Managing Complex Catchment Systems – Issues of Scale: A Case Study of Flood Management in the Hawkesbury Nepean Region

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Managing Complex Catchment Systems – Issues of Scale:
A Case Study of Flood Management in the Hawkesbury Nepean Region

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THE UNIVERSITY OF NEW SOUTH WALES
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Abstract

Unplanned urbanisation and natural resource exploitation have transformed the way natural systems function. This is further exacerbated due to climate change, creating uncertainty in the way these systems function. Under this premise, there is a greater need to understand the human-environment nexus to maintain the adaptive capacity of these systems to abrupt changes. This thesis focuses on the management of complex Socio-Ecological Systems (SES), discussing primarily the environmental and social barriers to adaptive capacity. It emphasises that in order to effectively manage these complex SES, there is a need to identify and address these barriers through an adaptive governance framework.

The Hawkesbury-Nepean catchment was chosen as the case study and complexities of the SES are addressed by examining the flood management issues in the catchment. In this catchment unique geographical characteristics create an environmental barrier making it susceptible to flooding which is likely to worsen with climate change enhanced weather variability. The socio-political barriers, on the other hand, emerge from a complex multi-tier system of governance that restricts flood management at jurisdictional scales. It also ignores cumulative impacts of development and is predominantly governed by a top-down technocratic mode of managing floods in the region.

This research emphasises that the complexity of managing a large catchment system such as the Hawkesbury-Nepean is strongly embedded in the way professionals and communities perceive the problem of flood management. This difference in perception has led to coordination and communication issues for effective adaptive management of flooding in this socio-ecological system. The research also identifies potential opportunities that could help to overcome these barriers. In doing so, it examines two regional scale models in Australia, the Catchment Management Model in Victoria and the Biosphere Reserve model in Noosa, Queensland. These models present opportunities for a more integrated regional scale management framework.

This research was applied and exploratory, requiring the use of a multi-methods approach for data collection and analysis. This research concludes that as a result of climatic variability and future uncertainties there is a strong need to manage floods at a regional scale to enhance the adaptive management of this complex Socio-Ecological System. This is possible if the system of governance is adaptive and integrates learning from different interest groups. Consequently an adaptive framework can be established through the formation of a regional entity that enables communities to be involved at local and regional scales of flood risk management; functions as a brokering organisation between different scales of management to enhance coordination; and integrates flood risk information with ensured access and utilisation by different interest groups.

Acknowledgments

This has been a very interesting journey for me. Towards the end of it though I realise that a PhD doesn't really increase one's job opportunities but rather it serves as a much more valuable purpose. It changes one's perspective about things. It transforms one into a more inquisitive individual who tends to look at other aspects of life from a different lens – a more philosophical and yet closely bounded by logic worldview. For such a transformative learning experience it is important to acknowledge the people who have been directly or indirectly part of this process.

First of all I would like to thank my parents for being the corner stone for all my endeavors in life. Their faith in my abilities and unwavering positive attitude has helped me become who I am and I am proud of it. I appreciate their patience for being very supportive towards my ambitions in life.

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Table of Content

List of Tables

List of Figures

List of Acronyms

AEP .... Annual Exceedance Probability

BMCC ....Blue Mountain City Council

BR .... Biosphere Reserve

CMA ....Catchment Management Authority

FMA .... Floodplain Management Association

FRM ....Flood Risk Management

HFRMS&P .... Hawkesbury Floodplain Risk Management Study and Plan

LEP .... Local Environmental Plan

LLS .... Local Land Services

SCA ……. Sydney Catchment Authority

SES .... Social Ecological Systems

TPCs ....Thresholds of Potential Concern

VFD ....Victorian Flood Database

WESROC ……………………….......... Western Sydney Regional Organisation of Councils

WSUD ………………………………………………… ....Water Sensitive Urban Design

Chapter 1: Introduction

'It is not the most intellectual of the species that survives; it is not the strongest that survives; but the species that survives is the one that is able best to adapt and adjust to the changing environment in which it finds itself" (Megginson 1963).

1.1. Chapter overview and research background

This chapter sets up the context, underpinning themes, and issues that are the focus of this research thesis. It defines the research questions and expected outcomes of the research. A conceptual flow chart in section 1.6 summarises the entire research and summarises important conclusions drawn from each analysis chapters.

Human activities have altered the global environment. Substantial evidence exists to suggest that, in response, the Earth's systems (natural processes) have been changing (Steffen et al. 2004). Demographic trends, degrading natural systems, and climate change uncertainties, challenge the sustainable provision of resources, goods and services from complex Social-Ecological-Systems (SES) (Warner et al. 2010; Anderies & Janssen 2013; Morán-Ordóñez et al. 2013). This trajectory is not only undesirable; it places mankind on a path to accelerated self-destruction. The State of the World report indicates that the society's consumptive patterns have exceeded the planet's regenerative capacity (Harding, Hendricks & Faruqi 2009). According to ecological footprint analyses 'Humanity currently needs the regenerative capacity of 1.5 earths to provide the ecological goods and services [consumed in a year]' (WWF 2014). Social drivers, ecological processes and economic interests have largely driven the patterns of growth and development. The uncertainty in the way social systems and institutions behave and the existence of imperfect and fragmented knowledge has created complexity in dealing with such wicked problems.

Under the current premise, there is a need to work towards reviving earth's natural ecosystems and their assimilative capacities to regenerate and adapt to change - the process is both ecological and social.

> Social change is needed if society is going to adequately address the environmental challenges threatening human societies and the global ecosystems on which they rely. We need a new approach to environmental management that supports collective action and

reflection directed towards improving the management of human and environmental interrelations (Keen et al. 2005).

The research in this thesis suggests that there are two dominant factors that create barriers to managing SES: environmental and socio-political (see chapter 2). Under the environmental barriers, climate change is a critical environmental phenomenon - an overarching problem that creates future unpredictability and potential for increase occurrence of severe weather events with considerable impact on SESs (Warner et al. 2010). Severe weather events can create social vulnerabilities in the form of economic loss and in some cases are a direct threat to survival. Climate change has both social and environmental consequences. It challenges the survival and functions of ecological communities in the form of species extinction and changes to the food chain (Doney et al. 2012). The resultant novel systems pose a challenge to the conventional paradigm of governance and policy (Williams & Jackson 2007). Within the context of a rapidly changing climate with extreme consequences, the inherent complexity of SES creates another barrier to sustainable management. In this thesis, throughout its various analysis chapters (particularly Chapter 4 to 7), there is evidence of how lack of understanding of the interconnectivity and inherent complexity in SES has resulted in failed management frameworks (Wood et al. 2012; Carter 2012; Wyborn & Bixler 2013; Ribbons et al. 2013 Wenger, Hussey & Pittock 2013; Braden et al. 2014).

The understanding of SES has evolved in the past several decades. Gunderson & Holling (2002) & (Allen et al. 2014) provide a more regional understanding of SES systems through the concept of Panarchy. This concept perceives SES as a multi-scale systems following a cyclic phenomenon - the adaptive cycle where systems (social, economic and environmental) are evolving and influenced by changes that are rapid, episodic and/or slow processes interacting at different scales from local to global (Gunderson & Holling 2002; Halliday & Glaser 2011; Allen et al. 2014). The Panarchy framework encapsulates two important components of SES: resilience and adaptive cycles (Gotts 2007; Fischer et al. 2015). Resilience has been defined in a number of ways, as:

- the ability of a system to recover and regain a state of equilibrium after disruption (Bodin & Wiman 2004; Liu et al. 2012);
- a measure of a system's ability to absorb change and still maintain its functions (Resilience Alliance 2007);

- the threshold of a system to resist change before it topples over to redefine a new state of equilibrium (Holling 1973; Sasaki et al. 2015);
- a system's capacity to rebound from adversity (Brown and Kulig 1996; Paton & Johnston 2001) or
- a capacity to continuously reconstruct (Waller 2001; Zhou et al. 2010).

In this thesis, resilience is considered as a capacity of systems to be able to buffer shocks and have flexible adaptive social institutions which have the ability to change development discourses when processes and external factors of socio-economic and environmental nature make the existing one unattainable (Schultz 2009). Hence resilience here is not inferred to be a system's capacity to resist change (perverse resilience) and conform to a rigid state of stability, a locked system where collapses due to change is more likely to occur.

SES are inherently complex and are influenced by changes from within and external drivers at scales from local and regional to national and international (Miller 2014). Socio-political barriers through intensive population growth, urbanisation, economic development and large scale development of infrastructure (reservoirs, dams, levees) constrain the function of SES hence locking systems into ridged predictable patterns. These socio-political influences are attributed to the diverse interests of stakeholders that influence policy and challenge the management of these systems (Haarstad 2014). Ecological systems are predominately managed by scientific understanding of these systems, where science is understood as an absolute knowledge to define policies (Brunner & Steelman 2005; Koetz et al. 2009). This scientific management regime fails when faced with unexpected system behaviour (Vojinović 2015). This thesis investigates how these socio-political and environmental barriers shape decisions to manage large catchment systems in Australia against extreme weather conditions.

1.2. Scope of this research - what matters?

Research into regional frameworks for SES (Gunderson and Holling 2002; Berkes et al. 2003; Walker & Meyers 2004, Walker et al. 2004) have transformed the understanding of these systems from linear to complex systems interacting at different scales. However, the practical implications of such frameworks are inadequately understood. This requires managers and policy-makers to clearly define aspects of managing an SES, specifically;

- the appropriate scale at which a system should be managed,
- the understanding that learning is an inclusive process that builds on social networks and social capital,
- use of local as well as scientific knowledge,
- that information and knowledge is a continuous process generated through experimentation, trailing and adaptation, and
- working collectively to determine how sustainable development, reducing risks and vulnerabilities that may otherwise lead to system collapse can be achieved.

In Australia, climate change impacts present uncertainties in the way SES respond. The IPCC report (Pachauri et al. 2014) indicates that Australian SES systems are vulnerable to more extreme weather conditions including intense summer storms of short durations resulting in increased frequency and intensity of damaging flood and storm surges. The Australian national strategy for disaster resilience lays responsibility to State Emergency Services to ameliorate disaster damages with shared jurisdictional responsibility to deal with extreme weather events (Council of Australian Government (COAG) 2011). The emphasis is on reactionary approaches to managing disasters and mitigating impacts whereas planning for risk management is reserved at local council levels with varying degree of linkages and support from different scales of management and governance within each region in Australia (NSW Government 2005; Queensland Flood Commission of Inquiry (QFCI), 2012; Box et al. 2013; NSW Office of Water 2014; Bell & Morrison 2015). Chapter 6 further elaborates the flood governance issues in this regard.

Defining appropriate scales of governance for natural resource management has been an evolving process in Australia. Natural resource management (NRM) governance has mostly involved three spheres of government; national, state and local (Brown & Bellamy 2007). Since the 1980s, regionalism in Australia has led to new governance arrangements for NRM focused on economies of scale, integrated management, and community-based approaches. There are 85 bioregions in Australia, each defined by unique geographical features that provide opportunities to achieve regional collaboration among stakeholders for common conservation goals (Australian Terrestrial Biodiversity Assessment 2002). Landcare groups, Catchment Management Authorities and Biosphere Reserves are examples of conservation frameworks that lay emphasis on managing resources at a scale that conforms to natural boundaries. Establishment of these regional scale frameworks demonstrates a shift towards more devolved governance structures. However, limitations of these frameworks exist in their lack of utility to manage SES that are subject to abrupt changes such as fires and flooding. In principle, regional frameworks provide the ‘right set of tools’ to inculcate an adaptive management process where communities are more informed of their risks, where decisions are made through consolidating a wide-group of stakeholders’ interests, values and concerns, and where an ‘openness to learning’ culture prevails. In practice, however, a deeper understanding of adaptive processes and resource investments are needed to deal with extreme weather conditions. There are bottlenecks to context specific solutions that effectively manage complex SES in a changing environment.

This research investigates the governance issues within the Sydney Bioregion[1] through an analysis of a complex SES — the Hawkesbury-Nepean Catchment situated in the west of Sydney. Changes to the basin hydrology of the bioregion are one of the major impacts posed by future climate change uncertainties (NSW and Department of Environment Climate Change and Water 2010). Provision of water supply to the growing urban centres, increased vulnerability of coastal and inland communities, and irregular environmental flows could create conditions for loss of resilience and a possible system collapse. Through a problem-based analysis of issues around flood risk management in this catchment, the socio-political and environmental barriers that create conditions of maladaptation and management at different scales of governance are explored. The research considers the efficacy of regional models, such as water scale catchment management and biosphere reserve frameworks, in addressing issues of flood management.

Looking at development and environmental impacts at a regional scale requires a system thinking approach – a holistic approach to management that bypasses jurisdictional boundaries (Ribbons et al. 2013). Currently, water resource management, within the region is sectorally managed by various governing bodies (NSW Office of Water 2014). Future uncertainties require trailing and testing of innovative approaches to identify effective management options, increase synergies between state and local partners, a greater level of integration between knowledge and research, and ways to bridge social and political gaps for informed decisions and collective management.

[1] Bioregions are usually understood as entities delineated by ecological and biophysical criteria and that reflect human identities with local and regional landscapes (Brunckhorst 2000 cited in Barquet 2015).

Catchment or regional scale frameworks that have a more holistic perspective can provide opportunities for better flood risk management (Ishwaran, Persic & Tri 2008; Williams 2010; Williams 2012). These frameworks (Figure 1.1) can provide opportunities for an adaptive system of governance, a dynamic learning culture, and greater level of integration of SES at a regional scale.

