored journal submissions. The details of these submissions are:

Kohlitz, J., Chong, J., Willetts, J., [in preparation]How are climate change vulnerability and resilience analyses related? An investigation of their application to community-managed water services

Kohlitz, J., Chong, J., Willetts, J., [under review]Analysing the capacity to respond to climate change: A framework for community-managed water services, submitted manuscript to *Climate and Development on 12 December 2017*

Statement of contribution

In the study that generated these journal submissions, I led the research design, literature review, and data collection and analysis. Joanne Chong and Juliet Willetts provided substantial feedback and advice on these activities. I wrote the journal submissions and Joanne Chong and Juliet Willetts reviewed and provided substantial feedback on and approval of the manuscripts.

5.1 Introduction

The purpose of this chapter is to address research question #2: How can climate change risk-hazard, vulnerability, and resilience assessments be conceptually integrated with respect to community-managed water services? In Chapter 4, I demonstrated that the risk-hazard, vulnerability, and resilience approaches provide different, but equally valid and valuable, contributions toward assessing how community-managed water services are affected by and sustained against climate change disturbances. I discussed that many factors will influence the decision of how to draw on the approaches. However, I argued that in most cases it will be beneficial to simultaneously draw on all three. Accordingly, in this chapter, I present a conceptual framework that acts as a heuristic for sensitising analysts to, and encouraging their critical thought about, different elements that contribute to the capacity of community-managed water services to sustain access to water against climate disturbances in a developing country setting.

The conceptual integration presented in this chapter focuses on a capacity to respond to climate change disturbances which is a concept shared by all three of the approaches (Adger, 2006; O'Brien et al., 2007; Engle, 2011). Although concepts of exposure and sensitivity are related to the capacity to respond, they are less nuanced and much better understood by both researchers and practitioners than capacity to respond (which continues to befuddle many WASH experts). Further, studying exposure is largely a matter of climatology and downscaling climate projections, which is researched extensively, and the sensitivity of water services to climate hazards has been researched in detail as shown in Chapter 4.2.1. Capacity to respond is highly nuanced by comparison and little researched in the context of rural water services. Another related concept, transformation, is deserving of its own extensive analysis in the context of water services."

Conceptually combining the approaches in a single analysis is advantageous because it allows for close joint consideration of different perspectives. Some authors remark that the three different approaches are largely complementary in forming a holistic view of a situation to inform policy, and that a joint application of them can yield helpful synergies (Eakin and Luers, 2006; Miller et al., 2010; Nelson et al., 2007; O'Brien et al., 2007; Turner, 2010). Another warns that each involves implicit trade-offs in policy formulation and policy outcomes (Eakin et al.,

2009). Conceptually combining the approaches facilitates the identification of synergies and trade-offs because it allows analysts to examine fundamental commonalities and differences between different worldviews. The framework I present in this chapter is a synthesis of risk-hazard, vulnerability, and resilience concepts that describe the capacity of a system to respond to hazards; a key point of convergence between the theories of the three approaches (Adger, 2006).

A conceptual framework is useful because it provides a "metatheoretical language" (McGinnis and Ostrom, 2014) that enables a shared understanding of a situation before action is taken. This shared understanding is missed when different approaches are taken in parallel and perspectives are compared only once each assessment is complete (as I did with the risk-hazard, vulnerability, and resilience approaches in Chapter 4). In reference to incorporating social science perspectives into resilience thinking, Fabinyi *et al.* (2014) claim that interdisciplinary dialogue is a more pragmatic and realistic way of joining perspectives than conceptual frameworks. However, I believe that the two drive, not detract from, each other. Further, whether consciously considered or not, all adaptation recommendations for building capacity to respond to climate change disturbances are based on assumptions of how capacity is created in the first place. Conceptual frameworks help make these assumptions explicit so they can be more easily analysed, critiqued, and justified.

This chapter is structured to begin with an overview of, and my commentary on, existing frameworks that aim to integrate risk-hazard, vulnerability, and resilience theories. Following this, I present my conceptual framework and provide illustrative examples of concepts in the context of community-managed water services. Next, I discuss areas within the framework where analytical choices must be made that have significant implications for how a capacity assessment is carried out. After, I discuss some limitations of the framework. I then retrospectively apply my proposed framework to my case study findings to demonstrate how the framework can be used. I conclude with remarks on the contributions of this chapter and further work that is needed.

5.2 A review of integrated conceptual frameworks

I now present an overview of conceptual frameworks that aim to integrate risk-hazard, vulnerability, and resilience theories. This is not an exhaustive review of frameworks in the literature but instead a review of frameworks that are highly influential in their field or reflect the latest thinking on the theories. I comment on their contributions and limitations to set the stage for my proposed framework. I first present four frameworks that integrate risk-hazard and vulnerability theories, then four frameworks that integrate resilience with vulnerability and risk-hazard theories. All of the frameworks refer to some form of capacity, or lack thereof, to respond to disturbances.

It should be noted that, aside from the frameworks that I review here, there are a wide range of SES or human-environment conceptual frameworks that can be used to assess the sustainability of natural resource management systems. Binder *et al.* (2013) review ten such frameworks including the widely cited SES framework developed by Ostrom (2009, 2007) that is used to identify key variables that influence the sustainable harvest of natural resources. There are also procedural frameworks (frameworks that provide a set of planning guidelines) such as IWRM (Binder et al., 2013) that could be used to analyse sustainability of water services. However, these sustainability frameworks do not have an explicit focus on how systems respond to environmental disturbances, which is a key focus of my research. Sustainability frameworks may implicitly address disturbances (one would assume that a system would need to accommodate disturbances in order to be sustainable), so this is not to say they are necessarily unsuitable for analysing interactions between systems and climate change disturbances. That said, they are less relevant than frameworks that explicitly address disturbances and some delimitation is required, so I do not review them here.

5.2.1 Integration of risk-hazard and vulnerability theories

As I explained in section 2.2, two broad research traditions have been predominant in vulnerability studies. One interprets vulnerability to climate change in terms of the amount of potential damage that a particular climate disturbance can cause to a system, and the other interprets it as a state of the system that already exists before a disturbance is encountered (Brooks, 2003). The former has been called outcome vulnerability and the latter contextual vulnerability (O'Brien et al., 2007).

The risk-hazard approach follows an outcome vulnerability interpretation while the vulnerability approach follows the contextual vulnerability interpretation. Although the following four frameworks do not use the same terminology that I do, they each recognise the two interpretations on which the risk-hazard and vulnerability approaches are respectively based and aim to integrate them to consider an "overall" vulnerability.

Two early and influential frameworks that conceptualised an integration of the two vulnerability interpretations are the "pressure and release" model and the "hazard of place" model. The pressure and release model developed by Blaikie *et al.* (1994) conceives vulnerability as being produced by economic, social, and political processes (called "root causes" and "dynamic pressures") that create conditions for a system that are unsafe with respect to a particular hazard. Thus, the model views vulnerability as a product of both exposure to a hazard and social pressures that influence people's capacity to respond to disturbances (Adger, 2006). The hazard of place model developed by Cutter (1996) similarly views overall vulnerability (termed "place vulnerability") as a combination of potential exposure to a biophysical risk (termed "biophysical vulnerability") and a social predisposition to susceptibility to environmental threats (termed "social vulnerability") (Cutter, 1996). These models were important early contributions to modern thinking on the integration of risk-hazard and vulnerability approaches but are limited in that they weakly consider the linkages between human and environmental systems and provide little detail on the structure of climate impact causality (Cutter et al., 2008; Turner et al., 2003a).

Later integrated frameworks reflected a development in terminology and climate impact causality. Füssel and Klein's (2006) framework for a "second-generation vulnerability assessment" conceives vulnerability as being jointly produced by biophysical climatic stimuli and non-climatic drivers, as do its predecessors. Moreover, the authors explicate causality through the expression of vulnerability as a function of exposure, sensitivity, and adaptive capacity. They define exposure as "the nature and degree to which a system is exposed to significant climatic variations" and sensitivity as "the degree to which a system is affected, either adversely or beneficially, by climate-related stimuli". Meanwhile, instead of a negative term indicating a social predisposition to harm, the term adaptive capacity

is used to mean the capacity of the social system to adjust to avoid harm or take advantage of opportunities from climate change (Füssel and Klein, 2006). The framework also acknowledges that vulnerability needs to be assessed at different scales (e.g. vulnerability for a country may appear low but can be high for certain sub-groups within it).

This second-generation vulnerability framework is still limited in two ways. First, although it recognises that the system of interest can be an integrated social-biophysical system (Füssel, 2007), there is still little recognition of the complex interactions between human and environmental systems that influence the capacity to respond to disturbances. In fact, there is little conceptualisation of how adaptive capacity is created at all. Second, there is no analytic disaggregation of the adaptive capacity concept. As a result, some vulnerability authors use the term to refer to the capacity to respond to specific anticipated hazards (i.e. the risk-hazard approach described in section 2.2.1) (Brooks et al., 2005) while others use it to refer to the capacity to respond to changing shocks and trends in general (i.e. the vulnerability approach described in section 2.2.2) (Jones et al., 2010). Both forms of adaptive capacity can be assessed at the same time but the framework provides no guidance on the delineation or interactions between the two forms.

More recently, effort has been made to reconcile different interpretations of adaptive capacity by explicitly distinguishing them and studying their relationships. Several authors distinguish the capacity to adapt to specific anticipated hazards from the capacity to adapt to disturbances in general by labelling them specific capacity and generic capacity respectively (Eakin et al., 2014; Lemos et al., 2013; Nelson, 2011). Eakin *et al.* (2014) propose a framework for analysing the relationships between the capacities. In some instances, the capacities have positive feedback relationships, such as when both capacities are low and poverty traps are created. Their framework also considers interactions between capacities at different scales. For example, in countries that have high generic capacity, individuals may have low specific capacity if they expect national authorities to look after them when a specific hazard is experienced (Eakin et al., 2014). As with the other vulnerability frameworks, this framework is socially focused and pays little attention to the role of environmental systems in building capacity to respond to disturbances.

The frameworks that integrate risk-hazard and vulnerability theories have made valuable contributions toward explicating how physical disturbances are experienced by a system and the different capacities of social groups to respond to disturbances. However, to-date, they have had limited engagement with how environmental factors influence this capacity. This is significant with respect to community-managed water services because climate change threatens to disrupt water ecosystem services that are vital for the ongoing delivery of water services.

5.2.2 Integration of resilience with risk-hazard and vulnerability theories

Although authors state that risk-hazard, vulnerability, and resilience approaches are complementary (Adger, 2006; Miller et al., 2010; Turner, 2010), few efforts have been made to integrate them in a conceptual framework. In this section, I present four such efforts and discuss their contributions.

Two of the reviewed frameworks conceptualise resilience broadly as a collection of different capacities for responding to disturbances, and consider resilience to be a component of vulnerability. For example, the framework by Turner *et al.* (2003a) shows vulnerability as a function of the system's exposure to a hazard, its sensitivity, and its resilience. Resilience is determined by the system's capacities to cope, adjust, and adapt to hazards, and the resulting impacts (Turner et al., 2003a). Similarly, the framework by Birkmann *et al.* (2013) shows vulnerability as a function of exposure, susceptibility, and resilience. Here, resilience is determined by the system's capacities to anticipate, cope with, and recover from hazards (Birkmann et al., 2013). In both these frameworks, an increase in resilience directly results in a decrease in vulnerability. They are similar in logical structure to the second-generation vulnerability framework described above but substitute adaptive capacity with resilience.

The framework by Turner *et al.* (2003a) further asserts that interactions between social systems and ecosystems influence the capacity of the system to respond to disturbances. Drawing on SES resilience theory (section 2.2.3), the authors conceive the system of interest as comprising social and environmental components (termed "human conditions" and "environmental conditions") that interact to influence the system's resilience. However, little detail is provided on the conceptualisation of how the human and environmental conditions influence resilience.

The other two reviewed frameworks interpret resilience as the capacity of an SES to absorb disturbances and maintain its key structure and functions which aligns with how I defined resilience in section 2.2.3. The framework by Chapin *et al.* (2009) views vulnerability and resilience as separate concepts but bridged by the concept of adaptive capacity. Vulnerability is defined as "the degree to which a system is likely to experience harm due to exposure to a specified hazard or stress" (Chapin et al., 2009) which aligns with the interpretation taken by the risk-hazard approach (section 2.2.1). Adaptive capacity is said to contribute to both reducing vulnerability and strengthening resilience. Thus, adaptive capacity is a capacity to respond to both specific hazards (reduce vulnerability) and disturbances in general (strengthen resilience). However, the framework does not disaggregate the adaptive capacity concept such that the capacities to respond to specific hazards and disturbances in general can be analysed separately. Similarly, the framework by Maru *et al.* (2014) also views vulnerability and resilience as separate concepts that are simultaneously influenced by adaptive capacity. Although, unlike Chapin *et al.* (2009), a contextual interpretation of vulnerability (section 2.2.2) is followed, so the capacity to respond to specific hazards is not conceptualised in the Maru *et al.* framework. Both of the frameworks by Chapin *et al.* (2009) and Maru *et al.* (2014) refer to SES resilience theory (section 2.2.3) to acknowledge that social-environmental interactions influence adaptive capacity and resilience.

The absence of a disaggregated conceptualisation of the capacities to respond to specific hazards versus disturbances in general in the integrated risk-hazard/vulnerability/resilience frameworks is significant because it overlooks the potential for either capacity to create different outcomes. Evidence is emerging that communities require both these forms of capacity to successfully adapt to climate variability and change (Lemos et al., 2016). A more nuanced conceptualisation of adaptive capacity is needed to address the different challenges of adapting to known hazards versus uncertain disturbances in general.

5.2.3 Summary

In summary, the integrated frameworks make important contributions that can be valuably synthesised. They all refer to the capacity of a system to respond to disturbances, albeit in different ways. Table 8 shows key analytical functions advanced by the frameworks developed since 2000 that I reviewed.

Table 8. Analytical functions of selected conceptual frameworks

	Füssel and Klein (2006)	Eakin et al. (2014)	Turner et al. (2003a)	Birkmann et al (2013)	Chapin et al. (2009)	Maru et al. (2014)
Distinguishes between capacity to respond to specific disturbances and capacity to respond to disturbances in general		✓				
Analyses interactions between specific and general capacities		✓				
Acknowledges that capacities to respond are differentiated across system and sub-system scales	✓	✓	✓	✓	✓	✓
Analyses interactions between capacities at system and sub-system scales		✓				
Considers interactions between ecosystems and humans in influencing capacities to respond			✓		✓	✓

5.3 Proposal of a novel conceptual framework

The conceptual framework that I propose builds on the contributions of prior frameworks to propose my conceptual framework for assessing the capacity of community-managed water services to sustain access to water against climate change disturbances (Figure 16). It comprises constituent concepts from theories of risk-hazard, vulnerability, and resilience that I have reassembled to guide a coherent and novel way of assessing a situation (as described in section 3.9). The theories encompass a wide range of concepts and the proposed conceptual framework does not utilise all of them. Rather, I chose to use concepts that were

most applicable for community-managed water services. Therefore, the framework is not necessarily the only way to combine the theories.

I present the framework by first describing its purpose and its delimitations. Next, I present the framework element-by-element as follows: i) describing the system of interest; ii) assessing social and biophysical characteristics that influence specific and general capacities to respond to disturbances; iii) assessing interactions between specific and general capacities; iv) assessing the capacities at different scales; and v) assessing the interaction of capacities across scales within the system. I provide examples in the context of community-managed water services throughout the section to illustrate concepts.

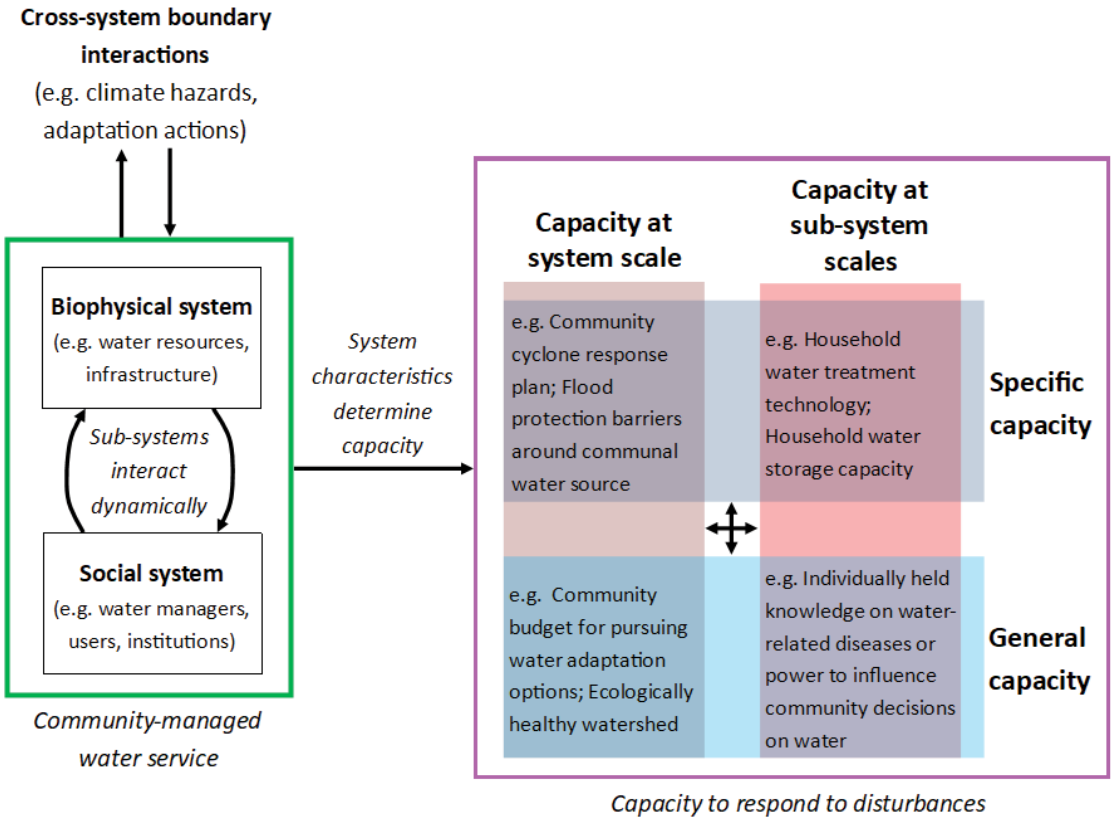


Figure 16. Conceptual framework for the capacity of a system to respond to disturbances

5.3.1 Purpose of the framework

The overall purpose of the framework is to guide interdisciplinary research on assessing the capacity of community-managed water services to sustain access to water against climate change disturbances. The value of the framework is that it i)

sensitises researchers to the different elements that contribute to the capacity to respond to climate change disturbances and ii) facilitates interdisciplinary research by framing disparate disciplinary concepts together and by drawing out their relationships.

I intend the framework to be a heuristic for bridging risk-hazard, vulnerability, and resilience approaches at a conceptual level. This means that it enables analysts to recognise a range of relevant and related concepts that may be worthy of consideration in their assessment. As such, it does not obsolete risk-hazard, vulnerability, or resilience theories. There is still a need for in-depth disciplinary knowledge to explain, elaborate, and operationalise the social and ecological concepts presented here. I also do not intend the framework to provide prescriptive, operational guidelines. Instead, it informs analysts of where important analytical choices need to be made and encourages critical thought about the implications of those choices.

5.3.2 Delimitations

I designed the framework with three key delimitations in mind. First, it was intended for community-managed water services in a developing country setting, although it may have application to other services that rely on natural resources. Second, the framework can accommodate systems at different scales, but it is primarily conceptualised around a rural community level. Lastly, the framework characterises how capacity to respond to disturbances is constructed, but it does not seek to characterise how adaptation actions actually materialise. I refer readers to Turner *et al.* (2003a), Cutter *et al.* (2008), and Birkmann *et al.* (2013) for examples of frameworks that characterise adaptation actions and responses.

5.3.3 Describing the system

I start with the boundaries of the system, which are represented in the framework by the green box on the left. The system boundaries determine what is considered to be part of the system and what is considered to be an external influence. These boundaries are subjective but should take into consideration both social and biophysical dimensions of the system. For example, an analyst could choose to align the boundaries with the land traditionally owned by a community or along an entire water catchment. I discuss the implications of defining boundaries in section 5.4.

Within the boundaries is the community-managed water service being assessed, which is represented as an SES (as I introduced in section 2.2). An SES is a system that comprises social/human and ecological/environmental sub-systems that interact dynamically. Community-managed water services can be viewed as comprising systems of water resources, infrastructure, and social systems that facilitate water access and demand (Moriarty et al., 2010). I group water infrastructure with water resources and associated ecosystems under the label "biophysical system". The social system comprises actors (e.g. water users and managers) and formal and informal governance institutions. Although it is useful to distinguish social and biophysical systems for analytical purposes, the framework emphasises that they are inextricably linked to each other. Changes in the sub-systems that make up a water service (e.g. water resources and different social organisations) inevitably have effects on other sub-systems, often with resulting feedback loops (Neely and Walters, 2016). The nature of the water service system is continuously changing due to dynamic endogenous processes (Neely, 2015) and cross-system boundary interactions (Carpenter et al., 2001; Smit and Wandel, 2006). An example of a dynamic endogenous process is a community improving its physical access to a water resource resulting in increased exploitation of the water resource that, in turn, reduces the quantities of water available to the community. Examples of cross-system boundary interactions are an international NGO visiting a community to provide training on water management or an improvement in surface water quality locally due to changes in land management activities far upstream.

The purple box on the right represents the overall capacity of the system to respond to climate change disturbances. Capacity to respond is determined by the social and biophysical characteristics of the system and encompasses multiple concepts, as will be discussed. Responses include adaptations, adjustments, coping actions, or simply resisting change. The capacity to respond may or may not be realised. Emerging research on adaptive capacity indicates that psycho-social factors influence how capacity is materialised into actual adaptation actions (Mortreux and Barnett, 2016). The analysis of translating capacity into action is beyond the scope of my framework.

The framework views the overall capacity to respond as being driven by two forms of capacity: specific and general. The risk-hazard and vulnerability fields distinguish between specific adaptive capacity (the capacity to respond to particular risks) and generic adaptive capacity (the capacity to respond to a range of stressors) (Eakin et al., 2014; Lemos et al., 2013; Nelson, 2011). Similarly, the resilience field distinguishes between specified resilience (the resilience of a particular part of the system to a specific threat) and general resilience (the resilience of all aspects of a system to unspecified disturbances) (Folke et al., 2010; Miller et al., 2010; Walker and Salt, 2012). I group characteristics that determine specific adaptive capacity and specified resilience under specific capacity, and characteristics that determine generic adaptive capacity and general resilience under general capacity.

5.3.4 Specific capacity: Addressing the specific climate impacts to specific system parts

Specific capacity in the framework refers to the capacity of the system to respond specifically to known hazards like droughts or floods. A system has multiple specific capacities, one for each concerned hazard (e.g. a specific capacity to respond to floods or a specific capacity to respond to droughts). Specific capacity is assessed with reference to those hazards that are relevant or threatening to the system of interest.