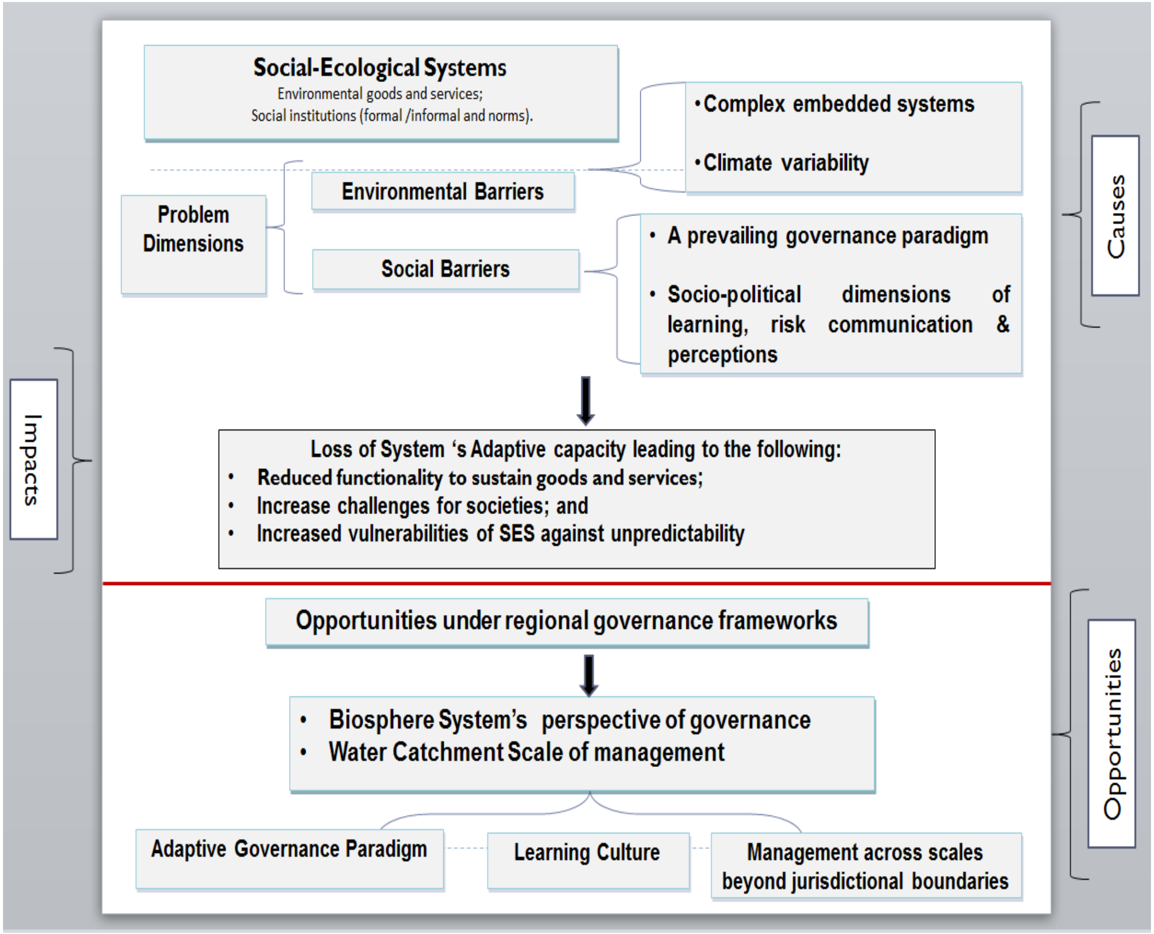


Figure 1.1: Conceptual framework of problems, impacts and opportunities for SES management

The current study demonstrates how catchment-scale authorities fail to create a better understanding of risks. Organisation becomes disjointed due to vested interests and perceptions playing a crucial role in engagement, trust building, collaboration and co-management. More particularly, the inherent complexity of SES is often reduced to narrow reductionist approaches of management that requires scientific modelling based on pre-defined parameters. Critical thinking is dominated not by accepting uncertainty, but rather toward interventions that ensure a desirable and definite outcome (Allan et al. 2008). There is little if any provision to undertake experimental interventions best suited to change. Knowledge of understanding systems at scales beyond jurisdictional boundaries is lacking (Ribbons et al. 2013). System resilience and its adaptive capacity can only be explored if a system is observed and managed more holistically than in parts, which is the prevalent management paradigm (Lebel et al. 2006; Vojinović, 2015).

This thesis will explore the idea that a biosphere perspective of management presents a more suitable framework for cross-sectoral management of resources at various scales of governance within the Sydney Basin Bioregion.

> Biosphere reserves offer such models [of continual learning and improvement where] rather than forming islands in a world increasingly affected by severe human impacts, they can become theatres for reconciling people and nature; they can bring knowledge of the past to the needs of the future; and they can demonstrate how to overcome the problems of the sectoral nature of our institutions (UNESCO 1996, p. 9).

Studying the implications of a biosphere perspective in this research is not intended to examine how and where in the Hawkesbury-Nepean Catchment it should be established. It is rather taken as a framework to be reviewed and to identify principles that are relevant for managing flood risks in the case study region. In order to manage resources and plan effectively, it is critical to identify relevant knowledge that is meaningful at the local level and also directs decision makers at various scales of management. It is hypothesised that such models provide important guiding principles that strengthen the social institutions and builds on effective learning to increase resilience of an SES under future uncertainties (see also Matysek, Stratford & Kriwoken 2006; Schultz, Duit & Folke 2011; Hahn 2011).

1.3. Why Hawkesbury-Nepean catchment as a case study?

The Hawkesbury-Nepean catchment is impacted by bank erosion, channel and floodplain widening from flooding in the 40s and 50s, land use impacts, clearing of floodplains for development and agriculture, storm water pollution and sediment discharge (Matthai et al. 2009; Pinto et al. 2013). Increases in the proportion of impervious surfaces have adversely influenced the hydrology of the catchment. The South Creek in this region is a highly degraded system impacted by storm water pollution and water extractions (Rae 2007). In addition to urbanisation and development, the in-stream flows are influenced by sewage treatment discharge into the system (Pinto et al. 2013). This catchment system presents a typical example of changing morphology of natural systems as a result of anthropogenic activities.

The Greater Blue Mountain World Heritage Site bound the catchment to the west and on the east the Sydney conurbation generates demand for drinking water supply, threated by increased inflows due to urban development on floodplains (Pinto et al. 2013). The hydrology is further impacted by storage infrastructure in-streams and intense weather events. The Warragamba dam, the world's largest drinking water dam, drains rivers from the Southern and Western region of this catchment (Sydney Catchment Authority 2010).

The catchment is managed by federal, state, regional and local agencies. This assemblage constitute approximately 19 government organisations, 15 non-government entities, 9 aboriginal council and a National Park Association with other branches in the region. The region has 23 local councils that have the responsibility of the management and protection of its natural resources and flood management (Plant et al. 2012).

The catchment generates multiple values as a natural asset, a major tourist attraction, a source of a significant component of the drinking water supply to Sydney and its surrounds, and as an area for future development with an expected 180,000 new dwellings on the floodplains (Smart Consulting 2013). Catchment management requires an understanding of the hydrological connectivity of the system in terms of how inflows from sources are collectively impacting the region and the risk it presents in an already flood-prone region.

The Hawkesbury-Nepean catchment in the Sydney bioregion presents an example of a how Social Ecological Systems (SES) can be complex and unpredictable. The classification of Sydney basin as a bioregion emphasises the need to recognise the inter-dependence of natural systems that goes beyond the jurisdictional governance arrangements of these complex SES. This research into flood management problems generated understanding to identify effective learning processes for a more adaptive decision-making framework. In this context, a biosphere/catchment-scale perspective presents an opportunity to manage SES like the Sydney Basin through an integrated planning process that links regional, national and international program and support information exchange through experimentation and consistent feedbacks.

1.4. Research objectives

The proposed research aims to examine the feasibility of applying the principles of biosphere and water catchment models for managing the Hawkesbury-Nepean flood risks under extreme weather conditions. To achieve this, the research focuses on the following research question and objectives.

Q1. What are the characteristics of a good governance system?

- To identify examples and research evidence of good governance models in NRM and FRM.
- To determine criteria for healthy/good governance systems.

Q2. What barriers exist in flood risk management in the Hawkesbury-Nepean region?

Specifically to,

- examine the current trends in flood management in the region,
- examine institutional gaps within the existing flood risk management of the catchment,
- examine issues of scale and determine the perceptions and approaches to managing floods in the region.

Q3. How can biospheric and catchment-scale frameworks improve flood risk management issues in the Hawkesbury-Nepean Catchment?

Specifically, to

- determine opportunities, strength and weaknesses of these frameworks for resource management,
- determine implications of such frameworks for the case study region, and
- recommend a conceptual framework, to be implemented at a regional scale that utilises the existing institutional arrangement of the Hawkesbury-Nepean catchment for improving flood risk management.

This research, although primarily focuses on barriers to governance in the case study area, at the same time it acknowledges this perspective that the existing system also presents attributes that are examples of good governance. However, the focus of the study was to increase the effectiveness of the existing system thus the case study was audited to identify existing gaps and recommend opportunities for further improvements.”

1.5. Expected outcomes - contribution to research

It is expected that this research will draw attention and focus on improving knowledge, education and long-term policy mechanisms as essential ingredients for adaption, readjustment, and, if needed, redefine the roles of stakeholders such as government, non-government entities, for effective management under the context of emerging problems of rapid urbanisation and climate change uncertainties.

More specifically,

- Experiences shared in this research are intended to provide important insights to resource management of complex socio-ecological systems and inspire discussion and future research to improve management of SES.
- Management, governance and institutional gaps discussed in this research could help improve approaches that increase adaptive capacities of social systems, generate positive resilience, and reduce vulnerability of natural systems in the context of climate change
- It is expected that this research will provide a practical model of adaptive governance at a regional scale and provide a case study test of the biosphere reserve and water catchment-scale models used elsewhere.
- Development of a context specific adaptive framework that enables integration of management efforts across jurisdictions and supports a multi-level governance system.

1.6. Analytical approach to research

In view of the nature of this research within interdisciplinary environmental studies, a mixed method approach for research analysis was used. Chapter 3 provides more details on this.

This has been applied and exploratory research where the boundaries of the research were loosely defined and over the course of this research gained in-depth knowledge and understanding of the flood risk problems. The multi methods allowed the examination of social constructs revolving around the research issues. Through document analysis and semi-structured interviews, the different dimensions of the research problems were identified and examined. The purpose of this research was not to determine the objective truth (a single reality) but to explore how different levels of understanding and perceptions of flood risk issues influence the policy and management discourses. At the same time the research acknowledges that although social construction of people's perceptions plays a strong role in flood management there is a reality outside people's interpretation: there is a technocratic management paradigm that sees decision-making occur with incomplete information.

This research is based on examining the issues in the Hawkesbury-Nepean catchment as a case study area. A case study approach has been taken to address issues of managing complex SES. The main reason for this is because the problems of SES are not only theoretical but rather have real-life context. The problem of flood management is a very current problem in the case study region. This thesis examines the gaps in implementation of adaptive principles of SES in this real-world situation.

1.7. Thesis structure and chapter overview

For ease in discussion and in-depth analysis of problems, this thesis has been divided into eight different chapters. Figure 1.2 provides a conceptual framework and the structure of the research study. It also summaries research findings of each of its analysis chapters.

Chapter 1 provides a preliminary introduction of theoretical frameworks, research rationale objective and methodological approach.

Chapter 2, provides a detailed analysis of the literature review of the problem, from a global perspective with a focus on the case study region. The emphasis is on the socio-ecological barriers facing SES and the influence of such barriers to SES vulnerability, resilience and adaptive capacity. This chapter also provides a descriptive analysis of two regional scale frameworks (Biosphere Reserves and Water Catchment Scale management). It identifies opportunities these frameworks present for improving resilience and adaptation under rapidly changing environmental conditions. The last section of this chapter introduces the case-study region and summaries the multi-dimensional problems of this catchment.

Chapter 3 provides a detailed account on the analytical framework used to conduct this research. It provides justification of the methods used and elaborates on the sample size, target organisations, and individuals that contributed to the research contents and provides information on data collection and analysis. It also links the research questions with methods used and also with the analysis chapter.

Chapters 4-7 constitute the crux of this research thesis results and analysis. These chapters help define the dimensions of the problems and provide examples of the prevalent socio-cultural, political and environmental barriers to flood management. In doing so, they address the second question and objectives of this research. Each of these chapters focuses on a particular problem and are organised around independent methodologies including information on participants who provided information.

Chapter 4 addresses issues of scale and how scale is understood by different stakeholders involved in water resource management or research or strategic planning at council level. The issue of scale is understood through a case study approach where the role of hanging swamps in the catchment's hydrology is explored and views from participants are gathered to shape this analysis

Chapter 5 sets the premise for the first research question as it answers the second research question by describing the trends of flood risk management in the Hawkesbury-Nepean catchment. It provides an in-depth analysis of flood management carried out by four councils that make-up most of the down-stream regions of the Nepean and Hawkesbury rivers, these include the Camden, Liverpool, Penrith and Hawkesbury City Councils and associated organisations such as the WESROC and Floodplain Management Association (FMA). Through micro case studies of two of the four councils, this chapter highlights issues of jurisdictional approaches to flood management and the risks it presents under extreme weather conditions.

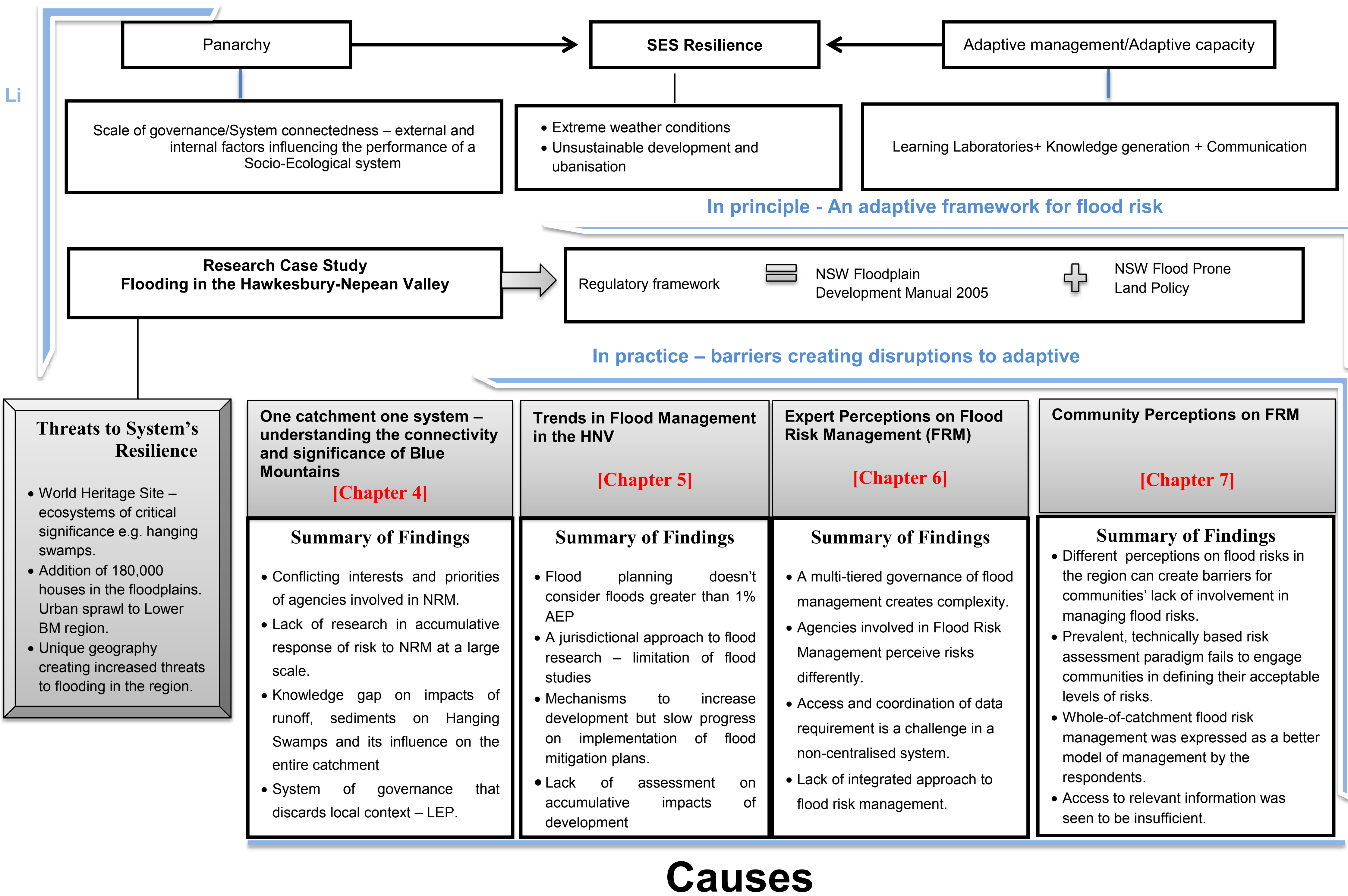
Chapter 4 and 5 lay emphasis on the governance and institutional gaps in flood management.

Chapter 6 provides a socio-political dimension to the problem through a focus on the bigger question – Why is it so? Specifically the issue of perceptions and how critical role perceptions of experts play in managing flood risk in the region. The scope of participants for this query was increased beyond government entities to include risk assessors in insurance companies and real-estate agencies. This chapter highlights significant issues that deter coordination, collaboration and learning to pro-actively and effectively manage this critical SES. Chapter 6 informed the design of the subsequent chapter.

Chapter 7 focuses on community perceptions. The design of this chapter was informed through the responses of community members residing in the floodplain regions of this catchment. It highlights their expectations and understanding of flood issues and their risk perceptions including lack of inclusivity and learning opportunities needed to be able to play a more participatory role in managing their flood risks. This chapter concludes the socio-political and environmental problems of the research issue.

Chapter 8 and 9 focus on the two frameworks. They examine their strengths, weaknesses and analyse what opportunities they provide for improving the existing barriers, highlighted in the preceding chapters of the research.

Chapter 10 provides conclusions and recommends a feasible framework that would help to transform principles of adaptation to practice for better SES management of this region under climate change scenarios.


Li
Panarchy
SES Resilience
Adaptive management/Adaptive capacity
Scale of governance/System connectedness – external and internal factors influencing the performance of a Socio-Ecological system
• Extreme weather conditions
• Unsustainable development and ubanisation
Learning Laboratories+ Knowledge generation + Communication
In principle - An adaptive framework for flood risk
Research Case Study
Flooding in the Hawkesbury-Nepean Valley
Regulatory framework
NSW Floodplain Development Manual 2005
NSW Flood Prone Land Policy
In practice – barriers creating disruptions to adaptive
Threats to System's Resilience
• World Heritage Site – ecosystems of critical significance e.g. hanging swamps.
• Addition of 180,000 houses in the floodplains. Urban sprawl to Lower BM region.
• Unique geography creating increased threats to flooding in the region.
One catchment one system – understanding the connectivity and significance of Blue Mountains
[Chapter 4]
Summary of Findings
• Conflicting interests and priorities of agencies involved in NRM.
• Lack of research in accumulative response of risk to NRM at a large scale.
• Knowledge gap on impacts of runoff, sediments on Hanging Swamps and its influence on the entire catchment
• System of governance that discards local context – LEP.
Trends in Flood Management in the HNV
[Chapter 5]
Summary of Findings
• Flood planning doesn't consider floods greater than 1% AEP
• A jurisdictional approach to flood research – limitation of flood studies
• Mechanisms to increase development but slow progress on implementation of flood mitigation plans.
• Lack of assessment on accumulative impacts of development
Expert Perceptions on Flood Risk Management (FRM)
[Chapter 6]
Summary of Findings
• A multi-tiered governance of flood management creates complexity.
• Agencies involved in Flood Risk Management perceive risks differently.
• Access and coordination of data requirement is a challenge in a non-centralised system.
• Lack of integrated approach to flood risk management.
Community Perceptions on FRM
[Chapter 7]
Summary of Findings
• Different perceptions on flood risks in the region can create barriers for communities' lack of involvement in managing flood risks.
• Prevalent, technically based risk assessment paradigm fails to engage communities in defining their acceptable levels of risks.
• Whole-of-catchment flood risk management was expressed as a better model of management by the respondents.
• Access to relevant information was seen to be insufficient.
Causes

Opportunities

Total Catchment Model + Biosphere Reserves
[Chapter 8 and 9]

Summary of Findings

- Regional strategy that helps to align different scales of governance and help prioritise funding with clear accountability.
- Regional organisation that provides opportunities to manage the region at a water catchment scale to ensure a more holistic flood risk management.
- Centralised system of flood risk information that is embedded in a participatory community education strategy.
- Community led board that defines risks and has control over trailling experiments that can help improve flood design, mitigation and knowledge through science, research and local knowledge.

Conclusions and recommendations
[Chapter 10]

Summary of Findings

Establishment of an adaptive framework through a regional entity that ensures the following:

- Communities are central to the decision-making and policy implementation process in FRM.
- Enhanced coordination between different scales of management.
- Alignment of community values, strategic goals and establishment of appropriate management interventions at local scale linking regional processes with local targets.
- Enhance coordination through effective risk communication, understanding perceptions and integrated information dissemination to interest groups.

Figure 1.2. Conceptual framework of the research study

2.1. Introduction

Human dominance over natural resources has transformed natural systems (Barnosky et al. 2012). This transformation is a consequence of unplanned urbanisation, increasing population size and concentration, development, human consumption patterns, resource exploitation and environmental degradation and has occurred across all scales creating altered, fragmented landscapes and even novel ecosystems (Barnosky et al. 2012). These impacts on the biosphere have given way to a high level of uncertainty and unpredictability in the stocks and flows of natural capital (Gunderson & Holling 2002).

The extent of this human alteration of the environment has given rise to a new geologic timescale, the 'Anthropocene'—the epoch of humans (Gowdy & Krall 2013). Steffen et al. (2011, p. 843) suggest that human activity is largely responsible for this exit from the Holocene epoch and that humankind has become a global geological force in its own right.

Climate change is a profound example of the extent to which human influences have transformed ecological systems on a global scale (Steffen et al. 2011). More importantly, it presents a challenge to the sustainability of the environment through creating greater uncertainty about the future of natural resources and the effective role societies need to adopt, in order to survive.

The arrival of the 'age of human' epoch creates an imperative to understand the dynamics of human-natural systems or Social-Ecological Systems (SES) (Fischer et al. 2015). Empirical research provides a number of frameworks to analyse and understand human-environment relationships and their importance in achieving sustainability (Binder et al. 2013; Hanspach et al. 2014; Fischer et al. 2015). These frameworks recognise that societies and nature are interdependent (Bodin & Tengo 2012).

> A social-ecological system can be considered as a system composed of organi[s]ed assemblages of humans and non-human life forms in a spatially determined geophysical setting (Halliday & Glaser 2011, p.2).

SES have also been defined as linked systems to emphasise their interdependence; integrated systems of ecosystems and human society with reciprocal feedback and interdependence (Resilience Alliance 2007).

Fischer et al. (2015) explain that SES are complex and adaptive, and are influenced by feedbacks across multiple interlinked scales. These feedbacks can also at times result in non-linear behaviour causing surprise and uncertainty in a system's behaviour (Fischer et al. 2015 p.145). This can reduce the adaptive capacity of the system through loss of resilience, where resilience is the property of a system to be flexible and allow change to occur without losing a provisioning function for resources, goods and services (Nelson, Adger & Brown 2007). The need for SES to be more adaptive has been extensively researched and discussed (Menzel & Buchecker 2013). The following section discusses the relationship between vulnerability, resilience, and adaptive capacity in SES.

2.2. Attributes of a SES - vulnerability, resilience and adaptive capacity

Resilience, vulnerability and adaptive capacity are interlinked concepts and are critical attributes that define the state of a SES. Adaptive capacity is described as a desirable property of a system in vulnerability and resilience literature (see Engle 2011). Gallopin (2006) elaborates on the diversity in the use and interpretation of these concepts in social and life sciences and concludes that a clear consistent definition is lacking. The following understanding of the three interlinked concepts applies for this thesis.

Vulnerability of a SES is the degree of sensitivity, exposure and capacity to cope (Adger 2006; Newton & Weichselgartner 2014). For instance, a low-income coastal community may have a greater degree of exposure to the impacts of climate change due to sea-level rise, have low coping capacity, and a high degree of sensitivity due to low resources to recover from damage. Alternatively an epidemic may severely impact children and the old whilst access to medical care may only be attainable for high-income earners who have greater coping capacity. Exposure in this case might be equally distributed (Gallopin 2006). Smit and Wandel (2006, p.286) suggest that most researchers define the relationship as 'vulnerability of any system (at any scale) is reflective of (or a function of) the exposure and sensitivity of that system to hazardous conditions and the ability, capacity or resilience of the system to cope, adapt or recover from the effects of those conditions'. Resilience in this regard can be taken as a component of vulnerability—an internal characteristic of a system that reflects a coping capacity (Gallopin 2006); whereas, adaptive capacity influences vulnerability as a moderator of system exposure and sensitivity (Adger et al. 2007, cited in Engle 2011).

In an inherently complex system with conflict of interest over resource use among stakeholders, management of resilience also becomes a question of governance (Engle 2011). In this social context, resilience is influenced by social capital, global and local economics, resources and spatial dimensions (Adger 2000; Goulden et al. 2013). More often ecological resilience is linked with social resilience because the ability to cope with environmental change relies on the development of institutional capacity (Adger 2000; Folke, 2006; Kelly et al. 2015); specifically, the capacity of formal and informal institutions to learn about changes in the system to enhance their adaptive capacity. Adaptive capacity in resilience studies is often described as "adaptability" and defined as "the capacity of actors to influence resilience" (Walker et al. 2004). Consequently, management for ecological resilience in an SES is impacted by the decisions made by various social actors (Kelly et al. 2015).

In climate change science, adaptation can be characterised as "adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects" (Parry et al. 2007 cited in Engle 2011). So, adaptive capacity is also an ability of an SES to transform into a more 'desirable' state if the existing state of the system becomes undesirable (Engle 2011). Hence adaptive capacity reflects the positive characteristics of a system, and vulnerability is an undesirable state (Engle 2011). Resilience on the other hand can be a desirable or undesirable property of a system as explained below.

Undesirable resilience or perverse resilience can be defined as: "Resilience within a system that is undesirable to the extent that it is socially unjust, inconsistent with ecosystem health or threatens overall system viability" (Phelan et al. 2013, p. 202).

Resilience in SES is strongly influenced by power in social systems. Phelan et al. (2013, p. 202) argue that political economic drivers in an SES "often have interests and values that are contradictory, even incompatible, and in conflict with maintaining the familiar stability of the Earth system". To maintain resilience there is a need to recognise what state of a system needs to be maintained and for whom. Therefore, resilience requires tackling with power dynamics at different scales of management (Phelan et al. 2013).

The resilience of a SES is strengthened through the development of social, human and financial capital that provides for institutions and networks that share information, interact and build trust to undertake collective action, generate and share knowledge, skills and the finances to support development and infrastructure (Brondizio, Ostrom & Young 2009; Pretty 2011). Ecological components also contribute towards system resilience through the provision of ecosystem goods and services (Pretty 2011).

If management is to take place in a complex environment, as is the case with SES, then adapting to change would require the ability to learn about the system changing in ways that actively enhance its adaptive capacity. Engle (2011) suggests that adaptive capacity as a social-political process is best illustrated through adaptive management and adaptive governance. These concepts suggest that the decision-making process needs to scale appropriately and acknowledges that natural systems are dynamic and should be managed as experiments from which to learn (Lee, 1993 cited in Engle 2011, p.652). Societies need the capacity to manage system resilience. They need to have the ability to self-organise and inculcate a culture of "openness to learning" (Lebel et al. 2006, p. 4) that entails the ability to acquire, process, integrate and effectively utilise information and knowledge to make decisions about these natural dynamic systems.