Gauging the risk levels of hazards determines which hazards are most relevant for an assessment of specific capacity. Risk is a product of the likelihood that a water supply will be exposed to a hazard and the severity of the impact if exposure occurs (i.e. the exposure and sensitivity concepts described in section 2.2.1). Likelihood can be determined by examining current exposure to climate hazards and/or by predicting how climate change will affect the frequency, magnitude, duration, or spatial distribution of climate hazards to which the water supply is exposed (e.g. an intensification of cyclones or a reduction in total annual rainfall). The effects of climate change on hazards can be predicted through climate projections (Howard et al., 2010), although projections continue to be limited by uncertainty at local scales (Knutti and Sedláček, 2012). Severity is gauged through an assessment of the degree to which the hazards can potentially disrupt water services (e.g. a reduction in rainfall is potentially highly disruptive to rainwater harvesting

systems). The potential degree of severity on water supplies may be assessed based on prior experience with hazards, expert opinion, or scenario building (Batchelor et al., 2011; Howard et al., 2010; Luh et al., 2017). Climate change hazards with the highest risk levels (i.e. the highest levels of likelihood and severity) may be prioritised as the most relevant hazards for a specific capacity assessment.

One way that specific capacity is assessed is through the characteristics of the biophysical system that allow it to withstand the impacts of the concerned hazard. These characteristics can be assessed in terms of the biophysical system's thresholds - the limits that certain variables can reach until functioning of the system dramatically changes (Chapin et al., 2009) (section 2.2.3). Thresholds can pertain to physical parameters of the water system (e.g. water quantity, quality, or continuity (Luh et al., 2017)) or ecological parameters (e.g. soil phosphorous content which contributes to the stabilisation of freshwater bodies in a clear-water state or a turbid-water state (Carpenter et al., 2001)). The higher the degree of disturbance from a hazard that the system can experience without a key variable crossing a threshold, the higher its specific capacity. For example, one way to assess a water supply system's specific capacity to withstand a drought could be to measure the balance of water in storage (i.e. measuring where the water quantity threshold lies) and how many days of drought can be experienced before the water source is depleted (i.e. measuring how rapidly the threshold will be reached).

Another way that specific capacity is assessed is through characteristics of the social system that enable it to anticipate, plan for, and react to specific hazards. Factors that contribute to specific capacity include awareness about possible effects of specific climate change hazards on water services, the presence of early warning systems (e.g. mobile phones and radios for receiving alerts), and possession of human resources (e.g. skills, knowledge, and tools) needed to implement risk management strategies. Regarding water services, risk management strategies include modified climate-sensitive Water Safety Plans which aim to identify and assess hazards, risks, and control measures to safeguard water services against impacts of climate variability and change (UNICEF and GWP, 2014). Although thresholds are relatively difficult to measure in social systems, they can also be relevant here. For example, analysts may inquire at what point do decreases in

water quality at one source cause users to change their preferences to another source.

5.3.5 General capacity: Handling any type of climate disturbance in general

General capacity refers to the capacity of the system to respond to uncertainty and a range of disturbances in general. It is influenced by system characteristics that enable flexibility, innovation, and freedom of choice such that the system has multiple ways of responding to a range of different disturbances. This contrasts with specific capacity which is determined by characteristics that are considered to be relevant with respect to a specific hazard.

Characteristics of the biophysical system that influence general capacity can be assessed in multiple ways. Research shows that redundancy and diversity (see Table 1, Chapter 2) within water ecosystems gives them an enhanced ability to absorb a range of disturbances and continue functioning because ecosystem components can compensate for one another (Biggs et al., 2015). Likewise, diversification of water supplies (Elliot et al., 2011; Kuruppu, 2009) and increased redundancy through an expanded number of discrete water supplies (Boelee et al., 2013; MacDonald et al., 2009) provide "insurance" against climate disturbances by giving more options for accessing water. Connectivity (Table 1), the degree and way in which system components are connected with one another, also influences capacity to respond by facilitating recovery or by propagating harmful disturbances (Biggs et al., 2015). Decentralisation of water infrastructure such that it is less likely that one disturbance causes all water services to fail (Howard and Bartram, 2010) reflects the connectivity principle. The biophysical system also influences general capacity through the presence of so-called "no-regrets" features. These are features that are believed to be beneficial under any climate scenario. It is argued that groundwater recharge, stormwater capture and control, and water conservation measures are no-regrets features of a water service (Elliot et al., 2011).

Characteristics of the social system that influence general capacity can also be assessed in many ways. Within the vulnerability literature, a wide array of characteristics is identified as influencing generic adaptive capacity (see Mortreux and Barnett (2016), and Warrick et al. (2017) for reviews). I proposed that these characteristics be organised using the Empowerment Framework developed by

Narayan (2005, p. 7) because it broadly delineates important social concepts (Figure 17).

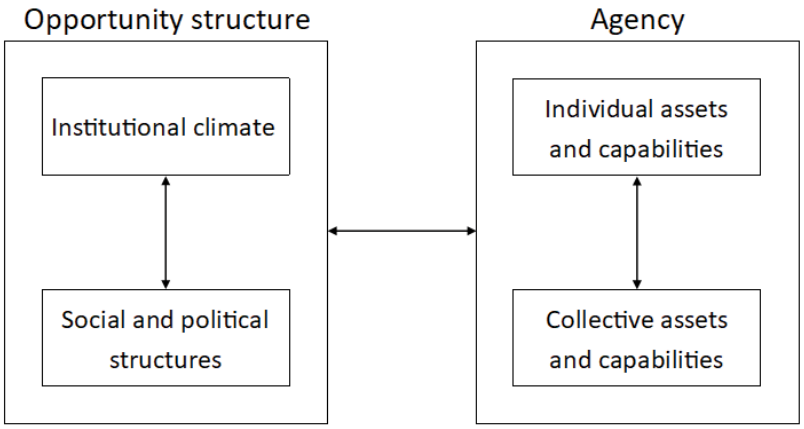


Figure 17. The Empowerment Framework. Adapted from Narayan (2005)

Agency and opportunity structure empower people to respond to all types of disturbances through expansion of their freedom of choice and action (Narayan, 2005, p. 4). Agency is built through material assets (physical and financial) that are individually or collectively owned and capabilities or power which enable individuals or groups to access and use their assets in different ways (Narayan, 2005, pp. 10–12). Assets and capabilities have long been believed to enable people to more effectively respond to shocks and stresses in general (Chambers and Conway, 1991, p. 11; Jones et al., 2010). Concerning water services, assets could include the physical tools that people use to make repairs to a water supply system or a community budget for pursuing climate change adaptations. Types of capabilities often cited in the adaptive capacity literature include social capital (e.g. social networks and relationships), human capital (e.g. education and health), and collective action (e.g. activity coordination) (Warrick et al., 2017). For water services, capabilities could include knowledge of water-related disease transmission or community processes for discussing and deciding upon water issues. Warrick et al. (2017) list numerous individual and collective assets and capabilities, such as traditional skills, access to relevant information, and experience dealing with climate events, that are especially relevant for Pacific

island communities. The relevance of these to water services are discussed by Kohlitz (2018).

The opportunity structure represents the institutions and socio-political structures that facilitate or impede the realisation of agency (Narayan, 2005, pp. 8–10). This includes informal and formal institutions and structures, such as gender relations, societal norms of power-sharing, local regulations, and laws. Fair institutions and structures have potential to reduce water-related inequalities (Mehta, 2014). An opportunity structure that enhances people's agency can also improve their capacity to respond to disturbances in general. For example, human rights dimensions of equitable distribution of resources and participation in decision-making, transparency in decision-making, and accountability of decision-makers influence the capacity of people to adapt to climate change (Ensor et al., 2015). The framework on the human rights to water and sanitation offers insights on how human rights principles enable water providers and users to adapt to climate change (OHCHR, n.d., pp. 25–50).

Resource management and governance regimes are another critical socio-political structure that are especially relevant for water services. Resource management and governance regimes that promote learning, participation, innovation, fairness, and risk sharing are structures that can be beneficial for both human agency and the ecological resilience of natural resources (Biggs et al., 2015; Jones et al., 2010; Lemos et al., 2013; Pahl-Wostl, 2009). In particular, these types of regimes help to promote self-organisation as described in section 2.2.3. Polycentric governance regimes (Table 1) are believed to enhance the resilience of natural resource management systems (Biggs et al., 2015). Specifically concerning water governance, it is argued that polycentric governance regimes that "combine the distribution of power and authority with effective coordination among various centers and across spatial levels" tend to have higher adaptive capacity than other forms of natural resource governance regimes (Pahl-Wostl and Knieper, 2014). For example, climate scientists that generate seasonal forecasts at regional scales can engage with local water resource managers to communicate to them what the

implications of seasonal forecasts are for water runoff and water availability (Ziervogel et al., 2009).

5.3.6 Interactions between specific and general capacity

Specific capacity and general capacity are closely linked to each other. In some ways they can be synergistic. It is argued that a minimum level of generic adaptive capacity may be necessary for a household to build specific adaptive capacity (Lemos et al., 2016, 2013). For example, with respect to a community-managed water service, a community can build a protected spring to protect water from contamination during flooding (an increase in specific capacity to floods), but require a supportive relationship with government or NGOs, or access to learning resources, to provide training on how to do it in the first place (a level of general capacity). Building specific capacity can also enable general capacity. For example, if a household protects its water supply from contamination during floods, a resultant improved overall health of the family may enable them to better cope with other disturbances. Consequently, building one capacity sometimes also serves to build the other such that they are mutually reinforcing (Eakin et al., 2014).

In other ways, specific and general capacity can be oppositional. Too much focus on specific capacity can weaken general capacity when resources spent focusing on the impact of a single type of disturbance on a particular part of the system causes neglect of the rest of the system (Folke et al., 2010; Walker et al., 2006). For example, a community that invests in developing a pumping system to maintain water continuity during droughts may require higher user fees to cover maintenance costs. Higher user fees, in turn, may burden poor families and reduce their general capacity to respond to other disturbances. Conversely, evidence suggests that building general capacity alone, such as through poverty reduction, may be inadequate for preparing communities and individuals to respond effectively to specific climate change hazards (Nelson et al., 2016). The precise ways in which specific and general capacity may strengthen or undermine each other across different settings are difficult to predict (Eakin et al., 2014). These interactions can be examined on a case-by-case basis by asking how an adaptation

intervention to strengthen an aspect of one form of capacity could positively or negatively influence the other form of capacity.

5.3.7 Scale of capacity: Acknowledging differentiation in capacity across different water users and system parts

Specific and general capacity can be assessed at the scale of the entire system, as defined by the system boundaries, or at some sub-system scale so that water access for different user groups can be compared. A sub-system here refers to a linked human-biophysical system (or SES) that comprises the same components as I described in section 5.3.3, but is nested within the broader system of analysis. As with the system boundaries, sub-system scales are subjective. They can be defined spatially/physically or along abstract, fluid social lines (Tschakert, 2012). The distinction between capacity held at either a system or some sub-system scale is important because high or low capacity at one scale is not necessarily indicative of the level of capacity held at other scales.

A focus at the whole-of-system scale can overlook differentiated capacity at smaller, embedded scales (Ingalls and Stedman, 2016). For example, a whole system could be taken to be a rural village and a spring from which the village extracts water. General capacity may appear to be high if the spring is pollution-free and surrounded by diverse vegetation, and if the village collectively supports a water committee that maintains shared assets on their behalf. Specific capacity may also appear high if the community has a preparedness plan for protecting the water supply when a natural disaster is expected. However, within communities, levels of vulnerability and resilience often differ across social groups (Béné et al., 2014; O'Brien et al., 2007) and are relational. Poor families in that same village may have relatively less specific capacity to secure water in the face of an impending disaster if they have fewer resources than other households for storing and treating water at home. Other families may have less general capacity relative to others if they are not fairly represented by the water committee. Likewise, high capacity of nested sub-systems does not necessarily signify high capacity throughout the entire system.

One of the major implications of the existence of capacity held at sub-system scales is that there are inequalities in the capacity to sustain water access against climate change disturbances. This means that some water user groups may be more likely

to suffer from impacts of climate change than other groups in the same system. Water user groups that suffer disproportionally from climate change may not always be visible if the system of analysis is only taken at the scale of a whole community (or whole collection of communities). Therefore, assessments should consider the ways in which capacity is unequally distributed within the system and why.

5.3.8 Interaction of capacity between system and sub-system scales

Assessments should also consider how capacities at the different scales can also influence each another. Localised changes in risk, vulnerability, and resilience can positively or negatively affect those at broader scales (Chelleri et al., 2016; Eakin and Wehbe, 2009; Folke et al., 2010). For example, in positive terms, a single community member that receives water management training could take their knowledge to a community water committee to promote appropriate climate change adaptations. In negative terms, a household could leverage their land rights during times of climate-driven water scarcity to secure a water source for their family to the exclusion of others in the community. Conversely, risk, vulnerability, and resilience at localised scales are influenced by those of the systems in which they are nested (Folke, 2006; Miller, 2014; Ribot, 2011). For example, the specific capacity of individual households to prepare for disasters is influenced by the capacity of authorities at broader scales to detect impending disasters and send out warnings. As with the interaction between specific and general capacity, how capacities at different scales interact with each other across different settings is difficult to predict. Case-by-case examinations of the interactions help to understand a particular situation, but further theoretical research is needed to guide these examinations.

5.3.9 Summary

In summary, community-managed water services can be considered as SESs that comprise dynamically interacting, interlinked biophysical and social systems. Characteristics of the social and biophysical systems, which arise and continuously change due to endogenous processes and cross-system boundary interactions, determine a capacity to respond to climate disturbances. The capacity to respond to disturbances can be disaggregated analytically into specific and general capacity. The former is a capacity to respond to specific hazards and the latter is a capacity

to respond to uncertainty and disturbances in general. The capacities are possessed differentially at a system scale (e.g. a community-water resource level) and sub-system scales (e.g. the interface between water supplies and individuals or groups of people). Interactions between specific and general capacity, and between capacity possessed at a system scale and sub-system scales, are existent and context-specific.

5.4 Making analytical choices when using the framework

While I have synthesised risk-hazard, vulnerability, and resilience concepts in this framework in a coherent way, certain parts of the framework still need to be negotiated between the different perspectives of the theories from which I drew. O'Brien *et al.* (2007) write that outcome and contextual vulnerability interpretations cannot be truly integrated into a common framework because they fundamentally differ in their conceptualisations of the causes and character of vulnerability. They go on to argue that prior efforts to develop integrative frameworks do not succeed in conceptually blending different theories but instead "formalize a single interpretation" (O'Brien et al., 2007). I believe my framework goes further in identifying common concepts of interest across risk-hazard, vulnerability, and resilience theories and in framing their relationships than earlier efforts. However, I agree that different fundamental values are a significant barrier to developing shared understanding and use of any conceptual framework. Accordingly, in this section, I describe four areas where analysts must make choices about the application of the framework amongst multiple options: the temporal frame of reference, system boundaries, the scale of inquiry, and the desirability of different forms of capacity.

First, the framework can be referred to in different temporal frames which influences how capacity to respond is assessed. Analysts must decide if capacity is being assessed with respect to the present, future, or dynamically across time (Füssel, 2007). High capacity in the present does not necessarily indicate high capacity in the future and vice versa. For example, a community-managed water service may presently exhibit many characteristics that indicate a high level of capacity to respond to disturbances, but may be considered to have low capacity in the long-term if water extraction rates eventually exceed what the water resource

can sustainably yield. This can be seen to create a tension between the realisation of the human right to water (i.e. moving as quickly and as effectively as possible using the maximum available resources to secure acceptable levels of water service (de Albuquerque, 2014)) and intergenerational equality. In such cases, the capacity to achieve each of these objectives should be weighed and reconciled.

Next, all system boundaries and scales of inquiry, even ones drawn along ecological features, are subjective (Ingalls and Stedman, 2016). This is significant because the choice of where to draw system boundaries has important implications for how the capacities are analysed. For example, the capacity of a community-water resource system to respond to disturbances could be determined to be high even if it was polluting downstream ecosystems and households beyond its boundaries. However, if the boundaries were expanded to include those downstream ecosystems and households, the system may be determined to have low capacity. Similarly, the choice of a sub-system scale of inquiry can exclude certain groups. For example, one might assess the differentiation in capacity between relatively poor and wealthy households but miss differentiations in capacity across gender. The choice of what to include within the system boundaries and scales of inquiry involves a value judgement based on perspectives about what is most important to consider. Explicit consideration of different perspectives in defining the units of analysis (Fabinyi et al., 2014) and what factors can be realistically controlled in a given context (Quandt, 2016), and scoping research to determine what factors are especially relevant in a given context, can assist analysts in defining boundaries and scales.

Lastly, although some levels of both specific and general capacity at both system and sub-system scales are always needed, the relative degrees to which each is required is context-specific and subjective. For example, some water users may desire specific capacity more if they are focused on protecting expensive water assets or if a particular hazard (e.g. sea-level rise) is especially concerning. Others may desire general capacity more if they feel that community institutions discriminate against them or if ecosystem viability is highly valued. Due to reasons like these, analysts may choose to concentrate more on one form of capacity. However, it is important not to neglect the other form of capacity, which is still meaningful in any situation, and to be mindful of potential interactions between

capacities. Further, stakeholders, including marginalised voices, must be carefully consulted in this regard because the capacities will be valued differently between actors.

When using the framework to analyse a situation on the ground, it is helpful to do so in consultation with community members. As noted in section 2.2, local community knowledge has a role to play in risk-hazard, vulnerability, and resilience assessments. Likewise, community knowledge is valuable for assessing the different elements of the framework. Depending on what dimensions are focused on, community knowledge may be essential to conducting an assessment.

Overall, the choices highlighted in this section are best addressed by considering different perspectives and being aware of their implications. Making final analytical choices (e.g. on where to draw system boundaries) will often be difficult but should reflect the purpose of the assessment and the values of the stakeholders.

5.5 Framework limitations

My proposed framework comes with important limitations. First, the applicability of the framework is limited at large scales versus a community-level situation. The intent of the framework is to guide assessments that can provide information needed for the development of locally appropriate climate change adaptations. In individual case studies at a community level, an analyst can consider a complex array of social and biophysical system characteristics that interact in unique ways. This can provide the level of detail and integration of knowledge and perspectives needed to tackle the highly complex challenges that climate change poses. At larger scales, indicators would need to be substituted for place-based assessments to feasibly apply the framework across many communities at once. Indicators may be too simple to develop a deep enough understanding of complex systems to inform appropriate management actions (Quinlan et al., 2016). However, the framework can be used as a heuristic to assess whether a strategy or intervention at scale is considering the key elements of my proposed framework. I demonstrate the use of my framework as a heuristic for assessing a strategy at scale further in Chapter 6.

The framework also does not conceptualise in detail the interactions between the system analysis and broader systems, for example at a national scale. The

interactions are important in shaping how local systems respond to change and disturbances (Miller, 2014). Although my framework does highlight the need to consider interactions across system boundaries, further conceptualisation of multi-scale interactions beyond the system would be useful.

Next, the framework is limited in that it does not theorise in detail the relationships between sub-concepts within elements of the framework; for example, the relationships between resilience concepts of diversity or connectivity and vulnerability concepts of agency and equality that all contribute to general capacity. Other frameworks can be nested within my proposed framework (such as I suggested with the Empowerment Framework (Narayan, 2005) for categorising social characteristics of general capacity) to provide additional layers of detail as needed.

Third, the framework itself does not provide guidance on operationalising the concepts that it uses and consequently developing practical strategies for building capacity to respond to climate change. As I have noted elsewhere, this is still needed, especially with respect to some resilience concepts and interactions between different forms of capacities at different scales, to more effectively inform climate change adaptations for water services. However, my findings in Chapter 4 and my retrospective application of the framework to the findings in the following section help to shed light on what these concepts look like in practice.

5.6 A retrospective application of the proposed framework

In this section, I demonstrate how my proposed conceptual framework can be used to guide an analysis of a community-managed water service. I do this by retrospectively applying my proposed framework to the findings from my case study in Namoru (sections 4.2.2.1, 4.3.2.1, and 4.4.2.1). I cannot apply the entirety of the framework to the findings in depth since I developed the framework after my fieldwork was complete and new theoretical elements emerged from my research after I finished data collection. However, there are sufficient data to illustrate major elements of the framework and to demonstrate the framework's usefulness.

5.6.1 Setting boundaries for assessment

An initial step that my framework guided me to consciously deliberate is the selection of the boundaries of analysis. In Namoru, I drew boundaries around the

houses that were considered by the community members to be a part of the village and around the water sources used by the community. This boundary encapsulates the community water users, the water infrastructure, and the portions of the water resources with which community members and water infrastructure directly interface. An image of the community and water service features included in my assessment are shown in Figure 7 in Chapter 3.

A limitation of using these boundaries is that they do not spatially capture activities happening in the wider watershed or conceptually capture other stakeholders. Other communities reside upstream of Namoru and their activities, such as pollution of the river or clearing of land for coconut plantations, can impact on the water resources that Namoru uses. Similarly, one community is located downstream of Namoru that could potentially be affected by activities in Namoru. These boundaries also do not include NGOs or the government that can provide water service or climate change adaptation support. This illustrates the point of my framework that awareness is needed on what factors are excluded from direct assessment when certain boundaries are drawn.

In this assessment, I focused on the present and near-future as my temporal frame of reference. This means that I assessed the capacity of the water service to be sustained under current environmental conditions and potential near-term (within 15 years) stresses. A limitation of using this frame is that it potentially neglects other longer-term stresses. For example, the combined stress of continued population growth, increased per capita water consumption, and climate change-driven changes in rainfall over a period of 20 years or more. This illustrates the emphasis of my framework on considering what the chosen temporal frame of reference leaves out and gives space to revise such decisions as appropriate.

5.6.2 Assessing specific capacity

Certain biophysical characteristics of the water service diminished its specific capacity against intensification and decreases in rainfall. As described in section 4.2.2.1, the primary piped water supply was sensitive to changes in precipitation. Either too much or too little rainfall could cause failures in the piped supply that forced some households to retrieve water from a stream. Unprotected springs, such as the one that served as the water source for the piped supply, by their nature are not robust against changes in rainfall. Decreases in rainfall strongly influence the

productivity of most springs, relative to deep-water sources such as boreholes, because springs typically emerge from shallow groundwater. Water shortages in Namoru were compounded by leaking pipes and taps which are common in community-managed reticulated water supplies. Increases in rainfall exposed the source to contamination from surface runoff which was potentially compounded by dirty water ingress through leaking pipes. Thus, these biophysical characteristics (i.e. the nature of the spring and the design of the water infrastructure) diminished the specific capacity of the system to withstand changes in precipitation.

Certain social characteristics also diminished specific capacity. For example, there was limited awareness amongst community members about climate change and its potential effects. When asked what they knew about climate change, five participants in Namoru responded that they had never heard of it, three had heard of it but were not able to explain any of its causes or effects, and only four were able to explain some effects. Each of the four that could explain some climate change effects explained them in terms of food production (e.g. some crops would grow worse or at different times of year than before). No participants identified any specific climate change effects on water services.

Furthermore, the water committee that was in charge of operating and maintaining the piped water supply did not have a strategy for managing climate risks like changes in rainfall. Some participants had ideas for control measures to manage risks to water security. For instance, with respect to dry spells, one participant remarked: "*During the night, if we close* [the tank outlet], [the tank] *will stay full. But during the night when we sleep, it runs. It runs out*[32]". However, the water committee did not proactively plan or take action to manage risks in ways like this. Instead, problems were allowed to self-correct (e.g. waiting for more rainfall to come) or reactively addressed after a failure (e.g. removing blockage from the intake after it was noticed that flow had stopped).

One biophysical characteristic that positively influenced specific capacity with respect to decreasing rainfall or dry spells was the robustness of the stream that the community used as a secondary source. Participants remarked that the stream

[32] Lo naet, spos yumi satem, antap bae em i fulap. Be taem lo naet yumi silip, em i ron. Em i ronaot.

always provided enough water to meet their needs (in terms of quantity), even during droughts. The stream, through natural characteristics of the environment, supported specific capacity of water services against dry spells by reliably provisioning water. However, the quality and physical accessibility of the stream was compromised by intense rainfall and human activities.

These examples show how my framework can guide the identification of multiple characteristics, across social and biophysical domains, that influence specific capacity of a community-managed water service. In any situation, there are likely to be many influential characteristics.

5.6.3 Assessing general capacity

Some biophysical characteristics hindered general capacity in Namoru. First, although the community had access to a stream and a river as secondary sources of water, most households were highly dependent on the singular, centralised piped supply. I observed the piped system to be in an advanced state of deterioration due to its old age (approximately 30 years) and minimal maintenance. No other water sources had been developed in Namoru over those three decades (i.e. there was little redundancy (Table 1, Chapter 2)). The neglect of developing a backup supply could be devastating for the community if the piped supply experiences catastrophic failure due to any kind of climate stress. Additionally, the highly connected design of the piped supply allowed disturbances at the spring source to propagate throughout the whole community. For example, one participant described how contamination at the source is delivered to standpipes throughout the village: "*Because when the rain comes, goes inside, then it goes to the tank and makes mud…Then, when we are using it, sometimes a lot of dirt or mud comes…They bathe with the water from the standpipe here and they see grass in it*[33]". Similarly, water shortages at the source were propagated throughout the community. Reliance on the singular piped water supply meant that the community had limited flexibility for accessing safe water against a range of climate disturbances. This is in contrast to Uripiv community where community members could often switch between rainwater harvesting systems (which were used when heavy rainfall contaminated the wells) and wells (which were used when

[33] From taem we ren i kam, go insaed, afta i kam go lo tang, mekem se sofmad. Ale, taem mifala stap yusum, samtaem bigfala toti o sofmad i kam…Oli swim lo wota blo paep hia, oli luk gras lo em

dry spells caused rainwater storage tanks to become empty). With reference to the Empowerment Framework shown in Figure 17 that I proposed for organising social determinants of general capacity, this represents an issue relating to collective assets.

On the other hand, general capacity was positively influenced by a social characteristic – the capability of the community to democratically elect and form a water committee. Water committee members were appointed by the community through a process where nominees were put forward by anyone and elected though a majority vote during a community meeting. All community members were invited and allowed to vote during these meetings. Committee members were unpaid volunteers, but were still willing to make time to carry out tasks like collecting water fees, repairing broken taps, and developing a plan for water supply development. If the community deemed that the job performance of the committee members was unsatisfactory, they could be replaced: "*There is a time when we meet together, the community, in a session…Because you see the committee is not working well, there is a period for it, a time for it, in the session where different people are put in*[34]". The willingness of community members to volunteer for the water committee supports general capacity because the committee acts as a conduit for collective action (such as the collection of user fees from individual households that can be used to finance maintenance and protection measures against climate disturbances). The democratic election of committee members, and a process for holding them accountable, helps to lessen the likelihood that a small minority disproportionately benefits from actions to respond to climate disturbances. With reference to the Empowerment Framework, this represents an enabling socio-political structure.

On the other hand, the water committee and the election of its members were likely shaped by local power and politics. Although participants stated that anyone was allowed to nominate another community member to be on the committee, and all adults were allowed to vote on nominees, it is not clear if this was followed in practice. As explained in Chapter 4, women often felt their voices were not listened to on matters of water and it seems likely that this would have influenced their

[34] I gat wan taem we mifala mitim tugeta, komuniti, lo wan sesen…From yu luk se komiti no wok gud, i gat periot blo em, i gat taem blo em, lo sesen we difren man i go.

decision to nominate someone or be nominated to serve on the water committee. The fact that the committee members were all traditional leaders (elder men) indicates that all social groups of the community did not have an equal opportunity to serve on the committee. Participatory mechanisms, such as the democratic election of water committee members, are often utilised by community elites to hold onto their power if special processes are not in place to give power to disadvantaged groups (Cote & Nightingale, 2012). No such processes were in place in Namoru. Further, it was up to the discretion of the committee members to decide when to use community funds to make minor repairs such as fixing leaking standpipes. Some community members stated that their standpipes were fixed regularly while others said their standpipes were not fixed if they did not pay their monthly water fees. There was no formal accountability mechanism present to show that the committee members fixed leaking standpipes consistently. It is possible that committee members used funds to fix standpipes used by their own family members quicker than taps used by other households.

As with the analysis of specific capacity, these examples illustrate how my framework guides the identification of social and biophysical characteristics that positively or negatively influence general capacity.

5.6.4 Assessing capacity at a sub-system scale

The analyses in sections 5.6.2 and 5.6.3 illustrate how specific and general capacities are held at a community level, but my framework also points to the need to consider the differentiation of capacity at sub-system scales. From my data, it was possible to see how specific capacity was differentiated between households within the community.

In section 4.3.2.1, I described how households in Namoru living on land further away from the water source experienced more climate-related disruptions at their standpipe and had more difficulty accessing water elsewhere. At the time of my visit, the community was seeking to address water shortage issues faced by all households by replacing the deteriorated storage tank with a larger one. However, insufficient storage capacity appeared only to be a partial contributor to shortages along with extensive leakage, pressure drops from informally added pipes, and variable production from the spring source. The community overall would have benefited from greater storage capacity to buffer against dry spells, but whatever

benefit a larger tank might bring would likely disproportionally go to the households closest to the source that already received better service. Due to leakages, poor pipe design and maintenance, and the relatively long distances to convey water, households living further away would still have more difficulty coping with dry spells.

This differentiation in specific capacity to respond to dry spells at a sub-community level influenced general capacity at the community level. When households experienced relatively poor service at their standpipe, some of them refused to pay their user fees: "*We are paying for this standpipe, but sometimes the water does not run. Sometimes our taps are not good…we ask if* [the water committee] *will come to fix them, but they do not. That is why we do not pay again*.[35]" The refusal of some households to pay user fees reduces the community water budget that could be used to maintain the piped water supply against climate disturbance or fund new adaptations. This example illustrates an interaction between capacity at a sub-community level with capacity at a community level, and an interaction between specific capacity and general capacity.

Agency with respect to managing water in the community was differentiated across women and men. As described in section 4.3.2.1, women generally had less capability to influence decision-making on water management in Namoru. As a result, this diminishes the capacity of women to make adaptive responses to sustain water access against changes in climate. This represents a differentiation in capacity at a sub-system scale. This differentiation, in turn, affects capacity at the system scale because if the agency women, who are the primary managers of water, is constrained, the rest of the community-managed water service is also constrained in its capacity to respond.

Interactions between specific and general capacity, and between capacities held at different scales, in SESs like community-managed water services are still weakly theorised. However, this brief assessment demonstrates the point of my framework that interactions do exist and are impactful.

[35] Mifala pem paep hia, be samtaem wota i no ron. Samtaem ol tap blo mifala i no gud…mifala askem spos bae ol i kam fixim, be no…Mekem se mifala nomo pem bakeken.

5.6.5 Summary

In summary, these analyses have illustrated the value of using my proposed framework to assess the capacity of community-managed water services to sustain access to water against climate change disturbances. Planning data collection activities using the framework as guidance, as opposed to applying it retrospectively as I have here, would be expected to generate more in-depth insights on the elements of the framework and how they are related to one another.

5.7 Concluding remarks

I conclude this chapter with some remarks on the contributions that this chapter has made and further work that is needed. The contributions include an advancement in theory on climate change impacts and a novel basis for sustaining community-managed water services against the effects of climate change. Further work needed includes theoretical and empirical research relating to elements of the framework, engagement with stakeholders to make decisions regarding use of the framework, and operationalisation of the framework.

One contribution made through this chapter is toward the field of climate change research in general. Although, the theoretical relationships between the risk-hazard, vulnerability, and resilience approaches have been explored significantly (Adger, 2006; Eakin et al., 2009; Gallopín, 2006; Miller et al., 2010; Nelson et al., 2007; Pelling, 2011; Turner, 2010), few attempts have been made to integrate them in a conceptual framework. The framework I have presented here builds on the contributions of previous frameworks and blends much of the latest thinking on climate change risk-hazard, vulnerability, and resilience research. This contributes to enabling ongoing collaboration between climate change researchers from different disciplines as their respective theories on climate change continue to evolve. Consequently, the framework represents a significant contribution toward facilitating the rapidly growing interest in interdisciplinary research on climate change (Milman et al., 2017).

Another contribution of this chapter is toward how the WASH sector can address the climate change problem. My research revealed that scholarly research in the WASH field predominantly follows a narrow conceptualisation of climate change as a biophysical problem requiring technocratic solutions (Kohlitz et al., 2017)

(section 4.5). This framework provides a novel way of conceptualising how community-managed water services interact with climate change that expands thinking to be more inclusive of social and environmental dimensions.

Further research is needed to strengthen the contributions of this framework. The interactions between specific and general capacities, and between capacity to respond at the system level and sub-system level, are still relatively weakly theorised. More theoretical research is needed in the climate change adaptation field to develop understanding of how these interactions can reinforce or undermine the capacity to respond to climate disturbances. Meanwhile, more engagement from the WASH sector with contextual vulnerability and SES resilience theory-practice is needed to produce empirical evidence of how general capacity is built in this context.

In order to translate this framework from theory to practice, engagement with stakeholders is needed. One reason for this is to facilitate deliberation on what outcomes are desirable as I discussed in section 5.4. To make consultations and deliberation more productive and meaningful, stakeholders must be aware of the elements of this framework. Thus, the framework must be communicated in a way that is understandable and relevant to stakeholders. In addition to informing stakeholders, consultations with stakeholders can also inform the evolution of theory informing my framework. Furthermore, engaging stakeholders representing different knowledge domains and marginalised voices, and communicating findings to the appropriate scales to build political will, also increases the likelihood that resultant adaptation actions will be successful (Miller and Bowen, 2013).

Another reason to engage stakeholders is to decide whether the goal of the framework, to support the sustainability of the community-managed water service being used, is desired. Many communities in developing countries have water services that are inherently environmentally unsustainable or discriminatory. There also may be situations where water stakeholders do not want to maintain their current water service but instead transform it entirely into something more desirable (e.g. to a utility-managed water service). In these cases, it may not be desirable to apply the framework to justify keeping the service in its current state,

but instead to indicate the need for major transformational change. In any regard, it is important to consult with stakeholders on what their water access goals are in relation to climate change before seeking to apply the framework.

Finally, stakeholders need to be engaged to assist with operationalisation of the framework. The empirical evidence that I have provided in Chapter 4 and in section 5.6 gives some illustrative examples on how this can be done. However, there is much room for advancement in this space. This could perhaps be done through collaborative workshops between NGOs, in-country stakeholders, and researchers to brainstorm and critique ideas, production of more empirical evidence through case studies such as this, or engagement with other sectors that have trialled vulnerability and resilience oriented programs to learn from their experiences. One strategy to put an operationalisation process into practices could be to identify case study sites and gain the involvement of different stakeholders with a variety of expertise. The stakeholders could work with one another, using the methods suggested above, to think through how elements of the framework can be applied in some specific and measureable way. Next, stakeholders can reflect on ways in which the elements of capacity can be realistically enhanced or improved using resources available to the community or supportive agencies like government or NGOs. Assessment tools that can be used to collect baseline data and monitor and evaluate progress in improving the elements of capacity to respond also need to be developed, and a plan for using the tools and learning from their findings put into place. Operationalisation is also dependent on the setting where the framework will be applied because every situation is unique. In the next chapter, I discuss how the findings from this chapter and Chapter 4 are relevant to the Vanuatu context where my field research took place.

5.8 Summary

In this chapter, I have presented a conceptual framework guiding assessments of the capacity of community-managed water services to sustain access to water against climate change disturbances in a developing country setting. Conceptual frameworks facilitate the integration of knowledge bases from different disciplines such that a shared understanding of a situation can be developed. I reviewed several conceptual frameworks that aim to integrate risk-hazard, vulnerability, and

resilience theories and discussed their contributions and limitations. Through a synthesis of risk-hazard, vulnerability, and resilience concepts into a shared framework, I have provided a heuristic for analysts to make sense of the different elements of the capacity to respond to climate disturbances and how they are related. My framework is not prescriptive and can be followed in different ways. As such, I have discussed the need to think critically about assumptions about the system regarding the temporal frame of reference, system boundaries, the scale of inquiry, and the most desirable forms of capacity. I then applied my framework retrospectively to my findings from Chapter 4 to demonstrate its usefulness in practice. I concluded with remarks on the contributions of this chapter and further work that is needed.

Chapter 6. Putting the framework to use: Informing stakeholders in Vanuatu

6.1 Introduction

The purpose of this chapter is to address research question #3: How can the findings from research questions #1 and #2 (i.e. the findings from Chapters 4 and 5) be drawn on to develop recommendations for policy-makers, practitioners, and researchers in Vanuatu to better assess the capacity of community-managed water services to sustain water access against climate change disturbances? In Chapter 4, I demonstrated the contributions that each of the risk-hazard, vulnerability, and resilience approaches make to understanding how community-managed water services are affected by and sustained against climate change disturbances. In Chapter 5, I proposed a conceptual framework for guiding analyses of the capacity of community-managed water services to sustain access to water against climate disturbances. In this chapter, I consider how the findings can inform government, practitioner, and research practices and processes for assessing community-managed water services to support climate change adaptation activities.

In addition to the contents of this chapter, the initial findings of my research led me to develop reports that provided insights for the communities that participated in my research. At the conclusion of my data collection activities in Namoru and Uripiv, I presented the communities with brief reports written in Bislama that used basic, accessible terms to describe how climate change would affect their water services and what they could do. The English version of the report that I delivered to Namoru is located in Appendix F to demonstrate how findings from this research can be communicated to local communities in a way that is understandable, relevant, and useful for them.

One way that my findings are useful for local stakeholders in Vanuatu is that my proposed conceptual framework can be used as a heuristic for evaluating the comprehensiveness of interventions or strategies to build or assess the capacity of community-managed water services to sustain water access against climate change disturbances. My framework (Figure 16, Chapter 5) emphasises six elements that make up this capacity: specific capacity (1) and general capacity (2) that are held collectively at a system scale (3) or differentially at sub-system scales (4) and are developed by social characteristics (5) and biophysical characteristics (6) of the of water service system. Table 9 shows a template that can be filled out to evaluate

whether, and to describe the extent to which, an intervention or strategy (or set of interventions or strategies) has considered the influence of all of these elements.

Table 9. Evaluation template based on my proposed conceptual framework

	Capacity at system scale	Capacity at sub-system scales
Specific capacity	B: S:	B: S:
General capacity	B: S:	B: S:

B = Biophysically focused; S = Socially focused

It is important to note that my framework proposes that the biophysical and social dimensions of community-managed water services are inextricably connected to each other, thus they should be assessed jointly. However, I present them as disaggregated in the template to ensure that the user gives due attention to both. I label the dimensions "biophysically focused" and "socially focused" to emphasise that while one dimension can be the focal point, it is still connected to and has implications for the other dimension.

In the next section, I demonstrate the value of my proposed framework as a heuristic for assessing strategies by filling out the evaluation template with reference to government policies on collecting data on water services. Where I identify gaps, I suggest ways in which they could be filled. I also discuss operational challenges at the local government level that need to be addressed in order for community-managed water services assessments to be successful.

In the second section, I consider how my proposed framework informs another framework that was designed to direct NGOs working in the space of community-based climate change adaptation in Vanuatu. Likewise, I identify what elements of my framework are reflected and suggest ways in which gaps could be filled.

In the third section, I reflect on my experience conducting the risk-hazard, vulnerability, and resilience analyses with an aim to provide methodological lessons learned to researchers interested in carrying out similar analyses. I also think prospectively about how my conceptual framework could be applied in future studies to guide interested researchers in Vanuatu.

6.2 Insights for government stakeholders: Expanding the comprehensiveness of government policy

My proposed conceptual framework is useful as a heuristic for evaluating the comprehensiveness of relevant government policies and other guiding documents in directing the assessment of the capacity of community-managed water services to sustain water access against climate change disturbances. I provide policy suggestions in areas where I identify that government documents do not address elements of my proposed framework. The purpose of this exercise is that it shows potential gaps in how government policy portrays the impact of climate change on community-managed water services which can be filled to ensure that important aspects are not neglected.

There are a number of policy documents and acts of legislation that have varying levels of relevance for water supplies and water resources in Vanuatu, but in this section I primarily focus on three: the draft 2017 – 2030 National Water Policy (NWP) (Government of Vanuatu, 2017b), the draft 2018 – 2030 National Water Strategy (NWS) (Government of Vanuatu, 2017c), and the draft Risk Resilient Planning, Budgeting and Monitoring Guidelines for Sub-National Government developed by the DLA (heretofore referred to as the DLA monitoring guidelines) (Government of Vanuatu, 2016d). I focus on these three documents because they directly refer to the collection of data pertaining to rural water services and climate change impacts.

The NWP, once endorsed by parliament, will become the primary document guiding the operations of the DoW, which is responsible for supporting the delivery of water services in Vanuatu outside of the capital, Port Vila. The NWP contains seven priority areas: ensuring water safety and security, developing water supply markets, enforcing water service standards, formalising water service providers, securing land rights for installing water assets, empowering provincial government to make water by-laws, and securing water services against climate change and natural disasters.

The draft 2018 NWS complements the NWP by providing detailed objectives for each of the NWP priority areas, and succeeds the current 2008 – 2018 NWS. Notably, the 2008 – 2018 NWS made little to no explicit mention of climate

change. The objectives of the 2018 NWS that are relevant to climate change adaptation are diversification of water resources and increasing water storage capacity, identification of water scarcity "risk areas", prioritisation of rainwater and groundwater for consumption and surface water for other uses, and the implementation of Drinking Water Safety and Security Plans (DWSSPs) and watershed management plans. Other related objectives pertain to various mechanisms for coordinating responses to disasters and for reducing greenhouse gas emissions.

The DLA monitoring guidelines describe the processes that local government authorities across all line ministries are expected to follow for identifying, prioritising, and budgeting for general rural development issues. An important process described within the guidelines is community profiling. The community profiling process is an activity that is intended to occur every five years where a range of data relating to numerous sectors, including water, are collected from communities using questionnaires. The data are to be collected by Area Secretaries with the support of a Technical Advisory Commission (TAC). The TAC is a provincial level body that comprises representatives from provincially based government departments and NGOs. The community profiling process is particularly relevant to this research because it includes the collection of data related to both water services and climate change impacts.

In the following sections, I evaluate these government documents against the template that I presented in Table 9. I present content from the documents that pertains to each quadrant of the template. Where relevant content does not exist (i.e. a gap is identified), I make suggestions as to how the policy could be strengthened to include assessments of the missing element.

6.2.1 Assessing specific capacity at the system scale

I first evaluate the extent to which the three aforementioned government documents guide the assessment of biophysically focused and socially focused dimensions of specific capacity held at a system scale (the upper-left quadrant of the evaluation template). In other words, to what degree do the government documents direct the assessment of biophysical and social components of community-managed water services that enable them to be sustained against specific climate change hazards?

One policy directive that is relevant to the assessment of specific capacity at a system (i.e. community-water resource) scale is the implementation of DWSSPs. The DWSSP is a modified version of a community-based Water Safety Plan. Water Safety Plans are a systematic approach to identify, prioritise, and manage risks to drinking-water safety in order to protect drinking-water quality before problems occur (WHO, 2012). DWSSPs build on Water Safety Plans by also including the identification and management of risks to water availability and reliability (Overmars et al., 2016). The NWP calls for "the extension of drinking water safety and security planning to all drinking water asset owners" (Government of Vanuatu, 2017b). The call for the implementation of DWSSPs is reinforced by policy objective 2.3.3 of the National Environment Policy and Implementation Plan (the principal policy guiding sustainable conservation and management of the environment in Vanuatu) which calls for "100% of community water supply systems with Drinking Water Safety and Security Plans by 2030" (Government of Vanuatu, 2017d).

It is not clear from the policies if the DWSSPs are to include the assessment of risks from specific climate change hazards to water safety and security, but climate hazards could be included in line with the specific capacity element of my proposed framework. A DWSSP template developed in the Pacific region demonstrates how climate hazards can be included in the systematic risk assessments (Singleton, 2017). The template instructs the DWSSP manager (one of the drinking water asset owners) to identify potential risks that are associated with droughts and floods, such as water resources exposed to pollutant runoff, leaking pipes, and water flowrates that are sensitive to changes in precipitation. The addition of other climate-related risks, such as salinisation due to storm surges or sea-level rise or wind damage from cyclones, is needed to assess specific capacity to respond to a wider range of hazards. Since future climate change projections have significant uncertainty at the community level, it is most practical to focus on climate hazards that currently cause problems to communities, but regularly re-visit the DWSSPs to identify any emerging hazards.

The benefit of including the systematic assessment of climate change risks into DWSSPs is that it covers the assessment of both biophysical and social dimensions of the specific capacity of the community to respond to climate hazards.

Concerning the biophysically focused dimension, the DWSSPs would assess how well water resources or infrastructure could withstand specific climate hazards (e.g. the DWSSP would check if springs were protected against flooding or not). Concerning the socially focused dimension, the existence of a DWSSP that was filled out by a community would indicate some specific capacity to detect and plan for climate change risks. This is supported by a four-country study (including Vanuatu) of communities practising Water Safety Plans that found the implementation of Water Safety Plans resulted in an improved ability of communities to identify and plan for the management of water safety risks (String et al., 2017).

Another policy directive pertaining to the assessment of the biophysically focused dimension of specific capacity relates to the identification of water scarcity risk areas. The 2018 NWS states that the identification of water scarcity risk areas is to be enabled through the development of comprehensive databases and models of water resources. Identifying risk areas through databases and models is presumably to be done via risk maps whereby geographic areas are assigned risk levels based on their likely exposure to a hazard and the potential detrimental impact if that area experiences the hazard (i.e. the area's sensitivity to the hazard) (Papathoma-Köhle et al., 2016). In this case, water resources that are exposed and sensitive to drying conditions are to be mapped and the surrounding areas identified as water scarcity risk areas.

Water scarcity risk maps contribute to the assessment of specific capacity against drying hazards, but my framework points to the need to assess specific capacity to a range of different specific hazards. This would usefully be addressed by the creation of other types of risk maps. For example, water quality risk maps could be created to identify water resources threatened by flooding due to projected increases in intense rainfall or by salinisation due to projected mean sea-level rise. Risk mapping is also complementary to the DWSSP in that it is a top-down approach that can be used to identify relevant climate hazards for communities to consider in the implementation of their bottom-up DWSSPs.

In summary, the implementation of DWSSPs and risk maps as recommended in government policy provide options for assessing biophysically and socially focused

dimensions of specific capacity at a system (i.e. community-water resource) scale. My proposed framework informs these processes through ensuring that they include an assessment of each relevant climate change hazard. The presence of DWSSPs in communities could be added as a question in the community profiling process as described in the DLA monitoring guidelines. The existence of risk maps could be checked by the government department that manages them, likely the DoW.