The ultimate goal of adaptive management and adaptive governance is to increase our socio-ecological adaptive capacity and reduce vulnerability (Pahl-Wastl 2009). Learning becomes a process of collecting updated and easily interpreted information that can inform various stakeholder groups by identifying optimal solutions that address their common interests. It can also help to determine institutional and governance challenges that can lead to maladaptation—"adaptation that does not moderate harm, but instead exacerbates it" (Engle 2011, p. 648). The *Threshold of Potential Concerns* (TCPs) approach applied in the management of the Kruger National Park is an example where a systematic process has been in place to identify environmental thresholds. The TCP approach helps to arrange the knowledge gaps through consistent monitoring and feedback loops that test policies and make adjustments to sustain the performance of ecosystems (Du Toit, Rogers & Biggs 2003; McLoughlin et al. 2011). Similarly, Engle and Lemos (2010) recommend a two stage process where variables that contribute to adaptive capacity are identified and then monitored for changes over time against climate change impacts.

In these examples knowledge and information that support a double loop learning process become critical in the identification of the state of an SES, to plan for desired outcomes, to manage thresholds, and to take appropriate policy actions that enhance adaptive capacity; however, the problem is that knowledge and information collection is rarely sufficient to address issues pertaining to the sustainable management of SES. It is the context in which the 'uptake' of knowledge and information takes place and presents a challenge due to socio-cultural and political influences in the decision-making process. The development of a 'learning culture' is critical for a complex system influenced by climate change uncertainties. Lorenzoni et al. (2007) and Connor (2010) elaborate on the social and institutional barriers and they identify denial, scepticism, the lack of trust in media and government action, an over-emphasis on scientific knowledge, a lack of political will and social norms as issues that challenge the 'up-take' of knowledge and its use for managing parameters like climate change.

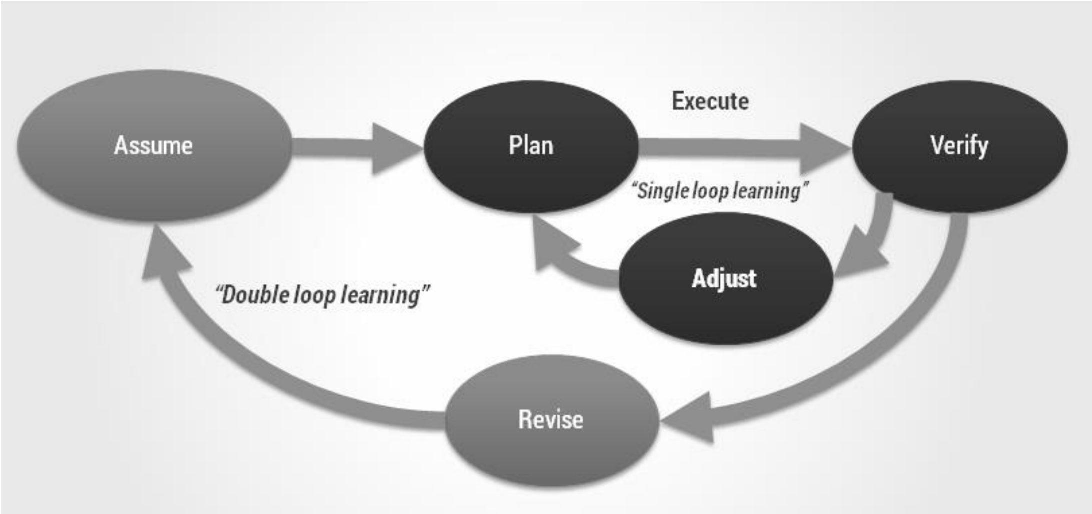


Figure 2.1. Single- and double-loop learning (Van Vliet 2012)

A review on the natural and socio-political barriers is provided in the following section to elaborate on the complexity of the issue in SES management to improve resilience and adaptive capacity.

2.3. Dimensions of the problem

Societies are challenged to deal with socio-environmental problems that have created an increased vulnerability of SES against an unpredictable future. In order to manage system resilience, factors that create SES vulnerabilities and are counterproductive to resilience need to be considered and assessed. The following main dimensions have been identified:

Environmental attributes that create management barriers

- **Complex embedded systems**—the inherent complexity of systems that are influenced by changes from within and outside (Walker et al. 2004)
- **Issues of uncertainty in a dynamic SES faced with climate change**—climate change being the overarching cause of enhanced vulnerability to SES.

Socio-political barriers

Urbanisation, large-scale development and population growth are some of the barriers that influence SES. This also includes the diversity of interests and conflicting values of stakeholders that influence policy and challenge the management of these systems:

- ***A Prevailing 'Command and control' governance regime for natural resource management (NRM)***—a dominant governance paradigm in the form of a scientific management approach that threatens SES by creating monocultures and loss of system diversity (Holling & Meffe 1996)

- ***The political influences of a 'command and control' regime***—the issue of rigid policies and legislative systems that fail to support dynamic environmental processes and issues of scale
- ***Socio-cultural and political dimensions of learning for managing NRM***—generated knowledge that can be readily utilised by end-users faced with a complex decision-making process influenced by political priorities and social values.

The following section will review the dimensions of this problem and how they influence the Socio-Ecological Systems.

The opportunities and challenges of participatory assessment and learning as seen through adaptive governance are discussed, followed by a biosphere perspective of governance to justify the context in which the proposed research intends to take place.

This review is divided into the following main sections:

1. Problem dimension I: Environmental Barriers
2. Problem dimension II: Socio-political Barriers
3. Opportunities and challenges of an adaptive governance paradigm
4. A biosphere perspective of governance—opportunities for managing SES at a basin-wide scale
5. A catchment-scale management of resources—opportunities for managing SES encompassing jurisdictional boundaries.

2.4. Problem dimension I: environmental barriers

2.4.1 Socio-Ecological Systems as complex embedded systems

The premise that ecosystems are not isolated entities but rather are dynamic systems interacting with the surrounding environment supports the General Systems Theory proposed by the biologist Ludwig von Bertalanffy (1972) who proposed that natural systems at a certain scale can be influenced by positive and negative externalities from another level of scale. Hence, SES are complex nested systems (Brondizio, Ostrom & Young 2009) where change is inevitable. Some recent literature describes the limitation and diversity in interpretation and application of this theory in practice (Moore et al. 2009; Jasinevicius 2010). Nevertheless, reference to general systems theory is made here to set the background context and emphasis on the complexity and embedded nature of Socio-Ecological Systems.

Holling (2001) and Gunderson & Holling (2002), in their book *Panarchy: Understanding Transformations in Systems of Humans and Nature* define the complexity of SES systems through the theory of Panarchy.

> A Panarchy is a representation of a hierarchy as a nested set of adaptive cycles. The functioning of those cycles and the communication between them determines the sustainability of a system (Holling 2001 pp. 396).

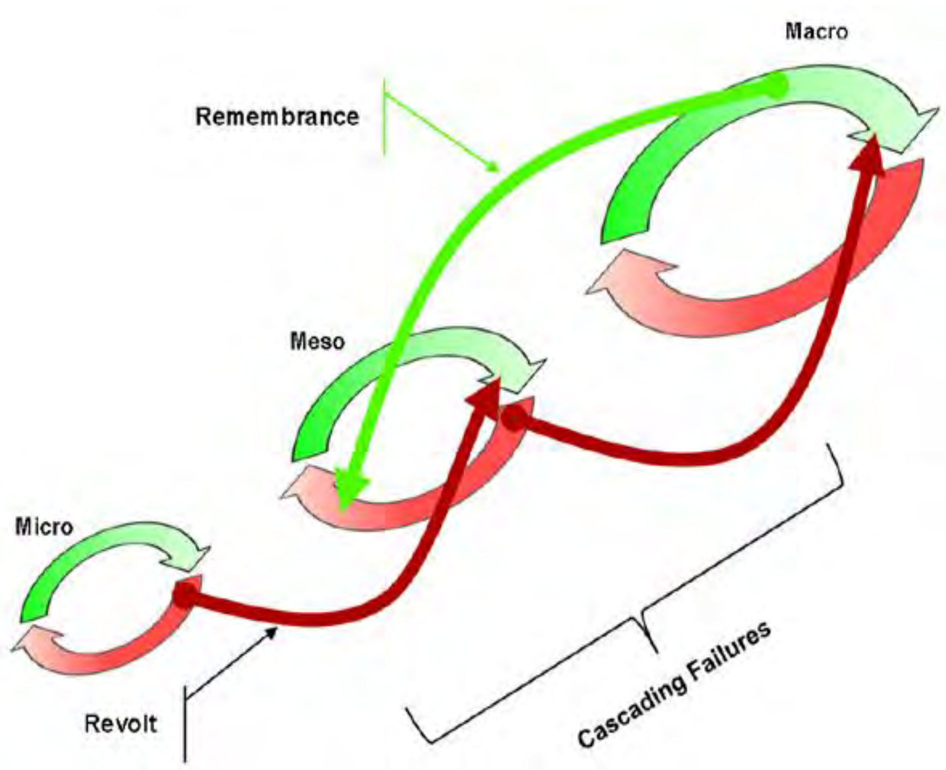


Figure 2.2. Panarchy Concept (Gartner 2010).

Panarchy demonstrates that an SES functions through the interaction of embedded systems at various scales. It defines a hierarchical arrangement where natural and social systems are linked in a cyclic process of four distinct processes of an adaptive cycle, (i.e., growth/exploitation, conservation, release and reorganisation). These cyclic processes are occurring at a scale ranging from cells to ecosystems and that of biosphere, and from societies to cultures over a wide range of temporal and spatial trajectories (Holling 2001). For instance, a pine-dominated ecosystem may comprise of needle, crown, patch and stand which represent different scales of structures (Holling 2001).

Within a particular system, larger scale, coarse-grained processes are more stable and slower to change as compared to smaller scale processes (Gunderson 2010). The larger scale processes help maintain the sustainability of lower faster levels (e.g., a forest stand provides the micro-climate to support life and its function at a lower level). Similarly, social systems are embedded in different boundaries of scale such as neighbourhoods, towns, and metropolitan areas (Gunderson 2010). In a social system, there are norms that define the boundaries for individual lifestyles (Holling 2001). Changes occur within these social and ecological boundaries at different scales (Brand 1994) and are also influenced by factors and disturbances across scales. The adaptive opportunity within each level is triggered through novelty and the overall relationship and linkage between these scales help maintain integrity and allows for a degree of stability (Allen et al. 2014).

“Due to the nature of these cross-scale interactions, they are viewed as being complex adaptive systems” (Gunderson 2010 p.2). “The interactions between living and non-living elements of a system within a single domain of scale, their development, growth and decay, has [sic] been described as an adaptive cycle’ (Allen et al. 2014, p. 579). Panarchy, therefore, can be described as ‘a nested set of adaptive cycles operating at discrete ranges of scale” (Holling 2002, cited in Allen et al. 2014).

Halliday and Glasar (2011) claim that societal and ecological issues are systemic management problems. They are systemic because they emerge from complex, interdependent processes spread across various scales. They are also management problems as they require consistent and coordinated efforts by policy-makers and other key stakeholders to identify and implement appropriate interventions. Holling (2001) emphasises that an understanding of the adaptive cycles and their scale is essential to recognise elements of sustainability, resilience and vulnerability. By gaining this understanding, leverage points can be recognised for developing appropriate policies to support sustainability and enhance system resilience. Management processes at the Kruger National Park are a practical example of managing ecological heterogeneity over multiple temporal and spatial scales. The perennial rivers at the west of the park boundary flowing into Mozambique require extensive collaborative management with multiple interest groups (Du Toit, Rogers & Biggs 2003). On a broader scale, management of large endangered species like the elephant and white rhinoceros require management that incorporates international interests and treaties (Du Toit, Rogers & Biggs 2003; Smit & Ferreira 2010; Cromsigt & Beest 2014) Management in the Kruger NP presents a practical framework that links science, policy and management practices through a hierarchical system of objective setting, trialling of management options and then monitoring the outcome of these actions and recalibrating efforts to meet the set objectives (Du Toit, Rogers & Biggs 2003; Biggs et al. 2011). The framework enables stakeholder engagement, while the vision and broader objectives are established, based on social values and needs.

Similar examples can be examined to gain an understanding of complex embedded systems such as the conceptual model or system-thinking frameworks used for identifying research needs and policy intervention in biosphere reserve management (Nguyen, Bosch & Maani 2011).

Developing a conceptual understanding of panarchy is critical in order to move away from traditional linear patterns of management where the focus has been on controlling specific variables of economic interests. Managing single variables has generally resulted in abrupt changes in system dynamics leading to system degradation (Folke et al. 2004). In the Kruger NP, previous management practices of cattle grazing and recently high density of mega-herbivores and their length of exposure to woody vegetation have impacted the density of tall trees and the associated biodiversity (Fisher et al. 2014). More often, slow changes that control a specific variable often are unnoticed or not monitored. Panarchy helps to understand the dynamics of social and environmental systems. Gunderson (2010) describes impacts from hurricane Katrina to illustrate the interconnectivity of social and environmental systems. Severe flooding caused damage at a local level to homes and municipal infrastructure and surrounding neighbourhoods whilst at the federal level, the slow response of disaster relief agencies exacerbated the situation (Gunderson 2010). The flood damage due to Katrina occurred at different temporal and spatial scales. About 50 levees were breached resulting in accounted losses of USD 50 billion (Kates et al. 2006). Recovery occurred at different rates and scales with some systems irreversibly changed (Gunderson 2010). Whilst planners and managers can deal with some of these impacts, many cannot be foreseen or predicted and therefore planning is required for those that are unexpected and never before seen (Gunderson 2010).