6.2.2 Assessing general capacity at the system scale

In this section, I evaluate the extent to which the government documents guide the assessment of the biophysically and socially focused dimensions of general capacity held at a system scale (the lower-left quadrant of the evaluation template). That is, a capacity to respond to climate change disturbances in general rather than specific hazards.

One way that government policy directives relate to the assessment of the biophysically focused dimension of general capacity is via the establishment of water protection zones. The draft 2018 NWS calls for the establishment of water protection zones that restrict certain human activities within watersheds. Although the 2018 NWS characterises water protection zones as objectives for achieving water security in general, they are also useful as responses to climate change because water services that are located in a water protection zone are less likely to be disrupted by all types of climate disturbances than water services that are not. This is because healthy ecosystems provide services such as the purification, regulation, retention, and storage of freshwater which improves water quality and quantity (de Groot et al., 2002). Checking whether community-managed water services are located in watersheds with water protection zones contributes to assessing the general capacity of the water services.

Another way that policy directives relate to the assessment of the biophysically focused dimension of general capacity is the establishment of multiple viable water sources for a community. The NWP encourages the development of multiple water sources through its call to “invest in the diversification, storage and regulation of water resources” (Government of Vanuatu, 2017b). The DLA monitoring guidelines also call for counting the number of different types of water sources to which a community has access during the community profiling process. Although the

government documents do not relate access to multiple water sources to climate change, I found it to be linked to climate change resilience in Chapter 4. The primary supplies for water users in Namoru and Uripiv frequently failed to meet all of the water users' needs due to climate disturbances. Secondary sources were highly important for ensuring that community members could get water in other ways. The value of multiple water sources as a source of water service resilience has also been documented in other Pacific island countries (Elliott et al., 2017). Counting the number of water sources that a community has access to during the community profiling process also contributes to assessing the general capacity of community-managed water services.

One way that policy directives relate to the assessment of the socially focused dimension of general capacity at a system scale is through the formalisation of rural water committees. The NWP encourages the formalisation of committees that oversee community-managed water services by confirming they are established in communities, registering them as legal entities, and supporting them to recover water service costs to ensure financial sustainability of the water systems. Formal registration of water committees could tie them more closely to government authorities and NGOs who could provide support in sustaining community-managed water services against climate change disturbances in general. Improved financial management by committees is also likely to be beneficial for responding to any climate change disturbance. Checking whether a community-managed water service is overseen by a registered water committee that has received financial management training contributes to the assessment of the social dimension of general capacity.

Another way that policy directives relate to the assessment of the socially focused dimension of general capacity at a system scale relates to the inclusion of women on the rural water committees. Although the NWP does not mention the inclusion of women on water committees in any of its objectives, it does refer to a 2016 amendment to the Water Resources Management Act that states that at least 40% of rural water committee members must be women. My findings from the Namoru community described in section 4.3.2.1 illustrate how the exclusion of women from water management decision-making can increase the vulnerability of community-managed water services to climate disturbances in general. This finding is

complemented by a study by Mommen et al. (2017) of 365 rural water committees in Vanuatu that found the inclusion of women in water committees was significantly associated with more effective water service management. Checking whether at least 40% of water committee members are women when the committees are registered also contributes to the assessment of general capacity at the system-scale.

In summary, checking whether a community-managed water service is in a watershed with a water protection zone, counting the number of water sources available to a community, and checking whether a water committee is registered, has received financial management training, and is at least 40% female contribute to assessing the general capacity of community-managed water services at a system scale. Although these directives are not explicitly tied to climate change in government policy, they are still relevant. Information on these directives could be collected during the community profiling process if they were added to the questionnaires.

6.2.3 Assessing specific capacity at the sub-system scale

I now move to evaluate the extent to which the government documents guide the assessment of the biophysically and socially focused dimensions of specific capacity held at a sub-system scale (the upper-right quadrant of the evaluation template). Here, the focus is on specific hazards again, but checking whether assessments consider differentiation across sub-systems.

There do not appear to be any directives in the government policies relating to the assessment of specific capacity at a sub-system scale. This represents a gap in the comprehensiveness of government policy in assessing the capacity of community-managed water services to sustain water access against climate change disturbances.

A biophysically focused way that this gap could be filled is to increase the detail of the aforementioned risk maps. Since certain water supplies, such as rainwater harvesting systems, are known to be especially sensitive to dry conditions (Luh et al., 2017), a map of different community water supplies could be overlain on the water resources map to provide more information on which water services are more susceptible to drought or declining precipitation. Primary users of these

specific water supplies may identified as at high risk. A map of water supplies in Vanuatu[36], developed from the national water database, already exists. Similar maps could be created for water services that are located in areas threatened by flooding due to projected increases in intense rainfall or for water services exposed to salinisation from sea-level rise.

A socially focused way that this gap could be filled is to check factors relating to equity in the implementation of the climate change-aware DWSSPs. Ensuring that DWSSPs provide equitable benefits to the whole community helps to ensure that all community members have their specific capacity built. Winterford *et al.* (2014) list numerous opportunities to integrate equity into the different stages of the Water Safety Plan process including preparation, system assessment, monitoring, management and communication, and feedback and improvement. For example, two opportunities are:

1. "Identify which different user groups and collection point types may be affected by different hazards and hazardous events" and
2. "Consider and prioritise disadvantaged groups after assessing risk of hazards and hazardous events" (Winterford et al., 2014, p. 6)

DWSSPs that explicitly include these steps with respect to climate change hazards would be able to assess if and how water access for disadvantaged groups is likely to be affected differently by particular climate change hazards. Checking whether community DWSSPs consider the differential impact of climate change hazards and include different users groups in their implementation, perhaps during the community profiling process, would contribute to the assessment of specific capacity at a sub-system scale.

6.2.4 Assessing general capacity at the sub-system scale

Finally, I evaluate the extent to which the government documents guide the assessment of the biophysically and socially focused dimensions of general capacity held at a sub-system scale (the lower-right quadrant of the evaluation template).

Again, there do not appear to be any directives in the government policies relating to the assessment of general capacity at a sub-system scale. This also represents a

[36] Available at https://vanuatu.akvoflow.org

gap in the comprehensiveness of government policy in assessing the capacity of community-managed water services to sustain water access against climate change disturbances.

One way that the socially focused dimension of this gap could be filled is to check whether all user groups can access the multiple water sources available to a community, as I described in section 6.2.2. For example, an assessment could check whether all user groups, especially people living with disabilities, are physically able to access the mutiple water sources available to the community (or have a family member or caretaker that can retrieve water from each source on their behalf) or if local rules permit all people to access each water source. This may be captured during national surveys.

Concerning the biophysically focused dimension, an assessment could check whether water resources at a more localised level are protected by some kind of buffer zone. For example, in Namoru, an assessment could check if the community has restricted land use activities in the immediate proximity of the spring source for the piped supply and around the secondary stream. This could be checked as part of the implementation of DWSSPs.

6.2.5 Summary of the government policy assessment

The extent to which the government documents that I reviewed direct the assessment of the various elements of the capacity of community-managed water services to sustain water access against climate change disturbances, along with my own suggestions of factors to assess, is summarised in Table 10. One assumption I am making is that government can and will monitor the processes laid out in the documents. It is important to note that even if all of these aspects are assessed, this is far from a comprehensive assessment of specific and general capacity at different scales. Rather, filling out this table demonstrates which elements are potentially being neglected.

Table 10. Evaluation of government documents

	Capacity at system scale	Capacity at sub-system scales
Specific capacity	B: Implementation of community DWSSPs (*inclusive of relevant climate change hazards); Production of climate change risk maps (*including climate risks additional to water scarcity) S: Community training on the implementation of DWSSPs	B: *Risk maps identify specific water supplies that are high risk S: *Climate change-aware DWSSPs prioritise needs of disadvantaged groups
General capacity	B: Establishment of water protection zones on watersheds; Development of multiple viable water sources for communities S: Formalisation of rural water committees; Inclusion of women on water committees	B: *Establishment of buffer zones around localised water sources S: *All user groups, especially people living with disabilities, can physically access all water sources

B = Biophysically focused; S = Socially focused
* indicates my suggestions beyond what is explicitly included already

It can be seen from the table that the policy directives tend to focus on aspects at a community or watershed scale with less focus on disadvantaged groups. This is not surprising given that the documents were crafted at a national level and the implementation and monitoring of policy directives becomes more difficult with increasing granularity. I have suggested aspects that could be included to give the government greater insight on the gaps. However, to put these assessments into practice, operational challenges need to be overcome. I discuss these challenges in the next section.

6.2.6 Operational challenges to making assessments at the local level

In order to institutionalise the assessments discussed above, a significant onus is put on local government authorities. Per the new policies, area councils (primarily the Area Secretaries) and provincial DoW staff are mainly responsible for profiling and collecting data on water services in rural communities in Vanuatu. I have outlined how existing policy supports, or can be modified to support, the assessment of different elements of the capacity of community-managed water services to sustain water access against climate change disturbances. However,

local government authorities tasked with putting the assessments into practice (with or without my added suggestions) are likely to face significant challenges. In this section, I draw on my interviews with government officials to discuss some of the operational challenges to local government authorities for realising these assessments.

The assessments can, in part, be done through community profiling as laid out in the DLA monitoring guidelines, but Area Secretaries and area councils are currently challenged to do community profiles for a few reasons. First, the process for visiting communities and documenting their needs has been unclear. Legislation requires that area council members produce plans for meeting development needs in their areas per the 2013 Decentralisation Act. However, a central government research participant reported that the process for this has not been articulated clearly and area development plans are rarely documented. Local DLA staff described the situation similarly. When asked why the area council was not able to produce an area development plan, one Area Secretary explained: "*We do not know what to say. If someone came to tell you to draft this and this…But because they do not make a training to tell us what to draft…*[37]".

The newly drafted DLA monitoring guidelines are meant to address the lack of clarity on how area councils engage with communities, but will require accompanying training. The guidelines provide step-by-step guidance on, amongst other processes, how communities are assessed and consulted to collect information for area development plans. It is during this process that community profiling is done where important information on capacity to sustain water access against climate change disturbances could be collected. The guidelines document is 127 pages long, so users of the guidelines (primarily Area Secretaries with the support of TACs) will require considerable training on how to follow them. Vanuatu has 72 areas and, according to one provincial government staff member, turnover for Area Secretaries can be frequent: "*One more challenge is when we have a new* [provincial] *council, they terminate all the area secretaries and employ new ones…When they are new, they do not know what to do and they do not know*

[37] Mifala no save blo talem olsem wanem. Spos wan man nomo i kam blo talem se yu draftem olsem, olsem, olsem…Be from ol i no mekem wan training blo mifala draftem olsem wanem…

their responsibilities…Then you have to train them again.[38]" Therefore, substantial resources need to be allocated for ongoing training on community profiling.

A second challenge is inter-departmental coordination. Since, per the DLA monitoring guidelines, members of the TAC are expected to lend their expertise to Area Secretaries in the community profiling process, coordination between the DoW and the DLA is needed to assess water services in communities. On paper, the provincial Secretary General, who works under the DLA, regularly calls TAC meetings where provincial government representatives have an opportunity to meet with one another and coordinate activities. However, in practice, there has been difficulty in getting a DoW representative to attend TAC meetings in the provinces that I visited. In one province, a provincial government staff member stated that the DoW ///ficer only attended TAC meetings when a natural disaster struck. In the other province, the DoW Community Development Officer stated that he had not been to a TAC meeting in years because, to his knowledge, the Secretary General had not called any.

New reforms within the DoW may improve the capability for inter-departmental coordination at the provincial level. A central government authority at the DoW stated "*Sometimes* [the communities] *come directly to us, but we are looking at strengthening the structure again*" with respect to working through the TAC and area councils. Under the new restructuring of the DoW, a new staff position called the Provincial Water Supervisor is being created. The Provincial Water Supervisor is to be permanently based in the provincial capital and is responsible for supervising the Community Development Officer and personnel that service urban water systems. Having an additional staff member from DoW permanently based in the provincial capitals provides a better opportunity for DoW to engage with other government departments, such as the DLA. Prior to this restructuring, Community Development Officers were the only DoW staff at the provincial level and consequently spent substantial time away from provincial centres whilst providing support to rural communities. The new Provincial Water Supervisors

[38] [Note: This participant code-switched between English and Bislama] One more challenge is when we have a new council, they terminate all the area secretaries and employ new ones…When they are new, they don't know what to do and *ol risponsibiliti ol i no save*…Then you have to train them again.

could usefully coordinate with the Area Council Development Officer (a position within the DLA that is responsible for overseeing Area Secretaries and area councils) to identify times when the DoW Community Development Officer can assist Area Secretaries on assessing water services during the community profiling process.

A third challenge to assessing water services in communities is that there are few paid and sufficiently funded provincial staff members available to carry out the task. The DoW Community Development Officers in the two provinces that I visited were responsible for providing support to tens of thousands of people spread out over terrain that is difficult and expensive to access. As a central government authority at the DoW explained:

"*Traveling to these islands is not very easy. And the budget that we allocate for these travels is very limited. Sometimes they will have to look into using other resources, maybe from other government departments…if there is a boat trip to another island by another government department or even the province,* [the community development officers] *can hop on the boat, collect some information and come back.*"

Although there are more Area Secretaries than Community Development Officers at the provincial level (12 in Sanma province and ten in Malampa province where the case study sites were located; 72 total in the country), Area Secretaries were also constrained in their ability to visit communities. One Area Secretary explained that he did not receive sufficient funding to pay for transport to visit communities in his relatively large area: "*In a whole year, I cannot visit everyone. Sometimes it takes two days to reach the other side* [of the area] *by foot*.[39]" Other area council members were essentially unpaid volunteers and thus were even more constrained in their ability to visit communities.

Since the community profiling process is planned to occur only once every five years per the DLA monitoring guidelines (Government of Vanuatu, 2016d, p. 9), it may be possible to cover all the communities in an area even with relatively few local government personnel. If the community profiling is planned and budgeted

[39] Lo wan ful yia, mi no save visitim everiwan…Samtaem em i tekem tu dei blo kasem narasaed long leg.

for as a census-like event, it is feasible that Area Secretaries, with technical support provided by DoW Community Development Officers, could assess all the communities in an area. Additional resourced may need to be provided by supportive external development agencies. An assessment every five years of the capacity of community-managed water services to sustain water access against climate change disturbances would likely be sufficient because of the slow development of the chronic effects of climate change. Preparation, response, and recovery for disasters, which occur relatively quickly, require separate governance mechanisms. The DoW, with the assistance of UNICEF and other NGOs, facilitate a WASH cluster group that assesses community-managed water services before and after disasters (Connolly, 2016).

In summary, limited clarity on strategies for community profiling, difficulties with inter-departmental coordination, and a lack of funding and human resources for local government to visit communities are obstacles to operationalising assessments of the capacity of community-managed water services to sustain water access against climate change disturbances. The newly drafted DLA monitoring guidelines and restructuring within the DoW may help to overcome these obstacles. However, designing appropriate adaptation interventions for specific communities will likely require additional in-depth, place-based assessments of the communities.

6.3 Insights for NGOs: Strengthening to the Vanuatu Community Resilience Framework

The conceptual framework can also be used to inform the approaches of NGOs working in the space of community-based climate change adaptation. There are several NGOs that do work on community-based climate change adaptation in Vanuatu. In lieu of reviewing the approaches of each NGO, I refer to the Vanuatu Community Resilience Framework (VCRF) under which six national and international NGOs operate. It should be noted that some NGOs in Vanuatu do not use this framework as guidance for their climate change work (Pritchard, 2017, p. 34) and presumably have their own in-house frameworks.

In 2012, a consortium of six national and international NGOs[40] supporting community-based climate change adaptation programs in Vanuatu developed the VCRF (Webb et al., 2015). The VCRF (Figure 18) was designed to develop a shared vision of community resilience to climate change amongst the NGO partners in order to improve their collaboration with one another (Webb et al., 2015). It conceptualises the resilience of communities to climate change as being built by the eight characteristics. Although the framework was initially developed to guide NGO collaboration for the *Yumi Stap Redi Long Klaemet Jenis* climate change adaptation program which concluded in December 2014, it remains central to the process of cooperation between Vanuatu-based NGO partners in developing climate change adaptation interventions (Maclellan, 2015). The VCRF is not meant to be sector-specific (Maclellan, 2015), but as an overarching framework for all community-based climate change adaptation work, it should be relevant to the water sector. The full contents of the framework are listed in Appendix G.

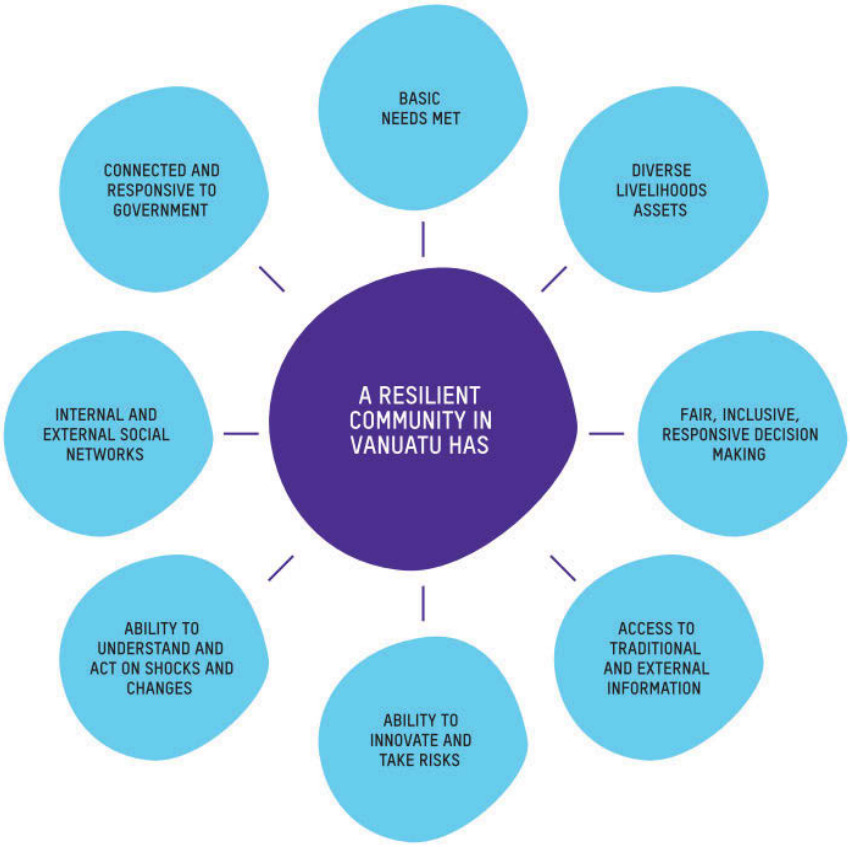


Figure 18. Vanuatu Community Resilience Framework. Source: (Pritchard, 2017)

[40] Oxfam, CARE International, GIZ, Secretariat of the Pacific Community, Save The Children, and the Vanuatu Red Cross Society

The VCRF was created by the NGO partners with guidance from a limited literature review and validated through interviews with other members of the same NGOs. Although precise details on the creation of the framework are not publicly available, Webb *et al.* (2015) write that the eight resilience characteristics were developed drawing from Twigg (2009) and Jones *et al.* (2010). Interviews later conducted with the NGO members found the respondents generally felt that the VCRF was a good expression of their own conceptualisation of community resilience to climate change (Webb et al., 2015). Some NGO members felt that the lack of validation by communities in Vanuatu was a weakness of the VCRF (Webb et al., 2015).

From an academic perspective, the literature used to inform the VCRF covers important social aspects, but does not cover a wide breadth of perspectives. The guidance note by Twigg (2009) proposes over 100 practical characteristics of disaster-resilient communities that relate to a range of conditions, processes, and mechanisms that enable communities to resist being disrupted by disasters or recover quickly after being disrupted. The background note by Jones *et al.* (2010) proposes five abstract characteristics of climate change adaptive capacity "at the local level" that emphasise social processes that enable social systems to adapt to climate change in general. Both notes are anthropocentric (i.e. focus on the impact of the environment on humans, but little vice versa) and focus on characteristics that are meant to be relevant across multiple sectors. The Twigg (2009) guidance note is mostly apolitical while the Jones *et al.* (2010) background note alludes to the need for equitable institutions and entitlements. Neither note engages directly with SES resilience theory (section 2.2.3).

Perhaps as a consequence of drawing on just these two notes and from a community development perspective, the VCRF is relatively confined in its scope. With reference to the six elements emphasised in the evaluation template that I proposed in Table 9, the characteristics identified in the VCRF almost entirely fall within the socially focused dimension of general capacity held at a system-scale (if the community is taken to be the system). There are a few exceptions. "Fair, inclusive, and responsive decision making", which in Appendix G specifically names women, young people, and vulnerable groups, and "diverse livelihood assets", which in Appendix G refers to equitable resource access and control, reflect

attention toward general capacity at a sub-system (i.e. sub-community) scale. Also, "ability to understand and act on shocks and changes" in Appendix G alludes to relationships between social, cultural, and natural systems, which touches on the biophysical dimension. However, overall, the VCRF characteristics relate little to biophysical components or specific capacity. The VCRF also, as indicated by the centre circle in Figure 18, is primarily focused on capacity held collectively at a community level.

My proposed framework could be used to evolve the VCRF in a few ways. The social focus of the VCRF, informed by socially minded community development literature and validated by experienced NGO practitioners based in Vanuatu, forms a strong foundation for assessing social components that are relevant to community-managed water services. This focus could be further strengthened with a more critical assessment of how the proposed social characteristics are differentiated across different social groups. The VCRF would also benefit from more explicit attention to how biophysical characteristics of the environment contribute to community resilience, especially in the context of water services in which the natural environment plays a major role (Hadwen et al., 2015). The VCRF would also benefit from more attention given to the capacity to manage specific climate change risks because development policies that fail to account for them can actually worsen them (Agrawal and Lemos, 2015). I therefore suggest three contributions that my proposed framework makes to addressing these gaps in the VCRF.

One contribution that my framework makes to the VCRF is the notion that resilience (as the VCRF labels it) is held at the sub-community level as well as the community level. The conceptual framework that I proposed makes the argument that a high capacity of a community to collectively respond to climate change does not necessarily indicate that all community members will benefit equally (section 5.3.7). For example, my research found that although the Uripiv community held diverse water assets in the form of multiple shared wells and rainwater harvesting systems, not all community members were able to access and control them equally (section 4.3.2.2). Adaptation programs that use the VCRF to assess community resilience should also be cognisant that different individuals or social groups at a sub-community level can possess different levels of a characteristic (e.g. some people may have more ability to innovate than others within a community). I

recommend that analyses of community resilience should be disaggregated at a sub-community level to check whether resilience is spread equally. This may have already been recognised by the NGO CARE International which pairs gender-awareness with each of the characteristics (Pritchard, 2017, p. 4). The characteristics could be compared across other social groups as well, such as disability or age groups.

Another contribution that my framework makes to the VCRF is emphasising the role of the natural and built environment in influencing community resilience. The VCRF mostly focuses on social characteristics that NGO partners believe build resilience. My conceptual framework makes the case that biophysical characteristics are also important to consider, particularly in the water services sector (section 5.3.3). For example, the stream in Namoru that was a vital, non-potable backup water source for the community required appropriate land management practices to strengthen water service resilience (section 4.4.2.1). Even aside the water services sector, rural communities in Vanuatu are typically highly dependent on their local environment and natural resources for their well-being (e.g. for food security or income generation). A valuable addition to the VCRF would be to consider how biophysical characteristics of the built and natural environment of the community contribute to enhancing each of the listed characteristics.

Finally, my framework points to the need for communities to have capacity to respond to specific climate-related risks in addition to characteristics that build general capacity (section 5.3.4). Since the VCRF is not intended to provide sector-specific advice, attention to specific sectoral risks should be included additionally through complementary frameworks. In the water services sector, the use of climate change-aware DWSSPs, which can be used to identify and manage specific climate risks to water safety and security, are a suitable tool for accompanying the VCRF. If the DWSSP and the VCRF are used to assess community-managed water service, they should be used jointly so the outputs and recommendations of each can be compared to see if they complement or conflict with one another. The conceptual framework that I have proposed provides a heuristic for considering integration of the tools.

In order to operationalise my suggestions to the VCRF, collaboration with other stakeholders would be beneficial. The NGO consortium partners likely have sufficient skills and resources to assess the existing characteristics listed in the VCRF at both a community and sub-community level. Collaboration with more environmentally focused NGOs based in Vanuatu, like Live & Learn or the Global Environment Facility, could provide expertise for assessing the role of the natural environment in enabling community resilience. The NGO partners could also collaborate with the DoW as they work to implement DWSSPs in communities. This would not only offer an opportunity to pair the two tools, but also an opportunity for NGOs to lend their resources and expertise for building the capacity of DoW staff.

In summary, the VCRF provides a strong foundation for assessing social dimensions of general capacity at a community-scale, but it would benefit from additional perspectives. In particular, the application of the VCRF across different sub-community groups and comparison of findings, inclusion of a more explicit focus on environmental systems that provide water purification, regulation, and storage services, and complementing the VCRF with frameworks that focus on specific climate risks would strengthen assessments.

6.4 Insights for researchers: Successes and challenges in conducting risk-hazard, vulnerability, and resilience analyses

In this section, I reflect on the analyses that I conducted throughout this research and offer thoughts on putting my proposed framework into practice in order to share lessons learned with other researchers in Vanuatu. I first discuss what worked well for me and what I found challenging in the field when working with each of the risk-hazard, vulnerability, and resilience approaches. I then discuss some of my lessons learned regarding putting my proposed framework into practice. These insights provide guidance to future researchers who wish to do similar assessments of community-managed water services in Vanuatu.

6.4.1 Reflections on risk-hazard analyses

While carrying out data collection activities in the rural communities, I had some successes and challenges related to the risk-hazard analyses, which I share here.

I found that identifying locally relevant climate-related hazards, an early step to risk-hazard analyses, could be effectively done by directly asking research participants. In particular, I found that directly asking community members if certain hazards (e.g. dry spells, flooding, bushfires) ever affected their water supplies was more effective than asking open ended questions like "How do changes in the weather affect water in your community?" Directly asking about specific hazards helped participants to remember specific incidents that they had experienced whereas open questions may have been too broad for some participants to answer. Following this technique, I could identify the most impactful climate hazards on water supplies within the first four to six interviews. However, throughout the course of all the interviews, I listened for hazards that I did not ask about at the beginning. For example, a few participants in Uripiv remarked that high temperatures caused their concrete rainwater storage tanks to crack and leak which I had not thought to ask participants. A limitation of this is that future climate change may create new hazards for water services that the communities have not experienced before.

If directed, research participants were able to talk at length about any climate-related hazard that affected their water access, not just ones that occurred recently. Another step to the risk-hazard analysis was to assess sensitivity, that is, the ways and degree to which climate hazards disrupted the communities' water services. Participants easily explained how climate conditions like dry or rainy conditions affected the physical characteristics of their water service, such as the quantity and quality of the water. I initially had concerns that the participants would speak more candidly about climate hazards they had experienced more recently than about less recent ones, but I did not find this to be the case. For instance, when I first visited Uripiv, the community had been experiencing a lengthy dry spell. However, the participants still spoke at length about how intense rainfall affected their water supplies when prompted.

Complementing the interview questions on climate impacts with a sanitary survey of the water supply was especially effective for understanding how climate hazards disrupt service. During interviews, community members pointed out risks that I would not have realised if I had conducted the sanitary survey on my own. For example, one well that I visited had a parapet about one metre tall. I would not

have guessed that annual flooding could be so intense that floodwaters would rise above the parapet and spill into the well if the community members had not told me. Likewise, my own expert knowledge came in handy. Participants could provide detail on how hazards tangibly impaired water access, but had limited knowledge of potential microbiological contamination pathways. Having been trained in water supply sanitary surveys, I knew that the absence of a well platform and well lining risked contamination of dirty water ingress underneath the well parapet even though none of the participants reported this. Sanitary surveys paired with qualitative interview questions were a simple and effective way to analyse how climate change impacts can locally affect a water service.

One challenge to assessing climate impacts on water services was tracking the multivariate ways that community members accessed water sources to meet their needs. It was clear from the interviews that different community members used different water sources for different purposes (e.g. drinking, bathing, cooking, etc.) depending on how climate conditions affected water quality and availability. At times, the numerous combinations of water access and use made it difficult to track whom was affected by which climate hazards using semi-structured interviews. Surveys (particularly computer-assisted surveys) are a potentially useful way of quantifying how many users use which water sources and for what purposes (MacDonald et al., 2016). Quantified survey results could give more clear insight on which climate hazards affect whom and in what ways their water access are disrupted.

Another aspect of the risk-hazard analysis that was a challenge was determining the frequency that communities experienced climate hazards. In a risk-hazard analysis, determining the probability or likelihood that a particular hazard will be experienced is a step in calculating risk (WHO, 2012). To assess the likelihood of hazards, I asked participants how frequently they experienced events like cyclones or rainfall that were intense enough to noticeably contaminate wells. Participants were often unable to provide an estimate of how many times in a year they experienced such events, or even to provide qualitative descriptors. Quantitative measurements, like gauges for measuring precipitation or groundwater levels over extended periods of time, would be much more accurate for assessing how frequently a water supply is exposed to particular hazards. Again, a limitation of

measuring current climate hazard exposure is that there is significant uncertainty at local levels associated with how climate change will alter the frequency of hazard occurrence.

Interview questions relating to the risk-hazard analyses were relatively "easy" compared to the vulnerability and resilience related questions. Since they focused on tangible topics, like physical changes in water service, and were apolitical, participants answered them confidently. I usually started each of my interviews with risk-hazard related questions first to ease participants into the interview before proceeding to vulnerability and resilience related questions.

6.4.2 Reflections on vulnerability analyses

One challenge of the vulnerability analyses was that vulnerability is constructed in complex ways and can be differentiated along many different lines, but I found this could be addressed with appropriate delimitations and familiarity with the studied context. Many assets, capabilities, and institutions are potentially influential on vulnerability. Furthermore, if a researcher wants to investigate differences in vulnerability amongst social groups, social group delineation can be made in a variety of ways (e.g. gender, class, age, disability, etc.). Some delimitation is needed since the amount of data that could potentially be collected seems overwhelming, even at a community level. One way to address the breadth of analytical pathways is to focus on a particular dimension of vulnerability. For example, Kuruppu (2009) used the Sustainable Livelihoods Framework (Scoones, 1998) to frame questions around the physical, financial, natural, social, and human capitals to which water users had access in order to investigate how assets influence the capacity of communities to sustain water access against climate change. However, it is helpful to have some familiarity with the studied context, if possible, before setting delimitations. I found it easier to define delimitations after I settled in with the communities and learned more about what assets, capabilities, and institutions were particularly relevant for them. I recommend scoping visits as a way of informing delimitations in vulnerability analyses.

Interview questions need to be modified frequently to explore interesting leads on complex social issues that arise in a vulnerability analysis, but this can come at the cost of lost consistency. I found that adding new questions to my interviews (and dropping old ones to manage the length of the interviews) allowed me to investigate

important social issues surrounding water access in the communities that I could not foresee before talking to community members. However, not asking the same questions every time made it more difficult to quantify responses to get a sense of the prevalence of a certain sentiment or perception. Nuanced, in-depth interviews are effective for understanding complex social issues, but other methods could be used to complement findings from interviews. Surveys or standardised questionnaires could be used to collect quantitative data on perceptions of vulnerability dimensions, such as how equitable water access and water management decision-making processes are within the community. Quantitative data from surveys could complement the qualitative data by providing a clearer picture of what proportion of community members (and what demographics) agree that issues recounted in interviews are significant. Participatory research methods have also been effective in Vanuatu for stimulating community members to work together to come to a consensus on articulating communities issues, as has the added benefit of providing learning opportunities to research participants (Warrick, 2009).

Vulnerability analyses can involve issues of politics and power, so participants need to feel that they can speak freely without being subject to reproach. This was especially important in the communities I visited in Vanuatu where people were highly non-confrontational and strongly valued communal harmony. I found that emphasising and reminding participants of the confidentiality of their comments appeared to make them feel more comfortable speaking about sensitive topics, such as whether the voices of women were listened to in the communities. I usually conducted interviews in the home and made a rule that only family members could be present. Having only family members present helped to enable participants to speak freely about the rest of the community, but also made it challenging to investigate intra-household power dynamics. I felt it was unethical to ask any family members to leave the house during an interview, so I avoided questions that were potentially contentious within the family. If differentiation of vulnerability within households is to be investigated, it may be useful to hold interviews at other locations in which participants are comfortable (e.g. interviewing women about their household while they are selling produce at the market).

I found that repeatedly asking "why" questions revealed interesting information about institutions that created differences in vulnerability in the communities. In particular, I found that repeatedly asking "why" questions relating to water access and power to make water management decisions was useful for understanding why certain inequalities existed. For example, it was immediately apparent that some households in Namoru received better water access than others. Asking why sometimes led to statements that homes further away from the source had lower water pressure at their standpipe. Asking why homes were located where they were led to narratives about land rights. Asking why people had rights to certain land sometimes led to narratives about migration and customs, and so on. Asking a series of why questions was thus effective at exploring deeper institutional issues that participants (and researchers) otherwise may take for granted in an interview. One limitation of this technique is that the information that can be uncovered is limited by the participants' knowledge of events. A method that could complement this is interviews with key informants that are knowledgeable about the history of development in the geographic area.

Overall, semi-structured interviews were a suitable method for conducting vulnerability analyses because they allowed for in-depth exploration of complex social issues. This contrasts slightly with the risk-hazard analyses which I found were more effective if interviews were more structured and accompanied by systemic risk assessments with sanitary surveys. In the following section, I reflect on the methods I used for my resilience analyses.

6.4.3 Reflections on resilience analyses

One of the foremost challenges I faced with conducting resilience analyses of community-managed water services was the operationalisation of resilience concepts. Although substantial progress has been made in operationalising and developing strategies for assessing resilience, Biggs *et al.* (2015) note that significant gaps remain. This is especially true with respect to water services in a developing country setting, although this research has documented valuable evidence of community level water service resilience. At times, this made it difficult to develop interview questions that made sense to the research participants and generated empirical evidence for a concept. More empirical studies that demonstrate how resilience principles (Table 1, Chapter 2) can be put into practice

in the water services context, and evaluations to demonstrate their effectiveness, remain a research need that will contribute to support future water service resilience analyses.

As with vulnerability analyses, resilience analyses of community-managed water services could potentially be done in numerous ways, so some delimitation is needed. Resilience theory encompasses a variety of analytical concepts such as learning, adaptive management, and social-ecological feedbacks (Miller et al., 2010). An investigation into a concept like learning alone could potentially be carried out in numerous ways and in substantial depth. Again, my experience was that familiarising oneself with the water service case study through a scoping visit or pilot study is useful for informing research questions on which aspects of resilience can be investigated in what depth.

I found that data on social-environment interactions could be collected through interviews, but complementary methods could be used to enrich the data. An important aspect of treating a water service as an SES in a resilience analysis is understanding how changes in water resources affect social behaviours and vice versa. In my analyses, I investigated these interactions via events as reported by participants (e.g. salinisation of a well in Uripiv due to pumping technology installed by the community). However, community members may not always be able explain changes in water resources. For example, community members may be unaware of changes in the microbiological quality of their water or in ecosystem health as result of their actions. A complementary method to assess social-environmental interactions within water services would be to measure changes in water resources (e.g. flow rates, volumes, quality) using technological instruments and to study qualitatively how water abstraction and use subsequently change and vice versa. A range of tools, including causal loop diagramming, Bayesian network analysis, stock-flow modelling, and agent-based modelling, can be used to map and analyse the documented social-environment interactions in community-level water services (Liddle and Fenner, 2016).

Thresholds, the limits that certain variables can reach until functioning of the system dramatically changes (Chapin et al., 2009), are a prominent concept in resilience theory that I found to be challenging to assess through interviews, but

could be measured through technological means. A key threshold of the water services in my sites, and likely a key threshold for most community-managed water services, related to the available quantity or flowrates of water from the source. One way to characterise this threshold was to identify how many days without rain could be experienced before flow at standpipes in Namoru, or water available in rainwater tanks in Uripiv, would go dry. I asked participants to estimate the number of dry days that could occur before water scarcity was experienced, but participants were often unable to provide estimates. This is another area where methods using technological instruments would be helpful in providing more accurate data on water availability. For example, rainfall gauges could be used to more precisely measure how much rainfall is needed over a given period of time to sustain water flow in the system. It is important to remember, however, that thresholds can move regularly due to changing variables (e.g. population growth, alteration of land, etc), so a single assessment will only provide a snapshot in time. To remain relevant for water management in practice, thresholds should be monitored as frequently as possible.

Overall, the resilience analyses were relatively challenging compared to the risk-hazard and vulnerability analyses. Abstract concepts and a general need for a mix of methods to measure different aspects of the SES are obstacles that must be overcome. Further empirical research on resilience concepts in the context of water services can help to address resilience operationalisation. Expertise in both social and water resource data collection activities is needed to conduct a mix of methods approach.

6.4.4 Reflections on applying the proposed conceptual framework

Finally, I offer some thoughts relating to the operationalisation of my proposed framework for future researchers. These thoughts may be considered an extension of my discussion presented in section 5.4. They are based on my reflections and lessons learned in designing the framework, applying it retrospectively to my findings in Chapter 5, and applying it documents earlier in this chapter. The above reflections on the risk-hazard, vulnerability, and resilience analyses are also relevant to the operationalisation of the framework, but my thoughts in this section are more purposefully directed toward the framework.

An early step to using my proposed framework to guide a study is to decide on to what depth each of the elements of the framework will be investigated. Depending on the research questions, it may not be necessary to do an in-depth investigation of every element. However, even if a researcher chooses to focus on collecting data on a particular aspect of a community-managed water service (e.g. how trust between water user groups builds general capacity at the community level), enough data should be collected on other elements of the framework to at least make some claims about how the studied aspect positively or negatively affects other aspects of the water service. How much data is enough is a matter of judgement on what are the most apparent or "key" influences of the studied aspect. If a more holistic assessment of all the elements of the framework is to be conducted, some delimitation, as I emphasised above in my reflections on vulnerability and resilience analyses, is still needed. To guide such delimitation decisions, researchers should consider the purpose of their research, who is the audience, and what actions the research is expected to inform.

In an ideal situation, it is advisable to plan and conduct studies in interdisciplinary teams, especially if social and biophysical dimensions of both specific and general capacity are being investigated in depth. This may not always be possible, such as with students conducting research for their degrees. Where possible, teams that include academics from different home disciplines are more likely to yield richer and more diverse insights than single researchers who may feel challenged to cover multiple fields of inquiry or disciplinary teams that may develop a narrow view of the situation. It is important for team members to discuss their interpretations of the elements of my proposed framework in order to develop a shared understanding of the problem. This is because researchers can have different assumptions about the meanings of concepts even when they are using the same terminology (Newell et al., 2005) which can lead to confusion. Research teams would also benefit from the inclusion of the insights of practitioners, government officials, and concerned community members in planning the research, although this can be practically challenging. Researchers should take advantage of opportunities to include other stakeholder insights to whatever extent is practicable.

In section 5.4, I identified areas where analysts using my proposed framework must make choices, one of which was where to draw system boundaries which can be locally informed in a few ways. Rural communities in Vanuatu typically have clear ideas of what is considered to be a part of their community which can be used to draw spatial boundaries. Spatial boundaries based on what the community claims is a part of it has the advantage of focussing assessments on aspects of water service that the community can usually directly influence. The disadvantage is that they can exclude other influential environmental or social factors such as upstream pollution or NGO interventions. Spatial boundaries drawn to include watersheds would help to capture more environmental factors in an analysis. However, watersheds in Vanuatu often extend into rugged, mountainous terrain with poor road access. There is also little secondary data available for water resources in Vanuatu. Whether an assessment aims to include the wider watershed may depend on whether there is a reason to suspect that there is something influential on a community-managed water service present (or if the community can influence something else). Many rural communities in Vanuatu are small and located in areas with little human activity. In these cases, it may not be necessary to explore the wider watershed if it is unlikely that there are significant upstream or downstream effects. In cases where there is significant human activity in the watershed, or the community potentially can create significant downstream effects, further consideration should be given to including the wider watershed within the boundaries of the assessment.

System boundaries are not necessarily spatial and can also include other actors outside the community. I have profiled two relevant government departments throughout this thesis; the DoW and the DLA. Many NGOs working in the spaces of WASH and climate change adaptation are also active throughout Vanuatu and could be included in assessments. Including non-community stakeholders within the system boundaries may increase the comprehensiveness of an assessment, but it also raises its complexity. For example, on a practical level, access is needed to the government authorities or NGOs to collect data from them. On a conceptual level, there is a question of what system-level capacity looks like when the system comprises a community, government departments, and NGOs? The inclusion of

non-community stakeholders within the boundaries of analysis mostly depends on the research questions and what data can be feasibly collected.

Once data collection has begun, it can be difficult to ascertain whether a certain aspect of a community-managed water service being studied is indicative of specific capacity or general capacity, or whether it is held at a system or sub-system scale. I was confronted by this challenge a number of times when I applied my framework retrospectively to my findings and when I applied it as a heuristic for assessing government policies. Frameworks inherently are a simplification of reality and the distinctions between different elements of the framework are not actually always so clear in practice. In an assessment, it is less important to decide whether something indicates specific or general capacity at a particular scale than it is to undertake the exercise of considering the different elements in order to broaden one's perspective. However, this a potential source of confusion for teams, so team members should have explicit discussions about how to classify different aspects of a community-managed water service.

The conceptual framework encompasses a wide range of concepts on how capacity to respond to climate change can be built in community-managed water services and, as such, there are a wide range of potential strategies that could be employed for developing capacity. Building specific capacity involved identifying the specific capacity of what and to what? For example, a particular climate hazard, like sea-level rise may be especially concerning in a given context. Strategies to strengthen specific capacity would involve assessing water technologies, water resources, the management practices of the community to identify critical thresholds and risks and implementing appropriate control measure to manage them. Building general capacity involves developing adaptive management and governance processes, institutions for the distribution of resources and enhancement of capabilities for accessing water when climate disrupts usual services, and diverse, decentralised water supplies that can take the place of one another when one fails. Processes for achieving this will vary widely across different contexts, but likely substantial support from government and civil society organisations are required to work with communities to assess current shortcoming, design context-specific solutions, share responsibilities, and monitor progress. Finally, assessing specific and general capacity at sub-system scales involves much of these same processes, but ensuring

that the benefits are equitably distributed across different individuals and groups without causing short-term or long-term detriment to key environmental resources. This can be achieved by disaggregating monitoring of outcomes for different groups and drawing the expertise of environmental professionals for assessing the health of water resources and associated ecosystems. Overall, further research in case study sites is needed to develop more specific guidance notes on how capacity to respond can be built in a given water service.

My proposed framework supports research that can go in many different directions, which is a strength, but can also feel overwhelming to researchers. With these thoughts, and my reflections provided on each of the approaches I used in my research, I have striven to make research in this space less confronting to future researchers in Vanuatu.

6.5 Summary

In this chapter, I have considered how the findings from my research can be used to inform stakeholders in Vanuatu in order to strengthen assessments of the capacity of community-managed water services to sustain water access against climate change disturbances. I first did this through demonstrating how my conceptual framework can be used as a heuristic for identifying gaps in how government policy directs the assessment of aspects related to community-managed water services and climate change. I then discussed how my proposed framework informs an existing framework developed to guide community-based climate change adaptation interventions led by NGOs. Finally, I reflected on the analyses that I conducted throughout this research and offered thoughts on putting my conceptual framework into practice in order to share lessons learned with other researchers working in Vanuatu.

Chapter 7. Conclusions

7.1 Introduction

In this chapter, I turn back to summarise, reflect upon, and evaluate my doctoral research. I structure this chapter in five sections. First, I summarise how my research findings answered each of my research questions and met my overall research aim. Then, I discuss the contributions of this research to the fields of WASH and climate change research and practice. Next, I discuss future research opportunities that could build upon my research. I finish with a self-assessment of my research against five quality criteria for transdisciplinary research and concluding remarks about what my research has accomplished.

7.2 How were the research questions answered?

I first explain how I answered my research questions in this thesis and how I met my research aim. Following the presentation of each research question, I broadly describe the steps that I took to answer it and outline my key findings. I then discuss how answering the research questions has achieved my research aim.

My first research question was:

What contributions do the risk-hazard, vulnerability, and resilience approaches make to understanding how community-managed water services are affected by and sustained against climate change disturbances?

I answered this question in two broad ways: 1) a review of the existing WASH literature in which I analysed the research questions, methods, results, and recommendations of the literature to determine how they problematised climate change in alignment with the approaches and 2) a case study analysis of two rural community-managed water services in Vanuatu in which I used semi-structured interviews, sanitary surveys, and observations to conduct my own risk-hazard, vulnerability, and resilience assessments.

I found that the risk-hazard, vulnerability, and resilience approaches each made different and valuable contributions to understanding how community-managed water services are affected by and sustained against climate change. The risk-hazard approach tends to emphasise the physical impacts of climate hazards on water service technologies and infrastructure. To this end, the risk-hazard

approach highlights a need for more physically durable water supplies that can withstand worsening climate hazards and for capacity of communities to manage these water supplies. Improving the ability of communities and supportive agencies to climate-proof water supplies against key climate change hazards will help to ensure that water availability and quality is not compromised. For example, in the case study communities in Vanuatu, an unprotected spring source and hand-dug wells were exposed and sensitive to intensification of rainfall and rainwater harvesting systems were especially sensitive to dry spells. The implication for WASH practice is that water technologies need to be adapted so that they continue to function under future climatic conditions. Climate hazards may not currently be a primary concern for water supply functionality in many areas, but they are likely to take on increased prominence. Promotion of more robust water technologies that function well against projected climate conditions, and developing the capacity of communities to manage specific climate hazards, should be included in climate-WASH policy.