For this thesis, it was essential to acknowledge the complexity of a SES as characterised through panarchy to recognise and evaluate various dimensions of the research problem (Figure 1.1 and Figure 1.2). In summary the following characteristics of this concept were deemed essential to address and discuss in this thesis and evaluate through answering the research questions described in Chapter 1:

1. The need for integration between social and environmental systems (Chapter 4 emphasises this as one of the issues in the case study area)

2. The need to recognise that SES are inherently complex and dynamic and that the climate change phenomenon further complicates their sustainable management (as discussed throughout this thesis)
3. The significance of understanding hierarchies of a SES should address both top-down and bottom-up processes. (Chapter 8 & 9 presents possible solutions to address this).
4. The need to adopt an adaptive governance paradigm; itself recognition of panarchy, for continuous learning and experimentation to enhance SES management. (Chapter 9 & 10 provides possible options for the case study).

2.4.2. Issue of uncertainty in a dynamic SES faced with climate change—an inevitable menace of modern times and the near future

This section provides a broader overview of the impacts of climate change on SES. Case study-specific implications of climate change are discussed in the later sections of this chapter.

The *Intergovernmental Panel on Climate Change* (IPCC) have indicated that the global increase in temperature continues to adversely impact natural and social systems (IPCC 2007; Pachauri et al. 2014). Sufficient research evidence now exists to highlight the possible environmental changes resulting from anthropogenic causes of climate change (Wang & Schimel 2003; Oreskes & Conway 2011; Australian Academy of Science 2010).

The IPCC report states that global greenhouse gas emissions are accelerating at a much faster pace than any other emission scenarios (Brunner & Lynch 2010). A global mean temperature increase of 0.75 °C since the pre-industrial era has been observed with an additional increase 0.5-1.0 °C to be expected due to past emissions (Solomon et al. 2011; Das 2015). This has and will, continue in future to change the way natural systems function and their interactions with the human environment. This creates uncertainty in the way different SES systems will respond.

2.4.3. Implications on the resilience of Socio-Ecological-Systems

Any abrupt changes in the Earth's climate will have an impact on its biodiversity, ecosystems and human livelihoods across the globe (Wang & Schimel 2003). Climate change creates unpredictability in the way ecosystems respond. From an ecological standpoint, the hydrological cycles are sensitive to the slight changes in temperature that create a 'ripple effect', threatening the composition and functionality of these systems. A consequence of climate change that results in the melting of arctic ice, an increase in sea levels and changes in the ice-sea extent can trigger changes in species composition, predation cycles and the food chain (Doney et al. 2012).

Major species shifts and distribution as a consequence of an anthropogenic-induced climate change may result in "no-analog"[2] ecosystems resulting in "ecological surprises" in an uncertain climate environment (Williams & Jackson 2007, p 475).

Variations in precipitation would more likely influence the tropical regions with water-rich areas receiving more water and drier regions becoming scarce in water. Hence, the gap between water-rich and water-poor regions is more likely to increase (Bates et al. 2008).

Wang and Schimel (2003) highlight the possibility that the increase in Anthropocene climate change is contributing to the changes in trends of naturally occurring climatic variabilities such as El Niño-Southern Oscillation (ENSO), North Atlantic Oscillation (NAO) and the Pacific Decadal Oscillation. The changes in these naturally occurring weather drivers are more likely to influence future climate change as the climatic impacts of these phenomena are evident in regions that are geographically apart (Wang & Schimel 2003). This has led to climate anomalies that have biological and social repercussions in the form of rapid and extreme weather events (Morss et al. 2011).

The impacts of climate change on ecological break-down extend to social systems connected to them. For example, sea-level rise poses a threat to coastal communities, damage of infrastructure and loss of livelihoods (Doney et al. 2012) and in recent years, the economic losses as a result of extreme weather events have increased (Brunner & Lynch 2010; Morss et al. 2011). El Niño events can create wetter than usual weather resulting in change in vegetation patterns that have had an impact on livestock dynamics in Africa (Wang & Schimel 2003). This has also resulted in the extinction of some invertebrates and disease outbreaks thus creating stressful conditions in the human-environment systems. Loss of natural buffers and natural pollution filters such as wetlands and mangroves that protect coastlines and inlands from inundation are also threatened (Doney et al. 2012).

Climate modelling, where various socio-economic and emissions scenario are used as inputs to project future environmental, socio-economic and technological conditions, is used to guide the decision-making process (Moss et al. 2010). As useful as these projections are, there are still gaps and uncertainty, creating a need for more current, localised or context-specific information for policy makers (Dessai & Hulme 2007).

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[2] Communities that are compositionally unlike any found today i.e. future novel climates will increase the risk of biodiversity reshuffling and ecological surprises presenting additional challenges to managing such natural resources (Williams & Jackson 2007).

2.5. Problem dimension II - socio-political barriers

2.5.1. A prevailing ‘command and control’ governance regime for managing NRM

Despite international commitments established through conventions, treaties and the Millennium Development Goals, aspirations to sustain environmental resources and social capital have not been met (Pretty 2011). The shortfalls in the expected outcomes could be accounted for in terms of governance paradigm adopted (Brunner & Lynch 2010), the origins of which date back to philosophers such as Rene Descartes, Sir Isaac Newton, and followed by a string of predecessors who support the idealism of conquering physical problems through existing scientific theory and knowledge, and that little is left for chance or discovery (Geyer 2003).

The 19th century scientific and industrial revolution produced a collection of accepted theories, standardised methods and analysis resulting in the development of management techniques (Harding, Hendriks & Faruqi 2009). This *scientific management* approach, originating from Taylorism in the late 1880s (Littler 1978), became the panacea to management problems (Brunner & Steelman 2005). It sought to “increase productivity through rational measurement, the elimination of waste and duplication, and the search for the one best way” (Brunner & Steelman 2005, p. 12).

This scientific approach to management was based on the three main underlying principles: **first** was the focus on the use of the best available scientific knowledge and experts to identify a solution, **second** was to direct policies that would promote technology and efficiency models, and **third** was the emphasis on a top-down approach where decisions were centralised (Brunner & Steelman 2005). Chapter 9 & 10 further discusses this paradigm in the context of the case study and elaborates on possible solutions.

These underlying principles reflect the limitation of this paradigm where problem-solving is sought only through a scientific lens based on accepted theories and methods. Science is seen as an objective, precise and reductionist approach to control problems (Walters & Holling 1990). More often the context is ignored as managers and decision-makers are preoccupied by policy preference, project limitations, funds and bureaucratic boundaries (Clark 2002). Thomas Kuhn (1962/1970, p.35) describes this form of science as ‘puzzle solving’ where the presumption is that existing scientific knowledge and practices are sufficient to resolve perceived problems. Failure to solve the problem is taken as a weakness of the scientist rather than seen as a flaw within the paradigm (Chalmers 1979). Kuhn claims that scientists are caught-up in this paradigmatic way-of-thinking to seek solutions for all problems—hence a single learning loop exists. This reductionist approach tends to exclude social interactions as an integral part of environment and is challenged when unexpected anomalies arise or where ‘normal science’ fails to provide an appropriate solution (Harding, Hendriks & Faruqi 2009, p.60). Under the climate change scenarios, if a ‘business as usual’ stance is maintained and greenhouse gas emissions continue to increase, drastic changes in the SES will potentially result in ‘no-analog’ communities (Williams & Jackson 2007, p. 475) and unexpected patterns of climate where past experiences provide few solutions to deal with the emerging environmental problems (Holling 1978).

Under this premise, environmental problems are dealt with only out of necessity (Clark 2002) and often as a reactive response. One such example is seen in the form of establishing protective areas and national parks—a notion indicating that “environmental consequences could be separated from the social and economic ones” (Holling 1978, p.28).

The second principle of the scientific management approach is the use of efficiency under the assumption that it will replace conflicts. This disregards the value of local institutions that represent social values (Brunner & Steelman 2005). Problems of resource management are multi-fold. They are an amalgamation of social complexity, varying degrees of conflicting interest, and values topped with future uncertainty (Clark 2002). Hence, the conventional approach to problem-solving is in itself a problem. “Conventional approaches tend to simplify policy problems, misconstruct some vital part of the context, or overlook the context altogether” (Clark 2002, p. 2). The scientific approach to managing resources applies predefined models to new problems. A ‘one-size-fits-all’ policy is utilised, hence the context is ignored. As the policy decisions and development plans are set at the early stage of the design phase, this provides a very narrow window for adjustment to development or policy shortfalls. In such a scenario, confrontation of different interest groups becomes inevitable (Holling 1978). Brunner and Steelman (2005) emphasise that the root cause of environmental resource management conflict is the lack of acknowledgement of the common interests of various groups of stakeholders.

The third notion of the scientific management approach is centred on the principle of a ‘command and control” or top-down regime under the premise that societies can be “rationally steered in a particular direction” (Harding, Hendriks & Faruqi 2009, p. 265). In such a scenario, the ecological systems are moulded into a predictable pattern to meet the demands of the society. The resultant short-term economic gains through technological inputs have eroded system resilience through the loss of system diversity (Holling & Meffe 1996; Vojinović 2015) and lessened the stability of ecological systems through massive infrastructure development (Gunderson et al. 2006; Pahl-Wostl 2007). Systems need to be managed as dynamic entities where adaptation results in flexibility rather than a state of equilibrium (Nelson, Adger & Brown 2007).

2.5.2. The political influence of a 'command and control' regime

The political influence of a 'command and control' regime is its tendency to discard scale dynamics and its recognition for effective policy implementation and development action. Discussions on scale in environmental governance of SES have gained significance in recent years (Termeer et al. 2010). Scale can be defined as 'the spatial, temporal, quantitative, or analytical dimensions used to measure and study any phenomenon and levels as the units of analysis that are located at different positions on a scale' (Gibson et al. 2000, p. 218). "In policy and interdisciplinary work, scale is often a synonym for 'level' defined in terms of spatial extent. In this context, interactions across scales refer to interactions that span the local, regional, national, and international or global" (Poteete 2012, p.139). Cash et al. (2006) defines these jurisdictional scales as "bounded by organised political units (e.g., towns, counties, states or provinces and nations) with linkages between them created by constitutional and statutory means'. Haarstad (2014) argues that 'scale is much more than a point in a vertical hierarchy of institutional arrangements; it embodies social, political, economic and discursive processes that cannot be reduced to one particular governance institution. These definitions indicate that scale is a socially and politically constructed concept just like jurisdictions (Wyborn & Bixler 2013). Howitt (2013, p. 69) also elaborates that scale in sustainability assessment requires more than technical considerations as it is political and conceptual.

Kok and Veldkam (2011) argue that scale sensitive policies in environmental management are needed and currently fail to exist. According to Haarstad (2014) the current governance framework does not align with the 'transboundary nature of environmental problems' such as climate change issues. Environmental problems can occur at different scales, therefore, management actions should target issues across these scales. Misconception of scales has resulted in failures to deal with sustainability challenges.

Sustainability, a key environmental policy concept, is a challenging objective to fulfil. Garmestani and others (2009; Ruhl 2012) argue that the emerging environmental problems are insufficiently addressed through the current policy regimes. They elaborate that a shift to a sustainability paradigm requires strong political support; however, rigid legislative systems requiring certainty do not correspond to the dynamic environmental processes. Policy should be seen as an evolving process and should be revised, monitored and recalibrated as and when needed. Another issue, with current policy implementation, is that policies often do not support the scale at which they are applied—scale mismatches also exist due to governance boundaries and socio-ecological processes. For instance, landscapes are controlled by multi-jurisdictions and are therefore, influenced by multiple-decisions from a landowner to state officials. In most cases decisions made for land management do not correspond to the scale at which desired ecological outcomes can be achieved. As an example, Garmestani and others (2009), claim that in water resource management, upstream users may have conflicting interests with other upstream users, whereas downstream users may be in conflict with other downstream users on options for water use. On a coarser scale and at a basin level, disagreements over resource use between upstream and downstream may occur. Cross-scale complexity results from diverse interest groups, resource ownership and power balances resulting in fragmentation in decision-making. Consequently, disconnecting between scales makes it difficult to manage resources across different regions (Haarstad 2014). Howitt (2013, p. 68) argues that scale is central to sustainability because for any policy and development action to be effective, under a climate of uncertainty, requires consideration of institutional arrangements 'across ecological, social, economic and political structures that are themselves scaled.'

Cash and colleagues (2006) define three major challenges of scale—the failure to recognise scale interactions, mismatch of scales, and the way scales are perceived and valued by different stakeholder groups (Chapter 6 & 7 discusses catchmentisation, regional planning and perceptions in this regard). There is always loss or gain for different actors when it comes to strengthening or weakening cross-scale interactions. Therefore, scale issues are linked with political issues (Cash et al. 2006). Re-scaling and 'scale jumping' are also political phenomena (Swyngedouw 2004) where scale is considered to be a hypothetical realm that helps social actors to organise themselves across different scalar resolutions (Herod & Wright 2008). Glocalisation, termed as the fusion of global and local forces where global level interventions can influence local socio-political and economic processes and vice versa (Ramutsindela 2004), influence environmental management decisions. Hence scale can be defined within the bio-physical context and also as a socio-legal construct such as jurisdictions where boundaries can be arbitrarily drawn.

Scale in water management is a critical aspect. Moss and Newig (2010, p.2) elaborate that due to its fluid nature, water is bounded by spatial limits; at the same time maintaining its bio-physical properties is a question of governance (i.e., determining the appropriate scales for organisations to monitor and maintain healthy river systems). Furthermore, wicked problems such as climate change need overarching governance units at national and international scale but de-centralised governance mechanisms require citizens' participation at smaller spatial units of water governance (Moss & Newig 2010, p.2). There is considerable mismatch between 'the scope of resources, environmental problems and the scales of institutions that govern them" (Haarstad 2014, p.88). The following figure demonstrates the scale mismatch between two different domains (i.e., the water management [dotted and hashed lines] and climate change research [dotted lines]). Research takes on a more global and national scale whereas water management actions are required at the grassroots.