The vulnerability approach mostly stresses socio-political structures that enable people to take action to secure equitable water access against the threats of climate disturbances in general. Consequently, the vulnerability approach highlights a need to ensure that processes for distributing the resources and decision-making power that people require to sustain their access to water services against climate change are fair and prioritise the people most in need. This focus on agency and equity helps to raise attention that people must be enabled to take adaptation actions and that no one should be left behind. For example, in the Namoru community, women were largely excluded from formal decision-making processes that affected their ability to voice concerns about how to respond to climatic disturbances to the community water service. In Uripiv, poorer households that relied on water from domestic rainwater harvesting systems owned by neighbours had to follow rules set by the owners for accessing water, which limited their ability to decide how water is managed during climate stress. The needs highlighted by the vulnerability approach have been largely overlooked by the WASH sector. Conventional development approaches in WASH that seeks to develop agency and equality in communities are often separated from climate risk management activities in WASH programming, policy, and funding, the latter of which has

focused on improved technologies. Instead, climate risk management should be integrated with conventional development approaches to ensure that WASH development enables people to manage climate risks, and that improved management of climate risks is done in way that promotes equitable outcomes and achieves development goals.

The resilience approach examines the interactions between water users/managers, water infrastructure, and water resources that either enable or restrict the ability of the community-managed water service to be adapted to climate conditions that change in uncertain ways. As a result, the resilience approach emphasises a need to ensure that an acceptable level of water service can be sustained even as the co-dependent social and environmental components of the water system change due to the effects of climate change. A resilience perspective emphasises the need for flexibility and adaptiveness in the face of climate change uncertainty and the importance of long-term environmental sustainability. For example, in Namoru, land use activities threatened the long-term quality of a stream that served as an important secondary water source that helped the community cope with climatic disturbances. In Uripiv, the community had access to different types of discrete water supplies which gave community members different options for accessing water if climatic disturbances caused some supplies to fail. The resilience perspective invokes a shift in thinking from conventional WASH approaches. Whereas risk management and development of agency and equity are familiar concepts to WASH researchers and practitioners, ideas relating to flexible and adaptive water services and long-term environmental sustainability are relatively less recognised. The significant uncertainty that climate change creates, and potentially devastating impacts for ecosystem services, raises the significance of planning for community-managed water services that can change when needed and sustainably manage water resources. Resilience concepts have already been and continue to be operationalised in other sectors, including the water sector in developed country settings, and more work is needed to consider how they may usefully be drawn on in rural settings.

I argued that the contributions of each approach on their own, while valuable, provide a limited perspective. None of the approaches necessarily excludes the objectives of the other, but the different focuses of each draws attention toward

different dimensions of water service and climate change. In my application of each approach to community-managed water services in Vanuatu, I found that the risk-hazard approach drew attention to technological issues, the vulnerability approach drew attention to social issues, and the resilience approach drew attention to natural resource management issues related to water service delivery. The result is that following just one of the approaches to understanding the climate change problem for water services can cause serious sustainability issues to stay hidden. Thus, in theory, policy-making, and practice, all three of the approaches should be drawn on when assessing the capacity of community-managed water services to sustain access to water against climate change disturbances in order to develop a holistic view of the problem. The factors that will best strengthen the sustainability of community-managed water systems vary widely across different contexts. The point of is not to review each of these approaches to determine which is "best" and give prescriptive advice, but instead to be cognisant of the options and to negotiate with stakeholders what adaptations are preferable and achievable. It is likely that in any context, there will be physical risks (e.g. water contamination of wells in Uripiv), social inequalities (e.g. unequal decision-making power between men and women in Namoru), and inflexibility (e.g. no alternative safe water sources in Namoru) that influence sustainability under climate change and require attention to adapt.

I also argued that drawing on all three approaches for understanding how community-managed water services can and should be sustained against climate change is not a straightforward process and that guidance is needed. Depending on the specific context of a situation, various concepts of each approach could take on special importance (e.g. reducing the exposure of groundwater supplies to sea-level rise where salinisation is a critical threat) and have positive or negative implications for other concepts (e.g. implications concerning water access and land rights if groundwater supplies are re-located). Politics and worldviews across different stakeholders in the WASH sector will also influence debate on how the climate change problem should be viewed. I have asserted that the best way to negotiate the different ways in which the climate change problem for community-managed water services should be assessed is through explicit consideration of different perspectives and how they relate to one another.. However, more explicit

analysis of how the different perspectives relate to one another is still needed to maximise their synergies and manage tensions between them.

This led me to my second research question:

How can climate change risk-hazard, vulnerability, and resilience assessments be conceptually integrated with respect to community-managed water services?

I addressed this question by examining the concepts of each approach and their relationships to one another through a review of the literature and the empirical evidence I gathered in Chapter 4. In particular, I used a conceptual blending technique that involved structuring a conceptual framework around nexus concepts and groupings of related concepts.

I first reviewed several existing conceptual frameworks that aim to integrate two or all of the risk-hazard, vulnerability, and resilience perspectives. I argued that while each of the frameworks have made important contributions to synthesising knowledge, each had limitations in scope that I could expand upon.

I then presented my conceptual framework (Figure 16, section 5.3) for guiding holistic analyses of the capacity of community-managed water services to sustain water access against climate change disturbances in a developing country setting. The framework comprises a synthesis of key risk-hazard, vulnerability, and resilience concepts and acts as a heuristic for sensitising analysts to, and encouraging their critical thought about, different elements that contribute to the capacity of community-managed water services to sustain water access against climate change disturbances.

The main features of the framework include the conceptualisation of a community-managed water service as a linked social-biophysical system with subjective boundaries; the conceptualisation of capacity to respond to specific climate hazards (specific capacity) versus the capacity to respond to climate disturbances in general (general capacity); the interactions between specific and general capacity; the conceptualisation of capacity held collectively at a system scale and capacity differentially held at a sub-system scale; and the interactions between capacities held at different scales. I also emphasised that analysts must consciously

make impactful, justifiable choices regarding where to draw the boundaries around the system of analysis, the temporal frame of reference, the scales of inquiry, and what form(s) of capacity are most desirable. I further demonstrated how the framework may be used by retrospectively applying to my findings from one of the rural community case study sites.

The implication of the conceptual framework for research and practice on community-managed water services is that capacity to respond to climate change needs to be built in multiple ways to enable services to sustain water access. Further, efforts to build capacity in one way can influence capacity, positively or negatively, in other ways. Whatever perspective or strategies WASH stakeholders take to assess or building capacity to respond to climate should ideally aim to build specific and general capacities at both system scales and equitably across sub-system scales. Ignoring one form of capacity, focusing on only one scale, or neglecting either the social or biophysical domain may result in maladaptations that make some people or the natural environment more susceptible to harm from climate change.

While my findings made clear conceptual contributions to addressing my overall research aim, I still needed to tie it to tangible, real-world issues. This led to my third research question:

How can the findings from research questions #1 and #2 be drawn on to develop recommendations for policy-makers, practitioners, and researchers in Vanuatu to better assess the capacity of community-managed water services to sustain water access against climate change disturbances?

I answered this question by investigating the operations of relevant government authorities using semi-structured interviews with local and central government officials, observations of the work environment of relevant government officials, workshops with local government officials on their role in providing support to communities with respect to sustaining water service against climate change, and document analyses of government policy documents and an NGO framework. I also reflected on my experiences conducting this research to offer lessons learned to other researchers based in Vanuatu.

I argued that one of the benefits of my research is that my conceptual framework could be used to inform government processes in Vanuatu for collecting data pertaining to climate change and rural water services. I aligned my framework with objectives and guidelines as laid out in government policy and strategy documents. Following this, I suggested that government authorities could track the inclusion of climate hazards in community DWSSPs and create risk maps in order to assess specific capacity at a system-level; monitor the establishment of watershed protection zones, the presence of multiple water sources in a community, and the presence of women on community water committees in order to assess general capacity at a system-level; further develop the aforementioned DWSSPs and risk maps to identify high-risk user groups and water supplies to assess specific capacity at a sub-system scale; and monitor the establishment of local water source buffer zones and check whether all users groups are able to physically access available water sources to assess general capacity at a sub-system scale. I found that challenges exist for carrying out these recommendations, namely a need for training at the local government level, inter-departmental coordination, and sufficient funding. However, I also found encouraging developments that could help to address these issues such as the drafting of new community profiling guidelines and organisational restructuring within the DoW.

I also asserted that my conceptual framework can be used to strengthen a framework (the VCRF) used by NGOs based in Vanuatu working in the space of community-based climate change adaptation. I argued that while the VCRF usefully brought together social characteristics of communities that build general capacity based on the experiences of practitioners, it would benefit from more engagement with academic literature. My recommendations included applying the framework at a sub-community level in addition to a community level, putting more emphasis on the role of environmental systems in enabling communities to adapt to climate change, and pairing the framework with sectoral tools that account for specific climate change risks.

Finally, I provided a range of reflections on my experiences conducting the risk-hazard, vulnerability, and resilience assessments of community-managed water services in Vanuatu, and thought prospectively about how my conceptual

framework could be used to guide future studies. These reflections and thoughts provide useful lessons for researchers planning to do similar analyses in Vanuatu.

In conclusion, my research has met my aim to provide holistic, detailed, and integrated knowledge and guidance on the ways in which community-managed water services are affected by and sustained against climate change disturbances in a few ways. My application and critique of risk-hazard, vulnerability, and resilience approaches in the context of community-managed water services each provide guidance for systematically and rigorously assessing how these services are affected by and can be sustained against climate change disturbances. By joining them in a shared framework, I have further made this guidance holistic and integrated. Finally, I illustrated the ways in which this guidance can be practically useful to different stakeholders in a real-world setting.

7.3 Contributions of this research

One significant contribution that this research makes to WASH research and practice is that it presents a range of ideas on what could be done to sustain water services against climate change. I have highlighted that the WASH sector has inadequately given explicit consideration of the possible ways in which water services are affected by and sustained against climate change disturbances, and that, implicitly, the scholarly WASH literature has favoured a technocratic framing of the problem of climate change (Kohlitz et al., 2017) (section 4.5). In this thesis, I have demonstrated multiple approaches for assessing climate change impacts on community-managed water services that open an array of useful pathways across different disciplines for thinking about what is needed to ensure water services are sustained. Furthermore, these approaches are each strongly theoretically grounded, which gives rigour to the assessments so that they can more easily be justified, critiqued, and evaluated. This contribution thus sensitises WASH researchers and practitioners to different approaches to understanding and responding to the impacts of climate change. Researchers may build on the theory and methodology that I used in this thesis to develop their own theories and methodologies. Practitioners may reflect on how the findings from my case studies are related to sites in which they work and how the identified issues may broadly be addressed.

Another significant contribution to WASH research and practice is increased awareness of the limitations of different perspectives on climate change impacts on community-managed water services. Given that climate impacts on water services are highly complex, context-specific, and cut across social and biophysical domains, it is wise to be critical about how one conceptualises the problem and consider dimensions of water services that could be overlooked. Each of the risk-hazard, vulnerability, and resilience approaches on its own is unlikely to portray a holistic picture of water access issues in a community. In this thesis, I have turned a critical eye toward the different approaches that I demonstrated to show that a pluralist approach within the WASH sector toward climate change is needed to account for the wide scope of the problem. This contribution is particularly relevant for policy-makers and practitioners. The findings demonstrate that development interventions may have limited effectiveness or even be counterproductive if other approaches are not drawn on as described above.

In addition to emphasising the strengths and limitations of different perspectives, this thesis has contributed guidance for strengthening the integration of these perspectives. Research and practice that blend disciplinary ideas are key to understanding and addressing the complexity and scope of the climate change problem for community-managed water services. This thesis provides valuable discussion and a heuristic for working toward harmonising different perspectives in the WASH sector such that they can leverage their synergies and manage tensions between them. Although the proposed framework does not provide step-by-step guidelines on how integrated assessments can be done in any situation, it does sensitise users of the framework to different dimensions of climate change impacts that require consideration. The practical examples provided throughout Chapters 4 and 5 provide inspiration for how different elements of the framework could potentially be operationalised. Operationalisation of the framework in different contexts is a major next step for further research and practice. This will best be done incrementally in different contexts through iterations of applying the concepts in practice and revising the thinking around them.

The SDGs offer an opportunity to consider how different approaches and perspectives can be harmonised. SDG 6 compels the WASH sector to achieve universal and equitable access to water while also addressing water scarcity,

preventing water pollution, and protecting ecosystems. Building bridges between the achievement of equitable water access and water resources management offers a path toward achieving SDG 6 while also laying important groundwork for preparing for climate change impacts. Thus, the SDGs are an opportune platform for engaging in discussions about the interface between social, physical, and environmental (including climatic) dimensions of water service delivery.

A major implication of these contributions is that the WASH sector can make more informed decisions about how climate change should be addressed. This thesis has taken a substantial step toward alleviating confusion in the WASH sector surrounding the wide range of climate change concepts, meanings, and viewpoints, an obstacle that has likely confronted and overwhelmed many WASH stakeholders eager to do something about climate change. Armed with a stronger orientation, WASH stakeholders can recognise various ways that climate change impacts a community-managed water service in a given situation, and engage in more meaningful deliberation about what should be done. The outcome is greater potential for resultant adaptation actions that are effective, efficient, equitable, and legitimate.

The conceptual contributions of this research are especially relevant for small island developing states, particularly those in Melanesia and the wider Pacific island region. Water resources and ecosystems in small islands are especially fragile and susceptible to climate change risks (Hay, 2013). The framework and analyses put forth in this thesis have given special prominence to the environmental dimensions of water service deliver that are often overlooked in the WASH sector (Carrard and Willetts, 2017). The focus on community-based water management processes is also especially relevant for Pacific island countries. While there is a significant push in the WASH sector for strengthening the role of local government as a water service authority or even provider in rural areas (Lockwood, 2011), this research documented that area councils in Vanuatu are severely limited in the role they can currently play in supporting communities. Therefore community-based management of water is likely to continue to predominate into the future in Vanuatu. Similarly, it has been questioned if rural local government in many Pacific island countries in general can ever be expected to develop into effective, modern authorities (Hassall and Tipu, 2008). Thus, findings in this

research relating to community level decision making processes and differentiation of agency at sub-community levels are likely relevant in other Pacific island contexts.

Although my conceptual contributions are relevant across a general small island developing setting, it may make sense to do some reframing for some islands that have substantially different water governance or geographic contexts. Some small island developing states, such as many of those in the Caribbean and Guam, American Samoa, Nauru and others in the Pacific, have water services entirely provided by centralised public or private utilities. In these settings, there is still a need for consideration of different forms of capacity and social-environment interactions, but more reframing to an organisational management and learning context is needed. On small atolls, such as those in Kiribati and Tuvalu, the existential threat of sea-level rise may require a greater focus on water management transformation than a capacity to respond to climate change as discussed in this thesis.

Although sanitation services were not discussed in this thesis, some of the findings of this research are transferrable. It is likely that sanitation managers similarly need both specific and general capacities to sustain sanitation access against climate disturbances. Concepts of risk-management, inequitable impacts of climate effects, and flexibility under uncertainty as advanced by the three conceptual approaches discussed in this thesis seem useful for sanitation services as well. One area of difference is that sanitation may be perceived to have less of a direct relationship with environmental resources than water supply does. Another area of difference is that sanitation services can have a much longer chain of sub-services – upkeep of latrines and collection, conveyance, treatment, and disposal of excreta – that can each have different management and governing authorities, and different issues in relation to climate change.

The thesis has also contributed to bridging the theories of risk-hazard, vulnerability, and resilience with respect to the wider field of climate change impact assessments. Although I have not added substantially to the individual theories, I have advanced thinking on the interconnections between the theories. The implication of this is that researchers and practitioners from different disciplinary

backgrounds will be better able to identify nexus points where their different lines of conceptual thinking are likely to be complementary. Methodologically, this thesis has demonstrated how case studies and different methods can be used to conduct risk-hazard, vulnerability, and resilience assessments of community-managed water services. Future researchers and practitioners may draw on this demonstration to design their own methodologies.

This research also contributes to climate change research and practice specifically within Vanuatu. The insights that my research provides to government, NGOs, and researchers in Vanuatu are helpful for informing operational and strategic decisions. In particular, the insights for government provide practical guidance for collecting and interpreting data on the capacity of community-managed water services to be sustained against climate change disturbances. This contributes to fulfilling policy objective 7.4.1 of the Vanuatu Climate Change and Disaster Risk Reduction Policy: "climate and disaster risk vulnerability assessments shall be undertaken within communities to inform the design of effective projects and programmes" (Government of Vanuatu, 2015).

The insights for NGOs expand on the experiences of practitioners to include academic contributions for understanding "community resilience". As a result, the NGO framework for envisioning community resilience to climate change in Vanuatu is strengthened by wider knowledge bases, which enhances its scope and capacity to inform adaptation decisions. This also contributes to the aforementioned policy objective 7.4.1.

The discussion on the NGO framework in section 6.3 is also applicable to the wider Melanesia region. Although the VCRF was developed based on practitioner experiences working with communities in Vanuatu, its contributions seem applicable to communities in Papua New Guinea, Solomon Islands, and Fiji. My suggestions for improving the framework – greater consideration of the built and natural environment, and disaggregation of the determinants across different community groups – are also applicable to the other developing Melanesian countries.

The insights for researchers will aid them in preparing in advance for obstacles and building on my methodology when planning and implementing similar research

projects. This helps to enable future research which aligns with policy objective 7.3.6 of the aforementioned policy: “In addition to furthering climatological research, efforts also need to be made in researching social and economic elements of climate and disaster resilience, including community vulnerability and capacity, and adoption of appropriate adaptation approaches.” (Government of Vanuatu, 2015).

Finally, the insights for local government authorities that participated in my workshops, and for the rural communities that received findings reports (and yet-to-be delivered updated reports), provide practical advice on sustaining community-managed water services. Community members learned more about how their own water services function from social, technological, and environmental points of view, how climate change could impact this functioning, and what they could do to ensure services are sustained. Likewise, local government authorities learned more about climate change, climate change effects, how these effects disrupt water services in general, and what they could do to support communities. These lessons have potential to help the research participants take their own actions to secure water access against climate change and give them information that helps them participate in discussions on climate change.

Having described the ways in which my research has contributed to WASH and climate change understanding and practice, I turn to other future research opportunities that could deliver further potential contributions.

7.4 Future research opportunities

There are five areas related to this thesis where further research could build on my findings. These areas cover research on the risk-hazard, vulnerability, and resilience approaches for community-managed water services, improvement and application of my proposed framework, and making the framework relevant to local stakeholders.

In relation to the three approaches that I presented in Chapter 4, more in-depth research on each approach in the context of community-managed water services is needed, especially on vulnerability and resilience. Although I have stressed the

importance of drawing on multiple perspectives for informing policy decisions, there is still value in in-depth research on specific climate change concepts and ideas that can then be situated amongst other concepts using my proposed framework. There exists substantial opportunity to explore vulnerability through studies on how climate or other environmental disturbances interact with socio-political structures that enable or restrict water access. For example, how climate change and gender norms interact to influence water management and use. Literature related to this topic likely already exists, albeit without explicit mention of climate change, that could be usefully synthesised to draw conclusions about climate change vulnerability and water access. Theoretical and empirical resilience research is also needed to further operationalise resilience concepts and principles and explore how they are put into practice in the field to enable water services to adapt to climate disturbances. Longitudinal, multi-scalar studies would be especially useful for capturing the dynamic nature of vulnerability and resilience. All of this potential research could also be extended to other forms of water services (e.g. utility-managed or public-private partnerships) and sanitation services.

As an extension of the above recommendations, evaluative research is needed to directly demonstrate whether the various determinants of risk management (e.g. early warning systems), adaptive capacity (e.g. inclusive decision-making), and resilience (e.g. polycentric governance), as proposed in the risk-hazard, vulnerability, and resilience literature respectively, actually help sustain water services against climate change disturbances. This type of research is challenging for many reasons, including the long timeframes associated with climate change, the context-specific nature of how climate change is experienced, and difficulty with measuring avoided climate change impacts (Bours et al., 2014a). Numerous climate change adaptation monitoring and evaluation guidebooks have been developed in recent years (Bours et al., 2014b) and relating them to this thesis could be a useful strategy for forming strong evaluative research projects on community-managed water services and climate change.

With respect to my proposed conceptual framework, more theoretical research is needed on the interactions between specific and general capacities, and between capacities held at a system level scale and a sub-system level scale, in the context of community-managed water services. It is apparent that both forms of capacity

at different scales do not exist in isolation of one another, but the ways in which they are synergistic or antagonistic are poorly understood. Future research may seek to focus on how interventions that have built specific or general capacity to respond to climate change in community-managed water services have influenced the other form. Research could also focus on understanding how individual household efforts to build their own capacities, or interventions that build the capacities of social groups such as women, influence the capacities collectively held at a community level. Findings from these studies could be used to develop grounded theory about the interactions between capacities which would strengthen and continue to evolve my proposed framework.

Another opportunity is to use my proposed framework as the theoretical frame for a research study or practical intervention. Although I have applied my framework retrospectively to my own findings, greater insights would likely be gained through its intentional use from the beginning of a study or intervention. The framework could be drawn on in studies and interventions in many ways which could then be used to critique and refine elements of the framework. Reflections from practitioners and the communities themselves on the usefulness and applicability of the framework would be especially useful because I developed the framework predominantly from an academic perspective. It would be further helpful to investigate if the findings from an assessment using this framework do, in fact, usefully inform the planning of climate change adaptation activities for community-managed water services (and if those adaptation activities actually sustain water access against climate change disturbances per the evaluative research approach that I described above).

Finally, further research on relating my proposed framework to existing structures and processes in the Government of Vanuatu and to the everyday lived experiences of communities would be helpful for maximising its impact. I began this process with a focus on the role of government, but encountered difficulties in accessing active local government authorities. The progress that I did make could be built on by working closely with the DoW to ensure that their provincial level staff are available to participate in a study, and by identifying area councils that are confirmed to be active. Also, because communities in Vanuatu may tend to conceptualise climate change in terms of their own lived experiences and

maintenance of their lifestyles (Granderson, 2017), further efforts are needed to understand how my proposed framework can be made relevant to lives of community members. As an extension of my thesis and in fulfilment of my obligation to the communities that participated in my research, I plan to investigate this myself in the near future.

Thus far in this chapter I have shown that my research has answered my research questions and met my research aim, described my contributions to relevant fields of research and practice, and discussed how my research lays a foundation for further valuable research. These achievements help demonstrate the quality of the thesis. In the following section, I further judge the quality of this thesis as a transdisciplinary research piece using established criteria.

7.5 Five quality criteria for assessing this thesis

Five quality criteria for assessing transdisciplinary research can be used to evaluate and reflect on my research. Reflexivity is an important part of being a transdisciplinary research and this section documents my thoughts on the strengths and potential areas for improvement of this research. In section 1.3.2, I presented my reasoning for adopting a transdisciplinary approach to addressing my research problem. Now, looking back, I assess how well I employed this approach with respect to the tenets of transdisciplinarity. I do this by evaluating my research against five criteria for quality transdisciplinary doctoral research, as developed by Willetts and Mitchell (2017). I discuss how my research meets each criterion and provide personal reflections throughout the section.

Criterion 1: Substantial, significant research that makes an original contribution to knowledge and other broader societal outcomes

With respect to this criterion, Willetts and Mitchell (2017) state that doctoral candidates should be able to relate the contributions of their research to three "outcome spaces": knowledge, a situation, and learning (Mitchell et al., 2015). The knowledge space refers to "the generation of relevant stocks and flows of knowledge, including scholarly knowledge and other societal knowledge forms, and making those insights accessible and meaningful to researchers, participants and beneficiaries". The learning space refers to "mutual and transformational learning by researchers and research participants to increase the likelihood of

persistent change". The situation space refers to "an improvement within the 'situation' or field of inquiry" (Mitchell et al., 2015).

The contributions of my research to the knowledge space have reached the domains of academics, practitioners, and local stakeholders in Vanuatu. These contributions are summarised in Table 11 below and listed in detail in Appendix H.

Table 11. Contributions of my research to knowledge stocks and flows

Academic	**Practitioner**	**Local stakeholder**
Four scholarly journal articles (two published; two under review)	Three international conference presentations	Two preliminary reports to rural communities
SES resilience workshop at Institute for Sustainable Futures	An article in *The Conversation*	A preliminary report to government
Thesis	Two book chapters (one published; one under review)	Two final reports to rural communities (under development)
		A final report to government (under development)

The knowledge stocks that my research contributed include journal articles, a workshop on the concepts and principles of SES resilience, which I delivered to staff at the Institute for Sustainable Futures, my PhD thesis, presentations at conferences that were well-attended by practitioners, an article in *The Conversation*, two book chapters targeting practitioner audiences, preliminary reports to the communities and government departments that participated in my research, and a final report for the Government of Vanuatu.

In addition to knowledge stocks, my thesis has contributed to knowledge flows. Knowledge flows relate to "how knowledge moves: between disciplines; between theory and practice; between academic and professional practice; from within to outside the project…" (Mitchell et al., 2015). My research contributions have joined knowledge across multiple disciplines including engineering, social science, and environmental science. However, there were limitations on the depth that I could

achieve in each of these disciplines, particularly with the social and environmental sciences. These limitations come with the trade-off of having a wide breadth of data, my lack of formal training in the social and environmental sciences, and challenges researching cross-culturally in Vanuatu. Deeper engagement with each of the disciplinary perspectives would have likely yielded richer data if were able to gain it. My thesis engages deeply in theory, but throughout also presents many practical examples of concepts. However, the framework that I present is conceptual and does not provide operational guidelines on assessing capacity to respond to climate change disturbances. Time and resource limitations within the PhD prevented further research and engagement with practitioner stakeholders to achieve more practical outputs. Finally, as evidenced by Table 11, my research has contributed to the flow of knowledge between academic, professional practice, and beyond. My contributions, as discussed in section 7.3, are substantial and original.

With respect to the learning outcome space, my research design explicitly contained components to encourage learning amongst research participants and implicitly facilitated a learning experience for myself. As described above, I presented reports and facilitated workshops to educate research participants on different ways of thinking about water service and climate change. The extent to which this learning was transformational for my participants is difficult to judge at this stage. A future potential visit to Vanuatu post-thesis would give me an opportunity to better judge and extend the learning impact. For myself, I learned a great deal about lifestyles, beliefs, and values in Vanuatu, such as what equitable development means to people in rural Vanuatu and the value of community harmony, that will influence how I think about development issues in the country in my future career as a researcher.

With respect to the situation space, this thesis has potential to make a tangible improvement to how climate change impacts on community-managed water services are understood and what can be done to sustain them in Vanuatu. In Chapter 6, I outlined numerous practical recommendations that could be taken up by government. In Chapter 5, I proposed a framework that could be taken up by researchers or NGOs as a tool to guide studies or interventions. In particular, the framework acts as a heuristic that researchers and practitioners can use to consider different climate change impacts on which to focus and ensure that certain

dimensions of water service are not neglected in existing or planned studies or interventions. Preliminary findings that I delivered to community participants could improve how the communities manage and develop their water services. Importantly, these improvements must also be seen as improvements in the eyes of my research participants. At this stage, it is too early to see if this research has or will eventuate legitimate improvements. A post-thesis visit to Vanuatu to engage with stakeholders and understand the extent of improvements in the research context would help me evaluate this further.

Criterion 2: Demonstrated reflexivity and responsiveness

I have demonstrated reflexivity at numerous points throughout this thesis. In section 1.3, I discussed my positionality and my personal approach to this research. In section 3.6, I described the ethical risks of my research and steps I took to question my own assumptions and line of thinking. Finally, I include multiple reflections on my research outputs throughout Chapter 7.

Practising reflexivity was a helpful and necessary part of completing my research, especially because I was doing transdisciplinary research in an international development context. Although I spent extended time in the Vanuatu context and have substantial experience working in Pacific island environments, I cannot claim to see or understand the world in the ways that the research participants did. When I listened to the participants and analysed my data, the best that I could do was try to separate myself from my experiences of being a male in the Western world and see and feel what my participants were experiencing. Similarly, I tried to suspend my own habitual interpretations of my data and see them through the eyes of adherents of different disciplines. Of course, it is only possible to accomplish this partially and I recognise that my findings are layered with my own biases. However, recognising that I could not automatically perceive the data from all viewpoints and instead needed to actively try to perceive it differently led to some of the most interesting and meaningful advances in my research.

I also demonstrated responsiveness throughout my research as I gained more information about the topic that I was studying. Responsiveness refers to "adjustments or adaptations in a research process as the result of close engagement with the research context…and evolving understanding…of the most appropriate,

credible and relevant research questions and approach" (Willetts and Mitchell, 2017). My research questions and approach evolved significantly over the course of my doctoral research. Initially, I had a much stronger focus on the monitoring and evaluation of climate change adaptation projects within the WASH sector. However, after engaging deeply with the WASH and climate change literature, I discovered that the WASH scholarly and grey literature seldom attempted to define key concepts or a theory of change that could be monitored and evaluated. Thus, I changed my line of inquiry to focus more on how WASH services were affected by climate change, although I maintained a research question on how local government could monitor climate change impacts on WASH services. After I took a scoping visit to Vanuatu, I narrowed my line of inquiry to just community-managed water services. Once I began my data collection activities in Vanuatu, I was confronted by the aforementioned challenges with the availability of active local government authorities. These challenges made it difficult to collect the amount of data I needed, so I expanded my focus to include more stakeholders. At this stage my line of inquiry arrived at the one that I present in my thesis.

Criterion 3: Research integrity as demonstrated by credibility, legitimacy, alignment

Credibility refers to research rigour and, in transdisciplinary research, includes a range of principles. In Table 12, I list 11 principles that Belcher *et al.* (2016) state should be used to assess credibility in transdisciplinary research and how I upheld them in my thesis.

Table 12. Assessing credibility in my thesis

Credibility principle	How I upheld it in my thesis	Where in the thesis?
Broad preparation	I undertook a broad review of global environmental change, WASH, and Vanuatu-based literature and took a scoping visit to Vanuatu to prepare the research design	Chapters 2 & 3
Clear research problem definition	I clearly defined the problem of climate change for water services and the need for more rigorous approaches to assessing the problem	Chapter 1
Objectives stated and met	I stated my research objectives in relation to my research questions and evaluated them	Chapters 1 & 7
Feasible research project	The methodology for my research was feasible as evidenced by its success in answering my research questions. I demonstrated the necessary level of responsiveness to adapt the project as needed	Chapter 3
Adequate competencies	I described my own competencies, limitations, and biases, and why I was in a position to make the research project succeed	Chapter 1
Research approach fits purpose	I described my rationale for drawing on different theories to address my research problem and why integration of approaches is needed	Chapters 1, 2, & 5
Appropriate methods	I described each of the methods and how I used them to answer my research questions, as well as why they were suitable for the approaches with which I was working	Chapter 3
Transferability of research findings	I discussed how I supported transferability of my findings through description of the research context, linking my findings to existing literature and theory, and consulting national level authorities and policy documents	Chapter 3
Limitations stated	I presented limitations of my own personal competencies, my research methodology, and my proposed conceptual framework	Chapters 1, 3, & 5
Ongoing monitoring and reflexivity	I described challenges that I faced throughout the research process and how I adjusted my research accordingly, and my personal relationship to the research	Chapters 1, 3, & 7

Source of credibility principles: Belcher *et al.*, 2016

Legitimacy relates to demonstrating that the research was ethical and accounted for stakeholder perspectives (Willetts and Mitchell, 2017). I documented my

consideration of ethics extensively in section 3.6. I have also demonstrated my engagement with different stakeholder perspectives through an extensive academic literature review, extended immersion in a rural community setting, consultations with government authorities and policy, and attention given to an NGO developed framework. Finally, in section 1.3.2, I described my strategy of empathic neutrality for taking on the perspectives of the research participants.

Alignment refers to alignment between epistemology, theory, methodology, methods, data, analysis, interpretation, and claims (Willetts and Mitchell, 2017). In this thesis, I took a pragmatic approach that intentionally used different theories on climate change impacts to address a real-world problem. In section 3.3, I described why a case study methodology was appropriate for each of the theoretical approaches with which I worked. Case studies are also advantageous because they are suitable for a variety of methods including interviews, surveys, observations, and document analyses, which I used in my research. The data that I collected from these methods were primarily qualitative. I analysed them using qualitative techniques (e.g. coding) and interpreted them in light of the risk-hazard, vulnerability, and resilience theories upon which I was building. Finally, the claims that I have made align with these theories and my initial intention to draw on them pragmatically to address the identified research problem.

Criterion 4: Appropriate breadth and depth of engagement with both research context and literature

The breadth of literature that I have engaged with throughout this research encompassed multiple disciplines and fields of study. In covering the risk-hazard approach, I engaged with literature with a focus on engineering, physical geography, and climatology. In covering the vulnerability approach, I engaged with a variety of social and critical studies. In covering the resilience approach, I engaged with literature in ecology, hydrology, and natural resource management. I also engaged with the WASH literature and Vanuatu-based development literature, each of which spans multiple disciplines themselves. This breadth was valuable for collecting useful inputs from a variety of perspectives.

I needed to balance the coverage of the breadth of literature with sufficient depth. I accomplished this by aiming to achieve sufficient depth to answer my research

questions. For example, research question #1 related to the demonstration of the different contributions of the risk-hazard, vulnerability, and resilience approaches. Thus, I aimed to provide enough depth such that it was apparent what the potential contributions were and how they differed from one another in the case study sites. Once that was apparent, it was not necessary (or feasible given the time and resource constraints of my research), to investigate each approach more deeply. Similarly, with respect to answering research question #2, I needed to interrogate different theories and relate them to one another. I focused on the theories' fundamental key concepts and how they related to one another. I identified key concepts by tracing back to seminal works or drawing on review papers that identified commonly used concepts. Again, it was not necessary (or feasible with time constraints) to delve into more concepts with greater nuance. This was an effective and successful strategy for answering my research questions, but a trade-off was that some of my findings remained at a high level of abstraction. I provided practical and empirical examples throughout my thesis to help make these findings more tangible.

I also engaged broadly with stakeholders in the research context. Ni-Vanuatu community members, local government authorities, and central government authorities participated in my research. Engaging with these stakeholders was challenging at times because they were often busy, geographically spread out, and communication media were often unreliable. However, I was able to engage with stakeholders enough that I could understand what value my research contributions could make to them in relation to research question #3.

While I was designing my research prior to data collection, I also attempted to engage with NGOs that worked in the fields of WASH and climate change adaptation to include their perspectives. I reached out to multiple NGOs on multiple occasions through my network of contacts, but I received few responses and consequently little access to their staff and operations. Thus, inclusion of the perspectives of NGOs in relation to research question #3 is relatively limited. A potential impact of this is that NGO stakeholders will not find my research outputs as useful as they would have if I had been able to consult them more. I can address this in the future by presenting my findings to NGOs post-thesis and making refinements based on their feedback.

Criterion 5: Coherent argument across diverse conceptual and methodological approaches

Despite the challenges of working across a diverse range of concepts and theories, I have presented a coherent argument throughout this thesis. My overall argument can be concisely tracked from the statement of the research problem and research questions in Chapter 1, across the summaries of Chapters 4, 5, and 6, and to the wrap-up described in section 7.2. My proposed conceptual framework further demonstrates my ability to synthesise knowledge across disciplines in a coherent way.

Working across diverse conceptual approaches was challenging, but illuminating. With a background in engineering and development, I felt comfortable with concepts from fields of natural hazards and social sciences. However, I did not have a strong background in environmental sciences and it took a long time for me to grasp concepts from the social-ecological resilience literature. I was able to overcome my discomfort with the resilience concepts through repeatedly reviewing the literature, thinking and writing about their application to water services, and discussing them with my colleagues and supervisors. Once I was more comfortable with the different conceptual approaches that I was working with, I found that the process of critiquing and relating them to one another expanded my appreciation of the different viewpoints and changed how I perceive the sustainability of community-managed water services.

7.6 Concluding remarks

Action is needed to address the potentially devastating effects to drinking water services as climate change continues to unfold over the course of the 21st century and beyond. Community-managed water services, which continue to provide water access for millions of people in developing countries, require special attention. To this end, the WASH sector is rapidly displaying an eagerness to implement climate change adaptation solutions that seek to build the "resilience" of water services in developing countries. However, in its newfound urgency, the WASH sector has perhaps moved forward so quickly that due diligence has not adequately been given to thinking about what the adaptation solutions are meant to do. Research studies, policy briefings, and technical notes in the WASH sector often recommend

resilience-building activities without first even attempting to conceptualise resilience, how it improves or sustains water services, or how exactly their recommended activities build their conceptualisation of resilience. Without clear conceptualisations, climate change resilience-building (or adaptation, vulnerability-reducing, etc.) activities potentially overlook critical dimensions of water service, create unnecessary redundancies, come into tension with one another, do not have a clear theory of change that can evaluated, or engender confusion that wastes resources. These potential issues diminish the efficiency, effectiveness, legitimacy, and equality of activities ostensibly meant to adapt water services to climate change in order to improve or sustain water access.

My research has tackled this problem by providing the scholarly and practical knowledge needed to conceptualise how community-managed water services are affected by and sustained against climate change disturbances. This knowledge draws from multiple disciplines and I have framed it in a way that facilitates collaboration across different perspectives. I further sought to put the knowledge into practice in Vanuatu to create real-world change. Increasingly building upon this knowledge, with inputs from both scientific and non-scientific communities, and putting it to practical use will work to support the sustainability of community-managed water services against climate change.

Appendix A: Consent forms and information sheets

Consent form (Given to community members)

I _____ *(participant's name)* agree to participate in the research project 'Local government monitoring of water service adaptation to climate change' (Reference number: 2015000306) being made by Jeremy Kohlitz (Phone: 563 4126; Email: Jeremy.Kohlitz@uts.edu.au) of the University of Technology, Sydney for his PhD degree.

I understand that the purpose of this study is to improve local government assistance to villages for helping them with their water systems.

I understand that I have been asked to participate in this research because my village takes care of its own water system and that my participation in this research will involve 30 minutes to 1 hour of my time. I will be asked questions about my village's water system and how my family uses it. I will also be asked questions about how bad weather, like cyclones and drought, affects my village and family. I understand our conversation will be recorded and written down. I understand the questions could make me remember painful memories and I can stop answering them if this makes me feel upset.

I know that I can contact Jeremy or his supervisors Juliet or Joanne if I have any concerns about the research. I also understand that I am free to withdraw my participation from this research project at any time I wish, without consequences, and without giving a reason.

I agree that Jeremy has answered all my questions fully and clearly.

I agree that the answers I give can be written in books or papers if my name is not used.

_____ _____/_____/_____

Signature (participant)

_____ _____/_____/_____

Signature (researcher or delegate)

NOTE:

This study has been approved by the University of Technology, Sydney Human Research Ethics Committee. If you have any complaints or reservations about any aspect of your participation in this research which you cannot resolve with the researcher, you may contact the Ethics Committee through the Research Ethics Officer (ph: +61 2 9514 2478 Research.Ethics@uts.edu.au) and quote the UTS HREC reference number. Any complaint you make will be treated in confidence and investigated fully and you will be informed of the outcome.

INFORMATION SHEET (Given to community members)

Local government monitoring of water service adaptation to climate change

(Reference number: 2015000306)

WHO IS DOING THE RESEARCH?

My name is Jeremy Kohlitz and I am a student at the University of Technology Sydney. My supervisors are Juliet Willetts and Joanne Chong.

WHAT IS THIS RESEARCH ABOUT?

This research is about how villages in Vanuatu take care of their water systems, and how local government can learn more about this. This research will be used to improve local government assistance to villages for helping them with their water systems.

IF I SAY YES, WHAT WILL IT INVOLVE?

I will ask you to talk to me for between 30 minutes and 1 hour. I will ask you questions about your village's water system and how your family uses it. I will also ask questions about how bad weather, like cyclones and drought, affects your village and family. I will ask you questions in your home or another place if you prefer. I will record our conversation and write down what we said.

ARE THERE ANY RISKS/INCONVENIENCE?

Yes, there are some risks/inconvenience. Some of the questions I ask about bad weather might cause you to remember painful memories. If this upsets you, we can talk about something else or stop talking.

WHY HAVE I BEEN ASKED?

You are living in a village that takes care of its own water system and you can tell me if its works well or not.

DO I HAVE TO SAY YES?

You don't have to say yes.

WHAT WILL HAPPEN IF I SAY NO?

Nothing. I will thank you for your time so far and won't contact you about this research again.

IF I SAY YES, CAN I CHANGE MY MIND LATER?

You can change your mind at any time and you don't have to say why. I will thank you for your time so far and won't contact you about this research again.

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 by phone at or by email at Jeremy.Kohlitz@uts.edu.au.

If you would like to talk to a ni-Vanuatu that is not a part of this research, you can call John Tasserei at

If you want to call my university, you can call them at +61 2 9514 2478 or email them at Research.Ethics@uts.edu.au, and give them this number: 2015000306

Consent form (Given to government officials)

I _____ *(participant's name)* agree to participate in the research project 'Local government monitoring of water service adaptation to climate change' (Reference number: 2015000306) being made by Jeremy Kohlitz (Phone: 563 4126; Email: Jeremy.Kohlitz@uts.edu.au) of the University of Technology, Sydney for his PhD degree.

I understand that the purpose of this study is to improve local government assistance to villages for helping them with their water systems.

I understand that I have been asked to participate in this research because I work for the government and can help communities with their water systems. I understand that my participation in this research will involve 30 minutes to 1 hour **OR** 1 full day of my time. I will be asked questions about my job and how I work with villages **OR** I will join a training session to learn how climate change affects our communities and what we can do about it. I understand our conversation will be recorded and written down. I understand that Jeremy will write down the things I do for my job and anyone can read what he wrote, but he will not use my name if I do not want him to.

I know that I can contact Jeremy or his supervisors Juliet or Joanne if I have any concerns about the research. I also understand that I am free to withdraw my participation from this research project at any time I wish, without consequences, and without giving a reason.

I agree that Jeremy has answered all my questions fully and clearly.

I agree that the answers I give can be written in books or papers if my name is not used.

_____ _____/_____/_____

Signature (participant)

_____ _____/_____/_____

Signature (researcher or delegate)

NOTE:

This study has been approved by the University of Technology, Sydney Human Research Ethics Committee. If you have any complaints or reservations about any aspect of your participation in this research which you cannot resolve with the researcher, you may contact the Ethics Committee through the Research Ethics Officer (ph: +61 2 9514 2478 Research.Ethics@uts.edu.au) and quote the UTS HREC reference number. Any complaint you make will be treated in confidence and investigated fully and you will be informed of the outcome.

INFORMATION SHEET (Given to government officials)

Local government monitoring of water service adaptation to climate change

(Reference number: 2015000306)

WHO IS DOING THE RESEARCH?

My name is Jeremy Kohlitz and I am a student at the University of Technology Sydney. My supervisors are Juliet Willetts and Joanne Chong.

WHAT IS THIS RESEARCH ABOUT?

This research is about how villages in Vanuatu take care of their water systems, and how local government can learn more about this. This research will be used to improve local government assistance to villages for helping them with their water systems.

IF I SAY YES, WHAT WILL IT INVOLVE?

I will ask you to talk to me for between 30 minutes and 1 hour **OR** join a full day training session. I will ask you questions about your job and how you work with villages **OR** ask you to think of ways to learn how climate change is affecting your communities. I will record our conversation and write down what we said.

ARE THERE ANY RISKS/INCONVENIENCE?

Yes, there are some risks/inconvenience. I will write down the things you do for your job and anyone will be able to read what I wrote. I will not use your name if you prefer so people will not know it is you.

WHY HAVE I BEEN ASKED?

You are working for the government and can help villages with their water systems. You can tell me what your job is like and how it can be made better.

DO I HAVE TO SAY YES?

You don't have to say yes.

WHAT WILL HAPPEN IF I SAY NO?

Nothing. I will thank you for your time so far and won't contact you about this research again.

IF I SAY YES, CAN I CHANGE MY MIND LATER?

You can change your mind at any time and you don't have to say why. I will thank you for your time so far and won't contact you about this research again.

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 by phone at 5 or by email at Jeremy.Kohlitz@uts.edu.au.

If you would like to talk to a ni-Vanuatu that is not a part of this research, you can call John Tasserei at

If you want to call my university, you can call them at +61 2 9514 2478 or email them at Research.Ethics@uts.edu.au, and give them this number: 2015000306

Appendix B: Initial rural community interview guide

Resilience

Who uses each water supply/source? (e.g. Just the HH, parts of or whole community, neighbouring communities)

Do you use the water outside the house, such as for a small business, gardening, or raising livestock?

(Following on or referring to the user survey) What are the main issues you have with your water supplies? Why is it a problem and what effect does it have on you and your family?

How often does this problem happen? How bad is it when it happens? Does it happen more or less frequently now than before?

Who is responsible for taking care of the water supply? Do they do a good job at it?

Has the government or any organisation ever helped you with your water supply or talked to you about it? What did they do?

(For older participants) What was your community's water supply like when you were young? How has it changed over time? What caused the changes?

Has there been a time when your water supply stopped working or you couldn't use it for some reason? What happened and what did you do? How was the problem fixed?

(For participants using multiple water supplies) What do you use each water supply for? What causes you to change between them? How do you feel using the different water supplies?

Do you think you will change water supplies in the future? Why?

Are you or your family having any problems with water right now?

Do you have materials to fix your water supply?

If there is a problem with the water supply, who do you tell? How long does it take for someone to do something about it?

Do the main problems cause all the water supplies to stop working or just some of them?

Vulnerability

Do some families or people in your community struggle with water problems more than others? Why?

How does your community/household make decisions about water supplies? Do you help make these decisions? If no, why not?

Where do you get money to pay for the things you need? If you don't have enough, does anyone help you?

Are you happy with your water supply? Why or why not? Do you think your community's water supply is fair to you and others?

Who is responsible for collecting water in your family?

Does your community have rules about collecting water? What are they?

If there is a problem with your water supply, who do you tell? Why that person? What can they do about it?

Risk-hazard

What problems does _____ cause for your household/community? How does it affect your water supply? (Fill in with heavy rainfall, storm surges, very hot days, floods, cyclones, wildfires, droughts) What did you do when you had these problems? Did anyone help you?

What is your water supply like during the rainy season? What is it like during the dry season?

What do you do to prepare for these events? Have you adopted any new strategies?

Which people in this community have the most problems when there is bad weather?

How do you know if something like a cyclone or a flood is coming? How do you know what the weather will be like this season?

Appendix C: List of risk-hazard, vulnerability, and resilience concepts

- ☐ Slow changing variables
- ☐ Multiple stressors
- ☐ Scales
- ☐ Multiple stable states
- ☐ Human-environment feedbacks
- ☐ Thresholds
- ☐ Diversity
- ☐ Redundancy
- ☐ Connectivity
- ☐ Polycentric governance
- ☐ Coping/Adaptation
- ☐ Adaptive management
- ☐ Perturbations
- ☐ Risk reduction
- ☐ Sensitivity to hazard
- ☐ Exposure to hazard
- ☐ Participation
- ☐ Agency
- ☐ Empowerment
- ☐ Learning
- ☐ Equality
- ☐ Accountability
- ☐ Transparency
- ☐ Social capital
- ☐ Human capital
- ☐ Natural capital
- ☐ Physical capital
- ☐ Financial capital
- ☐ Organisations
- ☐ Institutions (*kastom practices, religion, government regulations)*

Appendix D: Initial government interview guide

Central government interviews

What are the overall roles and responsibilities of local government staff in your department?