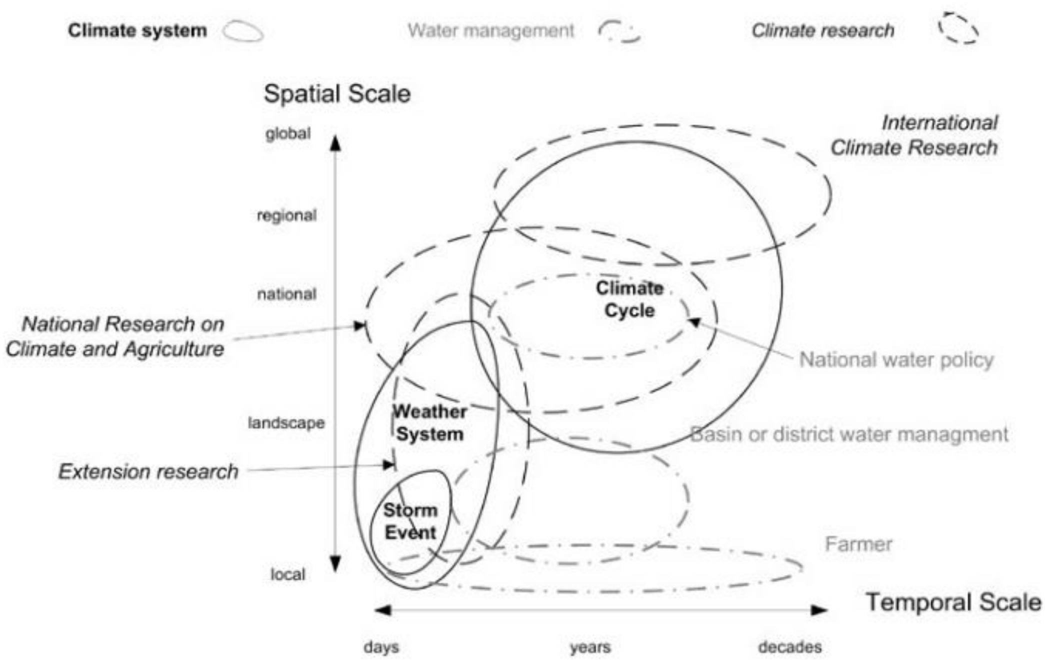

Figure 2.3. Scale mismatch (Cash et al. 2006)

This thesis discusses that there are issues of scale mismatch where scale as a socio-political construct is discordant with the more heterogeneous scales that are naturally defined and organised through environmental processes. Gale (2015) argues that geographic scale is critical in policy decision-making which is often ignored due to lack of geographic research in the public sector, incompatibility and also due to the lack of relevance in the terminologies used in the two interlinked but different arenas (i.e., public policy and geography).

It is crucial to define the scale at which resource objectives can be appropriately addressed. In the context of Panarchy, a nested set of institutions is needed to manage resources at a corresponding scale. This is essential, as federal and state agencies provide a legislative framework that supports regional or landscape scale policies, whereas institutions managing resources at smaller scale are influenced by public opinions at the grassroots. Garmestani (et al. 2009) suggest that such an arrangement allows for a greater level of interaction to understand scale-related issues and identify appropriate solutions. This requires a framework that links scale-related problems through a network of institutions and merges top-down and bottom-up approaches of governance.

2.5.3. The socio-cultural and political dimensions of learning in NRM

The politics of science and learning needs to be understood and acknowledged in order to enhance the practical implementation of conceptual frameworks that move away from the scientific management paradigms.

Despite various international efforts to integrate science and policy, a large body of literature indicates that a huge gap still exists (Van Wyk et al. 2008; Koetz et al. 2009). According to Spierenburg (2012, p. 125), policy-makers tend to ignore scientific information that does not support their policy interventions. Also, in certain cases, policy-makers are not sure of the actions that need to be taken against the uncertainty of certain scientific conclusions. The role of science is seen as an information provider, and policy-makers utilise this knowledge to develop appropriate policies. The process of developing policies, against issues to be addressed is a lot more complex than a linear causal relationship between science and policy. The complexity lies in the politics of the decision-making process, where decisions are weighed not entirely on the basis of science but rather on more practical socio-economic parameters such as costs, social benefits and trade-offs (Van Wyk et al. 2008; Spierenburg 2012). Within the political context, the decision-making process is also influenced by different perceptions about the values of different eco-system services. The overlying assumption that science will influence political processes by defining the desired policy responses is an overambitious expectation (Spierenburg 2012). Science needs to take into account, the socio-cultural and political dimensions of the decision-making process for policy development.

Climate change is an example of how science has failed to harness wide-scale acceptance. Scientists identify socio-cultural and even political attributes as strong influences to shape individual views about climate change (Hoffman 2012; Washington 2013a). They argue that scientists can define the technical information on climate change with evidence but that does not ensure that societies will relate, accept and understand these claims (Hoffman 2012). Individuals respond to complex scientific information based on their belief systems that are influenced by group values, cultural norms, and ideologies (Washington 2013b). Consequently, people tend to accept information that reinforces their association with valued groups and reject knowledge that reinforces values that are unaccepted. The issue of climate change pushes people to change their 'way of life' reorient their thinking and change practices that may impact climate change; in other words, it contests their worldviews.

Stratford and Davidson (2002) argue that a number of frameworks focused on decision-making in Natural Resource Management (NRM) tend to ignore the socio-cultural dimensions. Hence there is a need to search for models that take into account the socio-cultural factors that influence human judgements and decision-making. There is a need to use tools that help to understand the interrelationships among various cultural groups and forms of identification in order to tackle 'adversarial politics' (p. 431). Understanding socio-cultural dimensions is essential to improving policy decisions; it can also help to increase the adaptive capacities in a dynamic SES and enhance the ability to deal with land and water management issues. There is little evidence that socio-cultural factors are taken into account in policy development for NRM in Australia (Stratford & Davidson 2002). They are usually labelled as 'soft' or 'unscientific' observations.

In order to manage natural resources, the socio-political influences need to be considered. Castree & Braun (2001, p. 3) argue that human-nature relations are politically biased because the knowledge it produces tends to be technocratic. Since a key element for enabling communities to manage ecological resilience is through learning (Gunderson et al. 2006; Gunderson 2010), the assumption that generating scientific knowledge will automatically change social and political discourses needs to be considered realistically. Chapter 7 of this research thesis demonstrates how flood risk communication is an existing challenge in adapting a risk management approach by the communities. Conceptual models in theory may present ideal solutions but they need to be contextualised within the realities of human-nature relationships based on values and belief systems. Castree & Braun (2001) argue that decisions are often articulated to deal with environmental problems without addressing deeper causes responsible for such problems. Consequently, decisions are made by those and for those who have vested interest without having to pay the price for ameliorating environmental problems and the subsequent impact (Castree & Braun 2001).

2.5.4. Risk society, value of perceptions in creating SES resilience

Beck (1992) described modern society as a 'risk society': a transition from an industrial society concerned about goods and services to a society concerned with risk distribution (Harding, Hendricks & Faruqi 2009). According to Beck (1992), the risks associated with the early industrial era were linear where impacts could be directly linked with source; for instance, point source pollution, factory explosion or dam failures. However, risk distribution in a 'risk society' is far more convoluted and complex where pollution has wide-spread impacts; the impact is sometimes irreversible, risk increases with exposure and vulnerability and affects human and environmental systems. More importantly it is a social construct. Beck defines a risk society 'in which the social, political, economic and individual risks increasingly tend to escape the institutions for monitoring and protection in industrial society' (Beck 1992, p.5). In such a risk society, assessment of risk, its management and determining acceptable risks become essential components in environmental decisions (Harding, Hendricks & Faruqi 2009). Harding and colleagues (2009) argue that defining acceptable risk is complicated by diverse interests, perceptions and values of people. According to them, 'risk perception' is a 'critical element in risk management which is ignored at the decision-makers' peril' (Harding, Hendricks & Faruqi 2009, p. 242). Here, it is important to note that while risks can be defined in terms of quantifiable probabilities that determine the outcome or the extant of risk against a particular entity, uncertainty, according to Elliott & Dickson (2011) occurs when there is lack of statistical information to make informed decisions. Sven Ove Hansson (2009) argue that decisions are mostly made under uncertainty because even though statistical frequencies exist to assess risk, social factors and subjective judgements play a central role in assessing risks.

'Risk perception can be defined as "an inherently psychological construct—a subjective judgement about the felt likelihood of encountering hazards when objective information is minimal" (Gierlach, Belsher & Beutler 2010, p. 1539). While risk is a social construction, its assessment has a scientific and statistical dimension. Risk is broadly defined as 'a combination of the probability or frequency of occurrence of a defined hazard and the magnitude of the consequences of the occurrence (Harding, Hendricks & Faruqi 2009). Statistically, risk can be calculated as: Risk= hazard x vulnerability x exposure (Bradford et al. 2012). Gierlach et al. (2010) and Bradford at al. (2012, p. 2300) argue that differences in risk perception between different actors/groups occur due to the difference in defining risk. While the scientific community relies on the statistical assessment of risks, communities include experiences and feelings in their perception of risks. The way the public conceptualises risks is often ignored by scientists and policy-makers (Sjoberg & Drottz-Sioberg 2008; Bradford et al. 2012). Therefore, it is critical to understand how the public constructs risk concepts in order to implement successful risk management policies (Sjoberg & Drottz-Sioberg 2008). Sjoberg and Drottz-Sioberg (2008) found in their study that the public and politicians have different perceptions about risks to health and the environment than those of experts. There are a number of factors that can influence public risk perceptions. Gierlach et al. (2010) and Weber (2010) highlight demographic and cultural factors, Bosschaart et al. (2013) indicate knowledge and awareness as critical factors influencing perceptions and Viklund (2003) highlights trust as a critical factor to influence perceptions.

Resilience of a system requires the ability to adapt to changes. Therefore adaptive capacity would entail the ability of individuals or groups to recover from a hazardous event and make adjustments to become more effective in dealing with disasters (Birkholz et al. 2014). Birkholz et al. (2014) argue that to develop adaptive capacity there needs to exist interest and drive among the public to adapt and that is linked to their perception about risks. Chapter 6 and 7 of this thesis discusses perception as a critical barrier to the management of SES with particular focus on the current perceptions of communities in the case study area. Discussions ensue on exploring factors/drivers that influence their perceptions and the likely impact of such perceptions in addressing the flood management issue in the case study area.

2.6. Characteristics of a complex governance system in NRM

Governance is a central theme in this study. It is, therefore, necessary to define how this term is used and identify its characteristic features to aid in the analysis of existing system in the case study. Section 2.6.4 describes the criteria for analysing good governance in environmental management. In this thesis, discussions pertaining to governance will encompass several dimensions of this concept. Governance in this thesis is used as an analytical concept to understand how the existing system in the case study area is being governed and also to describe what are the preferred modes of governance are for addressing issues of management in the case study region (Buizer et al. 2011).

In environmental management, governance can be described as "processes and decisions enabled, made and/or coordinated by government and other institutions operating in the public domain"(Dovers 2005, p. 18). Governance of environmental management is a multi-actor process where actors within and outside the government can influence policy decisions (Harding, Hendriks & Faruqi 2009). This characteristic feature of complex governance system has been examined extensively. Bulkeley (2005) discusses this relationship through defining linkages between scalar and non-scaler domains; Bouwen & Taillieu (2004) discusses this through examining interdependenc of entities within a governance paradigm; Ostrom (2010), Newig & Fritsch (2009) and Emerson et al. (2011) call it polycentric, multi-level and collaborative governance, respectively, whereas Dale et al. (2013) define this feature as the structural and functional aspects of a governance system. Each of these concepts is briefly reviewed in this section to emphasise on this defining feature of a complex governance system, which is central to this thesis.

The concept of governance has transformed in the past several decades from hierarchical modes of governance emphasising a one-way flow of information to an iterative or cyclical consultation process with key stakeholders. Recently the scope has broadened to encompass community through co-production, co-management, developing networks and unique alliances (Harding, Hendriks & Faruqi 2009; Buizer et al. 2011). The concept has transformed from 'government' to governance or in certain cases without government (Buizer et al. 2011). Neoliberal governance represents this concept of governing without government, 'for neoliberals, governance is thus reduced to the role of managing conflict and organising negotiations between stakeholders in a free market environment' (Ives 2015). 'The role of the state is to create and preserve an institutional framework appropriate to such practices' (Harvey 2005, p.2). Pellizzoni (2011) describes some contestant views with regards to this concept in environmental governance, however, in relation to this thesis it was essential to mention this form of emerging governance while discussing different dynamics of complex governance.

Bulkeley (2005) while discussing the politics of scales and networks in global environmental governance characterised the nature of a complex governance system. He explains that current understanding of environmental governance outlines a 'territorial trap' regime system where management takes place through vertical demarcation of scalar boundaries and distribution of power largely relies within the state. The scalar divisions, therefore, are created by and for the state, catering to their interests (p. 878). According to Bulkeley (2005, p. 879), 'the scales at which environmental governance [thus] takes place are [considered to be] self-enclosed political territories within a nested hierarchy of geographical arenas'. He argues that environmental governance does not only operate within a demarcated vertical scale but horizontal governance structures also exist.

This multi-level form of governance is defined as 'political structures and processes that transgress the borders of administrative jurisdictions, aiming to cope with interdependencies in societal development and political decisions which exist among territorial units (Benz, 2006, p. 95 cited in Newig and Fritsch 2009).

These horizontal governance regimes work in the form of networks that engage institutions and a wide array of actors functioning across multiple scales. Ostrom (2010, p. 552) suggests that polycentric forms of governance systems have considerable advantages for learning and adaptation. Ostrom et al. in 1961 introduced the concept of polycentric governance which explain the interactions with multiple agencies, both public and private, to enhance resource management at multiple scales (Ostrom 2010). “Polycentric refers to many centres of decision-making that are formally independent of each other…to function as a system” (Ostrom 2010, p.552). In polycentric systems, each governance unit has independence within a specified geographic area and domain of authority, and each unit may link with others horizontally on common issues and be nested within broader governance units vertically (Biggs et al. 2012, p. 437). This need for connectivity and interdependence emerges from the realisation that societies live in a complex interconnected world where social and ecological dynamics play a critical role in contextualising a governance issue (Dale et al. 2013). According to Bouwen and Tailieu (2004, p. 140) early practices in NRM ‘led to growing awareness of the dysfunctions of ignoring, interdependences’ resulting in high external costs, time and resources ‘conflicts by poor boundary management and conflicts due to divergent points of views. Bouwen & Taillieu (2004) further elaborate that the characteristics that call for a collaborative governance is underpinned by a number of elements such as the conflicting issues of defining a problem where different stakeholders hold different levels of power, varying degrees of vested interest, disparity in resources and differential access to knowledge and information.

Parag et al. (2013, p.1067) advocate that in today’s context when policy issues are cross-disciplinary and ‘involve a variety of state and non-state actors’ it is important to analyse networks in policy governance. The horizontal transnational networks influence power based on their ability to generate information and knowledge and can work at different scale and territorial boundaries (Bulkeley 2005). This means that some of these networks operate at transnational, international arenas while others move away from state centred governance and operate through formal and informal authority. This is a critical factor to understand when analysing environmental governance as it encompasses scalar and non-scalar components. Bulkeley (2005) suggests that understanding the politics of scale and politics of networks is critical in implementing an effective environmental governance framework. The biosphere and other regional community-based management frameworks adhere to this form of governance. Chapter 9 of this thesis discusses the implications of this form of governance for resource management.

Parag et al. (2013) in their paper on ‘network approaches to local and community governance of energy’ argue that there are a number of challenges in conducting network analysis and determining their degree of effectiveness in environmental governance. Concepts of multi-tier/multi-level governance pertaining to jurisdictional or multilevel government have been discussed in terms of their complexity and coordination issues in chapter 10 (Termeer et al. 2010). Monocentric or a command and control form of governance highlighting top-down government approaches as a barrier to resource management have been discussed throughout this thesis (chapter 4, 6-8) (Termeer et al. 2010).

Another aspect that characterises the complexity of environmental governance and policy is the epistemological and ontological approaches to its analysis that is strongly embedded in the perceived knowledge of the analyst and the subsequent methodology used. ‘How a policy analyst interrogates the social world, and so builds his or her assumptive world, depends, on his or her epistemological predisposition’ (Dixon and Dogan p.210). Dixon and Dogan (2003, p.210) argue that the epistemological and ontological paradigms define specific methodologies each ‘adhering to its particular form of reasoning’ (p.213). As a consequence, an analyst adhering to one paradigm, for instance, the epistemological approach would use the subsequent methodologies for analysis and will unlikely deal with issues that stem from ontology and vice versa. Dale et al. (2013, p. 162) elaborate that frameworks used for analyzing ‘complex polycentric governance systems remain fragmented: displaying many disciplinary or sectoral biases’. It is, therefore, important to recognition this bias in policy analysis. Consequently while analysing policy governance failures it is essential to be sceptical about the cause-relationship drawn in the analysis and the subsequent solutions proposed bearing in mind that complex governance systems are likely to possess both components of success and failure (Dixon & Dogan 2003).

Governance of NRM is complex because it requires extensive and effective collaboration with institutes, formal and informal agencies across scales and within scale. It fosters interdependence that brings into play complex socio-political dynamics that are also influenced by environmental and ecological factors. The above discussion can be summarised into three key features of a complex governance system as prescribed by Dale et al. (2013, 166-170).

1. Complex governance cannot be viewed in isolation. Governance themes, domains and sub-domains are highly inter-connected. For instance, natural degradation will influence economic and environmental governance. Similarly, social and cultural aspects influence local natural resource management thus these social, economical

and environmental domains are inter-linked and need to be analysed as such.

2. Complex governance has a polycentric framework where 'governance systems at any particular spatial scale are influenced by and in turn influence governance and consequent system outcomes arising from different spatial scales'. Within a particular governance theme, for instance, social theme, domains within this theme such as health, education, social development function. Sub-domains which are activities under a particular domain 'tend to play out at different spatial scales and these scales operate in polycentric (not hierarchical) fashion (p.166).

3. Complex governance systems have structural and functional components because of their multi-level and polycentric framework. Structural component of governance include the 'purpose oriented activities'. Dale et al. (2013) define the standard structural components as objective setting, strategy development, implementation and review. The functional aspects of governance refer to the functional capacity of these structural elements both within and across. Integrated knowledge is central to improving the functionality of a system. Both these component are critical for an adaptive decision-making process and continual improvement in a complex governance system.

Section, 2.6.4 provides further elaboration in terms of characteristics of a healthy governance system and an analytical framework for such a system through an established criteria.

2.6.2. Opportunities and challenges of an adaptive governance paradigm

Opportunities for improved governance and management exist through mainstreaming an alternate governance paradigm that helps to bridge the gaps in traditional forms of management. A reformed governance model is needed—one that can harness context-specific learning and adaptation through testing and experimentation; that acknowledges various forms of knowledge; banks on social learning and capitalises on collaborative bottom-up approaches to management and functions within different geographical and governance scales. Adaptive governance demonstrates such principles of participatory engagement and learning.

Adaptive management is a multidisciplinary and integrated approach to address issues of uncertainty in natural systems (Termeer et al. 2010). It can be defined as a systematic process for improving management policies and practices by learning from the outcomes of management strategies that have already been implemented (Pahl-Wostl et al. 2007, p.51). The concept of adaptive management was rooted in the early 1900s (Haber 1964, cited in Stankey, Clark and Bormann 2005). The idea has been reflected in various disciplines, such as businesses where progress assessments and adaptive management processes inform decisions for improvement in productivity, profits and innovation in unpredictable economic market conditions (Senge et al. 1994, cited in Allen et al. 2001). They are also associated with organisational and social learning (Rendell et al. 2010) and experimental science such as hypothesis testing (Kuhn 1970, cited in Stankey, Clark and Bormann 2004).

In NRM, the need for an adaptive form of management emerged in the 1970s (Schreiber et al. 2004) with the realisation that resources are limited and that policies on environment should include aspects of society, economics and the environment (Schreiber et al. 2004).

An adaptive form of governance is seen as an emerging framework to manage complex environmental issues (Gunderson & Light 2006; Gunderson 2010). Adaptive governance enables the adaptability of systems where “actors have the capacity to reorganise the system within desired states in response to changing conditions and disturbance events” (Fold et al. 2005, cited in Termeer et al. 2010). It departs from the traditional scientific approach where “singular scientific and technical solutions [deprived] of political considerations” are in place (Gunderson & Light 2006, p. 325). “Adaptive governance integrates principles from adaptive management and community-based governance to address NRM issues” (Vella et al. 2015). It deals with social and human contexts to enable adaptive management. Hence adaptive governance provides a socio-political framework to allow adaptive management to take place. An adaptive governance system is prepared to deal with change and disturbances.

It can be defined as:

> ...linking a broad range of actors at multiple scales to deal with the interrelated dynamics of resources and ecosystems, management systems and social systems, as well as uncertainty, unpredictability, and surprise. Adaptive governance focuses on experimentation and learning, and it brings together research on institutions and organi[s]ations for collaboration, collective action, and conflict resolution in relation to natural resource and ecosystem management. The essential role of individuals needs to be recogni[s]ed in this context (e.g., leadership, trust building, vision, and meaning); their social relations (e.g., actor groups, knowledge systems, social memory) and social networks serve as the web that tie[s] together the

adaptive governance system. It has cross-level and cross-scale activities and includes governmental policies that frame creativity (Folke et al. 2005, p. 462).

Holling (1978, p. 6) termed it as "a kind of laboratory world for the development of alternative policies and for the exploration of their impact". This type of approach can make best use of optimisation methods which can assist in identifying appropriate policies that can achieve the set objectives that are in sync with the economic, social and environmental context (Holling 1978). This approach presents certain key elements that bridge the management gaps of the conventional scientific approach.

The art of *learning by doing* has always been an intrinsic capacity of humans from the very beginning when little knowledge was available about the world. The available information was used to test situations, and failures resulted in the generation of new knowledge and improved experimentation (Holling 1978). The adaptive governance paradigm takes into account uncertainty in the SES and relies on the principle of "learning by doing" (Cundill & Fabricius 2009) – trialling and experimentation to generate new information. It supports a system of management where a range of strategies can be run as experiments on a large scale to test various hypotheses that incorporate local and scientific knowledge (Schreiber et al. 2004).

There is an increasing recognition of the need to follow a more flexible decision-making process that supports a diversity of knowledge and values (Stiglitz 2002; Reed 2008; Harding, Hendriks & Faruqi 2009). Adaptive governance, in contrast to the conventional top-down command and control regime, promotes a polycentric form of governance (Moellenkamp et al. 2010). It operates at different scales, which allows for the sharing of management rights and power to not only enable stakeholder engagement but incorporate multiple forms of knowledge (Folke et al. 2005; Olsson et al. 2006; Lebel et al. 2006).

Social context is at the heart of this management approach hence inclusive participation of stakeholders is considered vital. Social networks are an essential component in the transformation of SES to adaptive governance. Past practices in ecosystem restoration have shown that such networks have been found to be effective avenues for trust-building, sense-making and conflict management (Olsson et al. 2006). They are used as knowledge hubs where information-sharing and learning takes place.

The Colombian River Basin, for instance, is often referred to as a good case example for implementing adaptive governance. It made use of an overarching network forum, *the Northwest Power Planning Council,* which served as a learning network to draw on various sources of knowledge and directed decisions based on common interest (Mclain & Lee

1996; Lee & Lawrence 1986). In another case such as the Everglades, there is a long history of shifts in the management regimes in response to unexpected system behaviour (Gunderson & Holling 2002; Gunderson & Light 2006) resulting in the emergence of learning networks for implementing alternate management approaches. These learning networks initially constituted only scientific and technical personal which were later extended to political and management arenas when adaptive governance was adopted as a management regime (Olsson et al. 2006).

A system's capacity to endure disturbances without losing the ability to learn and adapt requires resilience (Nelson, Adger & Brown 2007). Tompkins and Adger (2004) suggest that networks and institutions can help to reduce social vulnerabilities which in turn can increase ecosystem resilience.

In the face of uncertainty, a governance approach that is flexible and inclusive needs to be adopted. An adaptive governance paradigm advocates the concept of managing complex systems through a continuous learning process, and adaptive management in turn provides a mechanism to deal with future uncertainties.

2.6.3. Challenges to learning within an adaptive governance paradigm

As described in the previous section, adaptive management is a scientific and technical approach to resource management to tackle uncertainties (Holling 1978). This approach requires a specific set of socio-political and governance factors to facilitate implementation (Gunderson & Light 2006; Vella et al. 2015). Adaptive governance is a framework that can allow the application of adaptive management. Brunner et al. (2005, cited in Gunderson & Light 2006, p.325) explains that this is a form of governance "where the science is contextual, knowledge is incomplete and multiple ways of knowing and understating are present; policy is implemented to deal with modest steps and unintended consequences and decision-making is both top-down and bottom-up".

In theory, although the adaptive management approach is seen as a comprehensive model and has gained wide-scale recognition, the model itself poses complexities at various stages of its implementation where power structures and inclusion of common interests are a core problem threatening its on-ground feasibility (Schreiber et al. 2004; Vella et al. 2015). The Everglades is a prominent example, in this regard, where power structures and conflicting interests continue to stall the implementation of trialling and experimentation (Gunderson et al. 2006). The problem for implementing adaptive management is more political and social than technical (Allen et al. 2001; Wise 2014). The adaptive management paradigm takes a selective approach to political influences. It supports local governance mechanisms and in doing so it tends to 'miss out' the larger influence of politics at scales; factors that take into account societal conflicts and power structures that can influence the processes and selection of experimentation of policies for learning in such a paradigm (VoB & Bornemann 2011). The approach does not provide a systemic process that helps to establish links or an understanding of how experimental learning at a micro-level will be embedded in existing larger institutional arrangements and influence established political beliefs and values (Kiparsky et al. 2012). More often, policies do not support adaptive management which consequently runs the risk of excluding and overlooking interrelated problems or a systems-thinking approach to problem-solving which has been the case in the management of forest wildfire hazards in the US (Busenberg 2004). Prevailing policies and practices cause bottlenecks to the experimentation and trialling process (Gunderson & Light 2006; Kiparsky et al. 2012). There is also a prevailing organisational culture of 'risk aversion' where failures are punished rather than considered to be learning opportunities (Lee and Lawrence 1986; Allan et al. 2008). There is also the fear that adaptive management may expose the weaknesses in the past policies and decisions that the managers are not willing to acknowledge publicly (Allan et al. 2008).

Stankey et al. (2005) emphasise the need for implementing an adaptive management model that inherently banks on a consistent and long-term monitoring regime to provide context-specific experiential learning and knowledge generation mechanism to influence policies. There is, however, a need to gain best value from the limited monitoring resources in order to deliver information that is most meaningful to various stakeholders—decision makers, policy implementers and end users (Smajgl et al. 2010). Challenges do persist in the form of technical language used by water management bodies; inconsistencies in data collection strategies; and the scale at which data reported is available as many organisations are involved in data collection at various scales (Smajgl et al. 2010).

Despite the availability of a large number of monitoring frameworks, the lack of practical implementation of these frameworks remains an issue to be addressed. Hence the existing models of monitoring are either too theoretical to be adapted or are too simplistic and linear to address the uncertainties and complexities of natural systems and often tend to ignore the social variables (Guijt 2008; Cundill & Fabricus 2009). Furthermore, despite the legal framework that advocates stakeholders' participation in monitoring, it is often given a low priority due to the time/costs involved (Danielsen et al. 2008).

A predominant challenge in monitoring is maximising the use of monitoring to add value to the decision-making process (Danielsen et al. 2008). This also underlines the issue of setting and selecting indicators that are inclusive of various stakeholder groups' interest

(Brown et al. 2012). Danielsen et al. (2008) identified the need to review local and professional-based monitoring that makes a substantive contribution to the NRM.