What data or information do they collect from rural communities?

Is climate change adaptation or disaster risk reduction included in data/information collection?

What data/information are they expected to collect related to rural water services? How are they meant to collect it?

What resources do they have available to them to collect data/information?

Where is the data/information stored? How is it processed/analysed?

Who uses the information? What is used for and how? Whom is it meant to help?

After analysis/processing, whom is the information shared with? How is it disseminated? In what format?

How are local government staff members incentivised to collect data/information?

Have any organisations provided training or assistance with regards to all this?

Do they or are they supposed to interact with other government departments?

Local government interviews (Follow up with same questions specific to water)

<u>Responsibilities</u>

What are the responsibilities of your position?

If someone had to do your job for a week, what instructions would you give them?

Why is your job important? What happens if you do your job well?

<u>Interacting with communities</u>

How do you communicate with rural communities? Whom within the communities do you usually talk to?

Tell me about one of the communities you oversee. How do you know what you know about them?

Tell me about some of your past work supporting a community. How did you learn about their problems and needs? What did you report to your supervisors/co-workers and what support did they provide to you?

Interfacing with other government actors

How do you communicate with your supervisors?

What interactions do you have with other local government authorities?

Technical experience/expertise

Do you check water supplies or toilets? What do you check for to make sure they are working well?

Have you been trained/told to consider climate change adaptation in your work? In what ways? By whom? What you done in your work in this regard?

Do you have access to information on current/future climate risks?

Do you support communities during disasters? What if you are also affected?

Do you provide support for climate change adaptation or disaster strategies in any way?

Appendix E: Sanitary survey forms

Source of forms: (Howard, 2002)

Gravity-fed Piped Water

1. Does the pipe leak between the source and storage tank? Y/N
2. Is the storage tank cracked, damaged or leak? Y/N
3. Are the vents and covers on the tank damaged or open? Y/N
4. Do any tapstands leak? Y/N
5. Does surface water collect around any tapstand? Y/N
6. Is the area uphill of any tapstand eroded? Y/N
7. Are pipes exposed close to any tapstand? Y/N
8. Is human excreta on the ground within 10m of any tapstand? Y/N
9. Has there been discontinuity n the last 10 days at any tapstand? Y/N
10. Are there signs of leaks in the main supply pipe in the system? Y/N
11. Do the community report any pipe breaks in the last week? Y/N
12. Is the main supply pipe exposed anywhere in the system? Y/N

Spring

1. Is the spring unprotected? Y/N
2. Is the masonry protecting the spring faulty? Y/N
3. Is the backfill area behind the retaining wall eroded? Y/N
4. Does spilt water flood the collection area? Y/N
5. Is the fence absent or faulty? Y/N
6. Can animals have access within 10m of the spring? Y/N
7. Is there a latrine uphill and/or within 30m of the spring? Y/N
8. Does surface water collect uphill of the spring? Y/N
9. Is the diversion ditch above the spring absent or non-functional? Y/N
10. Are there any other sources of pollution uphill of the spring? Y/N

Hand-dug Well

1. Is there a latrine within 10m of the well? Y/N

2. Is the nearest latrine uphill of the well? Y/N

3. Is there any other source of pollution within 10m of well?(e.g. animal breeding, cultivation, roads, industry etc) Y/N

4. Is the drainage faulty allowing ponding within 2m of the well? Y/N

5. Is the drainage channel cracked, broken or need cleaning? Y/N

6. Is the fence missing or faulty? Y/N

7. Is the cement less than 1m in radius around the top of the well? Y/N

8. Does spilt water collect in the apron area? Y/N

9. Are there cracks in the cement floor? Y/N

10. Is the handpump loose at the point of attachment to well head? Y/N

11. Is the well-cover intact? Y/N

Rainwater Collection and Storage

1. Is rainwater collected in an open container? Y/N

2. Are there visible signs of contamination on the roof catchment? (e.g. plants, excreta, dust) Y/N

3. Is guttering that collects water dirty or blocked? Y/N

4. Are the top or walls of the tank cracked or damaged? Y/N

5. Is water collected directly from the tank (no tap on the tank)? Y/N

6. Is there a bucket in use and is this left where it can become contaminated? Y/N

7. Is the tap leaking or damaged? Y/N

8. Is the concrete floor under the tap defective or dirty? Y/N

9. Is there any source of pollution around the tank or water collection area? Y/N

10. Is the tank clean inside? Y/N

Appendix F: Preliminary findings report for Namoru community

Namoru Water Supply and Climate Change Assessment

September 2016

Summary of important points

1. The piped water supply sometimes has problems with dirty water and no water coming. Climate change will make these problems come worse.

2. Building a protected spring can help keep the piped water clean.

3. Toilets should be kept at least 15 meters from water sources and pipe joints.

4. Children aged 5 and under should drink water that has been boiled first only.

5. It is better for the community to have two water supplies. The second one should be closer to the houses that are far from the hill. The water deep underground is clean and still comes during the dry season.

6. The community must pay fees to cover all the costs of the water supply.

7. The water committee must make a budget and a project plan and they must tell the community where their money is going and give updates on the plan every year.

8. There should be a woman on the water committee. The rest of the committee must respect her.

9. The community must protect the land around the spring on top and around the small river. Do not cut the bushes and plant trees around the water sources to help block dirt and keep the water clean.

10. The water supply should be fair to everyone and people that have the most problems with water should be helped first.

What is climate?

Klaemet i averej paten blong weta long wan ples ova long wan longfala taem (eksambol 30 yia o moa). 'Klaemet' hemi difren long 'weta'. Wan toktok we plante man oli save long hem we i eksplenem gud tufala toktok ia hemi se 'klaemet hemi wanem we yu expectem be weta hemi wanem we i hapen o wanem we yu kasem'.

What is climate change?

Ol jenis we oli stap hapen long klaemet blong wol, hemia yumi stap tokbaot ol jenis we oli hapen from ol aktiviti blong man be tu hemi kavremap ol jenis we i stap hapen long nature. Ol jenis ia i save includum tu ol rabis weta event olsem draot, flad, saeklon mo ol jenis long averej renfol. Klaemet jens we i hapen from aktiviti blong ol man hemi bin stap hapen finis mo bai i continu blong hapen kwik taem mo bitim ol nomol jenis long klaemet from bigfala incres tumas long ol greenhouse gas.

How does climate change affect Vanuatu?

Climate change is coming slowly, but it will make big changes to the weather. Every year there will be more very hot and dry days than before. There will also be more days with big rain than before. Every year it will be hard to know if there will be big rain or if it will be dry and hot. There will be fewer cyclones than before, but they will be stronger.

Will climate change affect water supplies?

Yes. Some water sources might become dry and some might become dirty. It will become harder to find good water.

Water sources used by Namoru

Namoru village uses three water sources:

1. Piped water from a spring on the hill (main water supply);

2. A small river coming from a spring (close to the village);

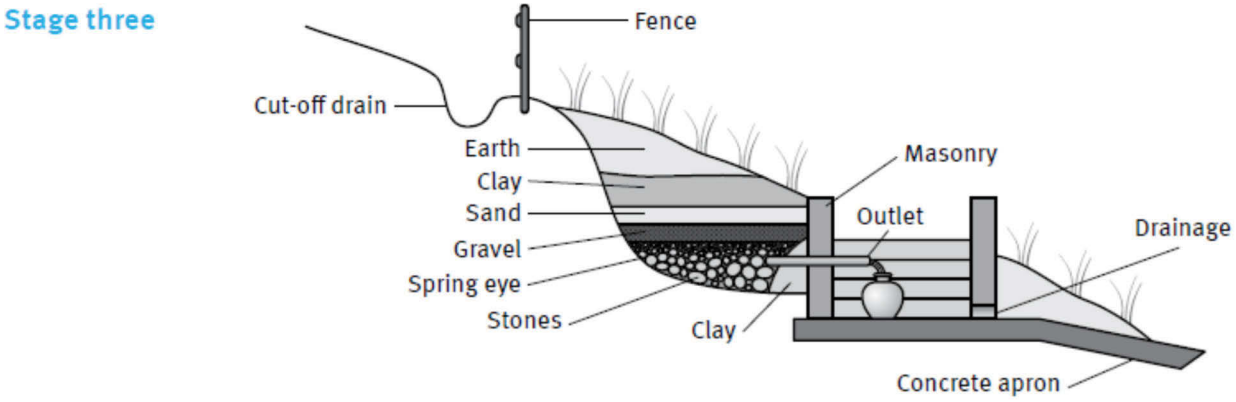
3. A big river (underneath the bridge)

Piped water supply

Water is dirty sometimes

Many families say when big rain comes, the piped water becomes dirty or sometimes it doesn't come. One reason for this is because when the rain comes, it washes dirt into the spring. To block the dirt from getting into the spring, the spring must be protected.

A protected spring will help block the dirt from spoiling the water and blocking the pipes. A protected spring is built by putting big stones on the bottom of the spring, then small stones, then gravel, then sand, then hard ground, and finally



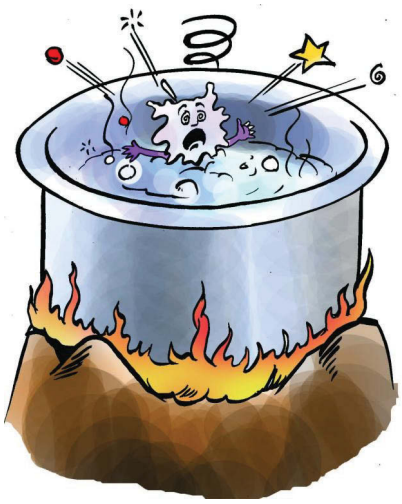
soft ground on top. A ditch should be dug around the spring to carry dirty water on top of the ground away from the spring.

Before building a protected spring, it is good to get help from a water supply expert to tell you how to build it good. If the protection is not built properly, the spring might not work well.

The tank is very old and it can make the water dirty, so it should be replaced. A good tank should have a cover on top so no sunlight can get inside because sunlight can cause algae to grow inside the tank. The tank should also be built on top of a platform so water does not get in through the bottom when big rain comes.

Some dirt can come inside the pipes through the joints that are leaking. If water comes out of the joint, that means dirt can come inside.

Even if the water looks clean, you can still get sick by drinking it. This is because some toti you cannot see, cannot smell, and cannot taste. This kind of toti comes from shit (olsem shit from toilets, shit from cows, shit from horses). Toilets and animals should always be at least 15 meters away from all water sources (spring, river, well).



Drinking dirty water can make you sick (olsem stomach aches or diarrhea). Small children that are 5 years old or under are not strong so dirty water can kill them. Children that are 5 years old or under should only drink water that has been boiled first. You can boil a lot of water, let it cool down, then put it in plastic bottles so they can drink it later.

Climate change will make more big rain come which can make the water dirty so it is important to prepare.

Water does not come sometimes

Many families say water does not run from the taps many times each year. This is because there are many leaks in the taps and pipes and because the population of the village is growing.

Broken taps and leaking joints must be repaired. If one tap is leaking, it takes away from the whole village, not just for the houses that are using it.

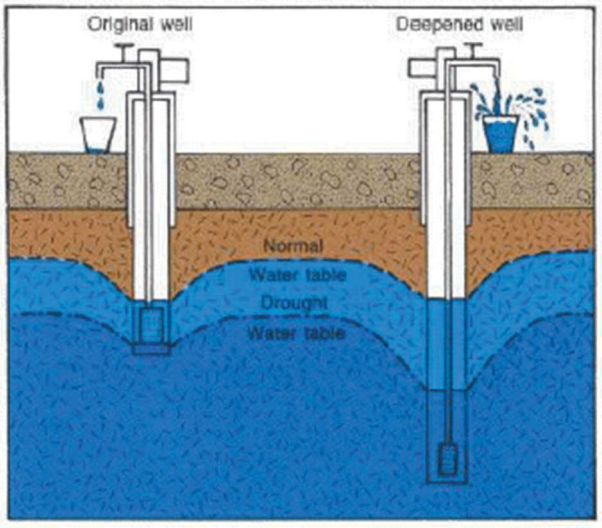
Building a bigger tank will help a little, but the spring on top of the hill is not big enough to support the village if the village keeps growing. A bigger tank will help the houses that live close to the source, but it will only help a little bit for the houses that live far away.

If you plant trees above the spring, this will help block some of the dirt from washing into the spring and it will help make the water underground which helps keep the spring flowing.

Many families say the piped water supply is not fair because the houses living far away from the source do not receive as much water. The community should think about making a second water supply to help the families that do not receive much water.

The new water supply can be a well, a borehole, or rainwater tank.

A well is cheap to build and a bucket or pump can be used to get water from it. But during the dry season, no water might come and the well water can become dirty if it is not protected good.



A borehole goes deep into the ground and gets clean water even in the dry season, but the borehole is expensive to build and needs a pump.

The church has a big roof and can catch a lot of rainwater to put in a tank, but if no rain comes for a long time then the tank will become empty.

The second water supply should give the biggest help to families that are not receiving much water. It is good to have two different water supplies because if a disaster breaks one water supply, the village can still use the other one.

Before you decide to build a new water supply, it is good to get help from a water supply expert to give you information on how to build the water supply correctly.

Climate change will make more very hot and dry days come, and the population of Namoru is increasing so more water sources must be developed.

Small river next to the village

When the piped water is dirty or does not run, many families must use the small river next to the village. This water is not as good as the piped water, but it is important to take care of it.

The water is good for bathing and for cleaning, but it is not good for drinking. When the water comes out of the ground, it is clean but when it is on top of the ground it gets spoiled easily. If people must

drink from the river, it is important to boil the water before letting children aged 5 or under drink it.

The river is good now because the water is clear, there is no smell, and there fish living in it. But if the river is not protected, the water will become spoiled. When the water is spoiled, algae grows very quickly and very strongly and makes the water turn brown or green, kills the fish, and makes the water smells bad. Once the river is spoiled, it is very hard to make it come clean again.

One thing that can spoil the river is too much shit getting inside (shit from toilets or shit from animals). When big rain comes, it can wash shit into the river from on top of the ground or even underneath the ground. Toilets and animals should always be at least 15 meters away from the river.

If fertilizer is used on the gardens close to the river, this can make the algae grow very quickly too.

It is also good to plant trees and don't cut the bushes around the spring because the trees and bushes help block the dirt and shit from washing into the river.

The small river is not as good as the piped water because if people have to go there to get water they feel tired, their bodies feel sore, or they can slip and fall down and get hurt. Many families say this is a big problem for them. But sometimes they don't have a choice so this small river must be protected.

Big river by the bridge

The big river by the bridge should only be used for bathing and washing. The people living upstream might be making the river dirty and there is nothing Namoru can do to control them.

Water supply expert

The Vanuatu Government Department of Water has one water supply expert for communities in Sanma province. His name is Peter Lulu. His phone number is 56 86 801.

His responsibility is to give support to communities, but the Department of Water does not have much money. If you pay for his transport, he can come to Namoru to give some training and advice on making a good water supply.

Money for paying for water supply

Sometimes government or organisations can help pay for water supplies, but they are very slow. It is better if the community pays for their own water supply

There are 4 kinds of costs that the community must pay for:

Capital: The cost of paying for a new water supply. For example, buying a new tank or new pipes for the first time. Capital is a big cost, but you must only pay for it one time.

Maintenance: The cost of making small repairs. For example, fixing leaking taps and joints. Maintenance costs are small, but you must pay for them every week or every month.

CapManEx: The cost of making big repairs. For example, replacing the tank or a big pipe after it gets old. CapManEx costs are big and you must pay for them every 5, 15 or 30 years.

Support: The cost of paying transport and food to have a water supply expert come to give you advice or training. This is usually a small cost.

The water supply in many communities breaks down because the community does not save money to pay for CapManEx. It is very important that you save

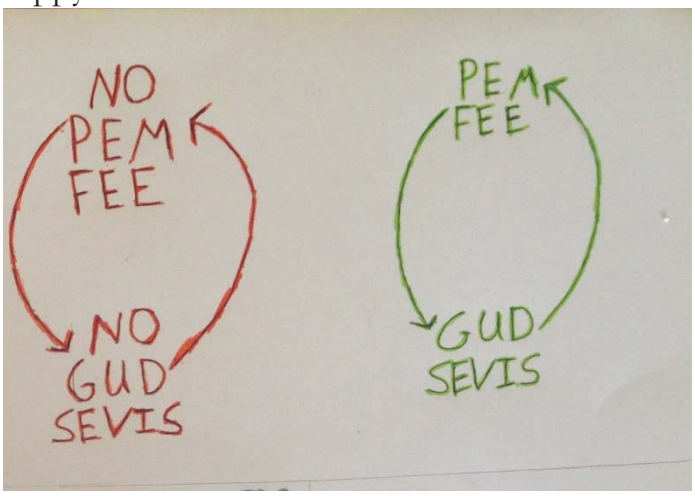
some money to pay for big repairs. Climate change will make cyclones and floods even stronger so you must save to pay for repairs if they damage the water supply.

The community should pay for maintenance costs first. Second, save some money for CapManEx. After you pay for those two, you can collect money to build a new water supply.

Right now each married couple pays 500 vatu each year for the water supply. This is not enough to cover all the costs so the fee must come higher. Some families are too poor to pay for the fee one-time, so they should be allowed to pay each month instead. For example, $\frac{1000\ Vatu\ wanwan\ yia}{12\ manis}$ = 85 vatu each month.

Water committee

It is a good idea to have a water committee. But right now, many families are not happy.



Some families do not want to pay fees because they think they are paying for nothing and the water supply does not get better. If families don't pay the fees, the committee cannot fix the pipes so the water supply comes worse. After, even more families do not want to pay their fees. This is a vicious cycle.

The community must do something to move to a good cycle. In a good cycle, the families pay their fees and committee uses the money to make the water supply better. After, the families are even happier and will continue to pay their fees.

The committee should make a budget and a project plan. The budget should show how much money is being used to pay for each cost (maintenance, capital, CapManEx, support). The project plan should show what the plan is for improving the water supply. There should be meeting once or twice every year

to give the community an update on the budget and project plan. Right now, many families don't know where the money they are giving is going and some are worried that it is being stolen.

There should be a woman on the water committee. Women have more problems with water because they need more water for things like cooking, washing, and cleaning. Women also have different water problems than men. For example, some women are afraid they will be attacked if they go alone to the river at night. Some women will be more comfortable talking to a woman committee member than a man committee member.

If a woman is on the committee, she must be respected. If a water supply expert comes to the village to give training on building a good water supply, the woman must receive this training too.

Climate change

Climate change will make more problems for the water supply. More big rain will come and more hot and dry days will come. The community must start acting so that when the children grow up, they will still be able to get good water. The community must also act because the population of the village is growing.

There are two important things to remember when preparing the water supply for climate change:

1. The water supply should be fair to everyone. Sometimes poor families or women need extra help. The families that have the most water problems should be helped first.

2. It is important to take care of the land around the water sources. Keep this land clean, don't cut the bushes and plant trees to help keep the water source clean. Trees also help make the water go under the ground which helps to keep the spring flowing.

Appendix G: Contents of the Vanuatu Community Resilience Framework

Source: (Ensor, 2015, p. 6)

"A resilient community in Vanuatu:

1. Has their basic needs met, so they are healthy and safe;

2. Can build their livelihoods on a diverse range of material assets and know how to best utilise and improve their value and sustainability in a way that provides equitable access and control across the community, including shelter, land, water, natural resources, financial assets has strong social structures that support its members in times of need;

3. Has leadership and decision making processes that are fair, inclusive and responsive to the needs of the whole community including women, young people and vulnerable groups that can plan for current and future needs that fosters belonging and connection;

4. Has access to relevant information, both traditional and external, and can use this to their advantage — this means the mechanisms for all community members to access and share information they need are in place;

5. Is supportive and open to innovation and new ideas, and has the leadership that is flexible and forward looking;

6. Has a belief system and culture that can help understand and act on shocks and changes, and foster relationships between the natural environment, social and cultural systems;

7. Has social networks that extend beyond the immediate community, so that it can draw on knowledge, resources and new ideas; and

8. Has governments at different levels that are connected, listen to and are responsive to community needs, is innovative, has strong leadership and is transparent and accountable."

Appendix H: Outputs from my doctoral research

Journal articles

Kohlitz, J., Chong, J. and Willetts, J. 2016 Monitoring the human rights to water and sanitation: An analysis of policy in the Pacific islands. *Water Policy*, 18(6), 1436-1453

Kohlitz, J., Chong, J. and Willetts, J. 2017 Climate change vulnerability and resilience of water, sanitation, and hygiene services: a theoretical perspective. *Journal of Water, Sanitation and Hygiene for Development*, 7(2), 181-195

[Under review] Kohlitz, J., Chong, J. and Willetts, J. 2018 Analysing the capacity to respond to climate change: A framework for community-managed water services. *Climate and Development*

[Submitted] Kohlitz, J., Chong, J. and Willetts, J. 2018 How are climate change vulnerability and resilience analyses related? An investigation of their application to community-managed water services. *Regional Environmental Change*

Conference presentations

Kohlitz, J., Chong, J. and Willetts, J. 2015 'Government-led monitoring of water, sanitation, and hygiene service adaptation to climate change.' Presented at the International Development Evaluation Association Global Assembly 2015, Bangkok

Kohlitz, J., Chong, J. and Willetts, J. 2016 'Monitoring the human rights to water and sanitation in Pacific island countries' Presented at the WASH Futures Conference 2016, Brisbane

[Forthcoming] Kohlitz, J., Chong, J. and Willetts, J. 2018 'Climate change vulnerability and resilience of Pacific island water services' Presented at the WASH Futures Conference 2018, Brisbane

Book chapters

Uitto, J., Kohlitz, J. and Todd, D. 2017 'Evaluating Sustainable Development in the Small Island Developing States: Lessons from the Pacific and the Caribbean'. In: Evaluation for the 2030 Agenda, van den Berg, R., Naidoo, I. and Tamondong, S. (eds.)

[Under review] Kohlitz, J., Carrard, N., and Foster, T. 2018 'Social-ecological Resilience for WASH Services'. In: Systems Thinking for WASH, Neely, K. (ed.)

Grey literature

Kohlitz, J. 2016 *Namoru Water Supply and Climate Change Assessment*. Institute for Sustainable Futures, UTS, Sydney. Produced for Namoru community.

Kohlitz, J. 2016 *Uripiv Water Supply and Climate Change Assessment*. Institute for Sustainable Futures, UTS, Sydney. Produced for Uripiv community

Kohlitz, J. 2017 *Resilience of Rural Water Services to Climate Change: Preliminary Report*. Institute for Sustainable Futures, UTS, Sydney. Produced for Government of Vanuatu.

Media

Kohlitz, J. and Mukheiber, P. 2015 'Pacific islands are not passive victims of climate change, but will need help'. Available at https://theconversation.com/pacific-islands-are-not-passive-victims-of-climate-change-but-will-need-help-47207. The Conversation, Melbourne

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