A plethora of literature exists in support of involving stakeholder groups in data collecting, assessment and monitoring regimes. More particularly, specific case studies provide a window for examining the benefits of community-based monitoring of natural resources (Bliss et al. 2001; Mayoux & Chambers 2005; Sharpe & Conrad 2006; Metzger & Lendvay 2006; Gurung 2007; Kongo et al. 2010; Brown et al. 2012). Generally, the pre-dominant argument in support of community-based monitoring states that such an approach provides an opportunity to identify local priorities and capture 'dissimilar mind frames' (Timmerman 2005) and an effective participatory monitoring framework enhances communication of data by the communities (Smajgl et al. 2010; Brown et al. 2012).

In practice, the cited literature suggests that monitoring in an adaptive governance paradigm is a challenging ordeal. In most cases, adaptive governance fails to optimally function where opportunities of social learning are not created in the form of institutions (Korten 1982, cited in Mclain & Lee 1996; Kiparsky et al. 2012) weak policy development processes that fail to promote development of shared understanding among stakeholders (Mclain & Lee 1996; Haase 2013) and the absence of community forums and decision-making processes that foster new learning (Allan & Curtis 2003 & 2005; Haase 2013).

So far, adaptive management implementation falls short in the commitment to use monitoring as a learning process (Schreiber et al. 2004). Allan (2005) suggests that the reason for failure in adaptive management at the regional level in Australia is due to the lack of systematic monitoring processes for learning. This is further exacerbated with the absence of long-term funds for monitoring (Schreiber et al. 2004).

More often, monitoring is used to fulfil specific objectives, but elements of social learning are ignored. An example is the Everglades in Florida USA, where complex networks predominated by formal organisations primarily focus on the accumulation of information and not the understanding and learning about the system in ways that may put in question the existing policies (Gunderson et al. 2006).

Carl Walters (cited in Stankey, Clark & Bormann 2005) argues that most of the adaptive ecosystem management interventions fail to materialise on-ground, and the ones that have been implemented are not effectively designed.

Under the above premise, the question remains as to how to manage resilience of SES. What form of governance regime/framwork is needed to break the pathology of NRM, that will identifiy appropriate scale for management and creates learning opportunities to enhance adaptive capacities of SES? Since a key element for enabling communities to manage ecological resilience is through learning (Gunderson et al. 2006), there is a need to review the on-ground existing practices that provide opportunities for social learning and improve understanding on ecological systems. Regions are suitable scales to study SES as they represent interlinkages for institutional, social and physical space critical for humans (Hanspach et al. 2014). A biospheric or total catchment management perspective can provide opportunities to manage inherently complex SES under extreme weather conditions.

2.6.4. Characteristics of a good governance framework in environmental management

The previous sections expand on the characterisation of a typical complex Social-Ecological System. These complexities are described through examining the environmental, social and institutional problem dimensions. Based on the discussion above a SES can be characterised as a system that has linkages both social and ecological across scales, its complexity is entailed both by ecological dynamics and social set-up. In addition, the socio-political construct can advance SES management and can also limit its functional capacity. So far the limitations have been discussed with emphasis on poor governance where scientific and technological inputs support a strict top-down governance regime; centralised decisions lead to exclusive governance, absence of acknowledging different stakeholder interests and knowledge with the understanding that societies need to be steered in a particular direction as oppose to co-adaptive management. Scale is also discussed in the context of policy miss-match and lack of acknowledgement of scale sensitive problems.

This section further expands on the governance understanding in environmental management context. It is intended to discuss typical features that characterises a healthy/good governance framework and outlines a set of criteria that define can be used to analyse a complex governance system in NRM. In doing so, it provides an analytical framework on which regional scale models, discussed in this thesis, i.e the biosphere and catchment scale frameworks, are measured for suitability in resource management with particular focus on flood risk management.

Bulkeley (2005, pp. 877) discusses the reconfiguration of environmental governance by recognising the emergence of transnational networks to manage problems which have global context. Climate Change issues and local biodiversity problems thats emerge in a particular area can have impacts that go beyond the state or national boundaries. The governance arrangement in this context would require international institutions with state-national authority guided by agreed norms and processes to manage issues of the identified areas. Biosphere Reserve frameworks discussed in the later sections of this chapter are an example of reconfiguration of environmental governance where transnational networks are at work. According to Bulkeley (2005, p. 878) such forms of governance regimes 'strengthen the territoriality of nation-states, by reinforcing the importance of the inter-state system, while at the same time weakening notions of territorial sovereignty by allowing the 'global community' to regulate processes occurring within what is frequently considered to be sovereign state space.' This approach also acknowledges the role of non-state actors in policy implementation.

Leys and Vanclay (2010), present a social learning approach of adaptive co-management to deal with the multi-scale society-environment dilemmas in NRM governance. Adaptive co-management gives flexibility to stakeholders in defining their negotiations without being regulated by formal institutions. Leys and Vanclay (2010), argue that for good governance, the need for social networks to address place-based problems is critical. They present four qualities of a good governance system as described below:

1. Nesting or up-scaling of grassroots participatory processes into regional governance systems;
2. Recognising connectivity in NRM and interdependence between vertical levels of governance;
3. The existence of bridging organisation to facilitate collaboration between local and regional scale in a multi-level NRM governance structure;
4. Inclusive multi-level and cross scale participation. Adaptive co-management that enables '[interest groups] to collaborate and respond to change through co-operation and partnerships between diverse stakeholders' (Leys & Vanclay 2010, p.6).

Then main constituent of good governance is its collaborative nature. Green and Dzidic (2014, p.1784) argue that inclusiveness and integration are key principles in a collaborative governance approach. Furthermore, they claim that to achieve holistic good governance in NRM requires improving relationships between community, catchment and regional entities. Wallington and Lawrence (2008) claim that when planning processes in NRM are streamlined according to local aspirations and beliefs they are far more likely to succeed. Thomsen (2008) also emphasis that complex environmental governance becomes positively functional when there is recognition of the value of integration of different forms of knowledge to address NRM issues.

Emerson et al. (2011) presents an integrative framework for collaborative governance in the form of three nested dimensions i.e. collaborative governance regime, where regime refers to decision-making process that enables cross boundary collaboration; system context; and drivers which form the collaborative dynamics and are influenced by the system context resulting in either refraining or facilitating collaborative governance. Emerson et al. (2011) integrated framework identifies three main drivers for collaborative governance which include engagement as a central driver, in addition to capacity for joint action and shared motivation in a defined system context. These drivers inform a collaborative governance regime, forming the second dimension of nested governance that results in collective action and evaluation of impacts for adaptation. Elements of leadership, trust, interdependence, legitimacy, knowledge and resources are some of the criteria that define this integrated form of collaborative governance.

Based on the above premise it can be concluded that a complex governance framework needs to have a number of features for it to foster a healthy SES. The requirements of a good environmental governance framework have also been discussed in previous section of this chapter. In summary, frameworks that support socio-cultural parameters in policy decision-making (Stratford & Davidson 2007, section 2.5.3); the capacity of a system to assess and manage risk in environmental decisions (Harding, Hendricks & Faruqi 2009, section 2.5.4); incorporation of processes that facilitate multi-level, cross scale interacions (Gale 2015; Haarstad 2014; Kok and Veldkam 2011; Moss and Newig 2010; Termeer et al. 2010; Garmestani and others 2009; Cash et al. 2006, Section 2.5.2); and recognition of the inherent complexity of SES (Holling 2001; Gunderson 2010; Halliday and Glaser 2011, Section 2.4.1) have been discussed as principles for a healthy system of governance.

In order to analyse a complex governance system, Dale et al. (2013) outline a five-step process supported by seven attributes of good governance which are similar to Lockwood et al. (2010), see below. According to Dale et al., the first step for analysing complex governance system is to contextualise the system. This requires scoping the system that is to be analysed and streamline the global context in which it fits i.e. defining the governance themes (social, economical, environmental) and domains and sub-domains (activities taking place under each domain/sectors of governance). This requires the examination of legal frameworks, network mapping, culture and diversity components of the system. The second step entails benchmarking desired system outcomes. This requires determining the outcomes that the governance system is trying to achieve and the structures and functions available to achieve it. The third step involves outlining the system's structural and functional characteristics. Examination of structural components requires mapping of institutes involved in different roles and responsibilities in vision and objective development; research and assessments; strategy development and implementation. The functional components, on the other hand, would include analysis of knowledge generation and information dynamics between institutes; degree of collaboration/coordination between institutions; technical, skill and financial support for involved participation, other attributes include leadership, motivations and negotiation capacities of participants. The fourth step focuses on the application of a common set of evaluation principles Dale et al. (2013) discuss seven attributes for analysis: sustainability, equity, accountability, adequacy, effectiveness, efficiency and adaptability. The final stage of analysis of a complex governance system involves the development of strategic reforms for system improvement that emerge from information gained from previous steps.

Dale and collegue's (2013) five step strategy for analysing complex governance system are applied to the case study with mapping and role recognition carried out as a 1st step (Chapter 4 & 5), followed by mapping out the structural and functional components in Flood Risk Management (Chapter 6 & 7) and examination of a criteria to evaluate the success of regional frameworks and its implication for the case study area (Chapter 8 & 9) with conclusion of recommendations for an improved framework (Chapter 10).

Lockwood et al. (2010) argue that in order to deal with complex wicked problems in NRM a reform of conventional governance frameworks is required. The new governance framework 'would posses the capacity to deal with uncertainty, manage interdependence among actors and foster connectedness between diverse interests at different scales and across jurisdictions and galvanise resources skills and knowledge more effectively than conventional [model]' (Lockwood et al 2010, p. 988).

In Flood Risk Management, which is the key component of this research, criteria for assessing healthy governance system entails attributes that are similar to that of a good governance system for NRM. Ward et al. (2013) discusses a number of components that characterise governance in Flood Risk Management. According to them the governance structure is multi-level across different sectors; this supports a catchment-scale approach which is a critical pre-requisite for water resource management and supports multi-actor governance with effective stakeholder engagement and participations. There is transparency and openness regarding roles and responsibilities and it presents a flexible system of regulation and policy. Finally its context should support a range of social and economic values. Alexander et al. (2015) identify legitimacy and societal resilience as the capacity to absorb shocks and recover adaptive capacity. Financial and economic efficiency are also critical merits of effective flood risk governance. These attributes are also used to evaluate flood risk governance (Kaufmann 2015). In addition, as with NRM governance, collaborative governance, multi-level stakeholder engagement and social learning elements are deemed imperative for flood risk governance (Hutter 2016; Challies et al. 2016; Kuhlicke et al. 2016; Thaler & Levin-Keitel 2016).

For the purpose of further analysis in this research, governance principles as defined by Lockwood et al. (2010) have been used as the main criteria for identifying strengths and weaknesses in the regional scale NRM management models used i.e for Biosphere Reserves and Catchment Scale models (See chapters 8 & 9 for details). Lockwood et al. (2010) define eight key principles of good NRM governance, which have been adopted as assessment criteria for this research.

Table 2.1. Eight essential principles for good governance of NRM and a summary of attributes.

#	Principles	Main attributes
1	Legitimacy	• Validity of an organisation's authority to govern. • Maintain dialogue between stakeholders and their constituencies. • Allow stakeholders to influence decision-making. • Exercise authority with integrity and honesty.
2	Transparency	• Visibility of decision-making process. • Clear communication of reasons behind decisions. • Accessibility of information on organisational performance.
3	Accountability	• Clearly allocated responsibilities. • Access to information for meaningful consultation. • Enables active participation from citizens/informal institutions.
4	Inclusiveness	• Provides opportunities for stakeholders participation in decision-making process and action[1]. • Equal opportunities for engagement for all stakeholders. • Fosters collaborative approaches and decentralize governance.
5	Fairness	• Respect for stakeholders views. • Absence of personnel bias in decision-making. • Fair and equitable exercise of authority.
6	Integration	• Coordination across different governance levels. • Horizontal coordination and connection between organisations. • Alignment of plans and activities across governance organisations.
7	Capability	• Technical, financial, human and other resources to effectively deliver organizational responsibilities. • Effective business/knowledge systems to deliver NRM obligations.
8	Adaptability	• Ability to incorporate new knowledge and learning into decision-making. • Anticipation of risk, threats and ability to manage them.
[1]According to Lockwood et al. (2010) this overlaps with the first principle but the primary focus of the first principle is representation and acceptance where as inclusiveness focus of opportunity for participation.		

A review of literature in this section demonstrates that a good governance framework can be evaluated in a number of ways and that a wide-range of criteria for analysis exists. A workable governance system will have both strengths and weaknesses to make it work.

This thesis centres on issues of governance in a complex SES where scale is central to the discussions. Consequently, the two frameworks analysed as good governance models present ideal examples of a multi-scale mode of governance in NRM and flood management. Likewise they set good examples of fulfilling most of the criteria set for a healthy system of governance as outlined by Lockwood et al. (2010). The following sections introduce these frameworks, which are later discussed in comparison to the governance system used in NSW and evaluated against the good governance criteria (See chapter 8 & 9 for details).

2.7. A biosphere system's perspective of governance—opportunities for managing SES at a regional Scale.

Chapter 9 of this thesis elaborates on the practical implications of a Biosphere Reserve framework to address the management barriers in the case study region. This section, however, provides a conceptual understanding of Biosphere Reserves framework and its origin. "Biosphere refers to that part of the earth supporting life. The biosphere provides our living space and our economy" (Brunckhorst 1999, n.p.). It can be described as a "thin layer of earth, air and water that covers the face of the earth and encloses everything that lives . . . "(Giacomini 1978, p. 196)

UNESCO's *Man and the Biosphere Program* (MaB) initiated in the 1970s recognises that people transform their environment based on individual values, beliefs and opinions, independent to nature. "Man is treated in as much as he is an agent of deterioration of the biosphere, and it cannot be denied that this is a reality" (Giacomini 1978, p. 196). Hence the planning and management is a process that entails "development taking nature into account [and] conservation taking man into account" (Giacomini 1978, p. 197).

The Biosphere Reserve (BR) program differs from other global conservation frameworks and conventions such as the Ramsar and the World Heritage, primarily because it allows sustainable development and designates a relatively small area as 'core' protected area (Price, Park & Bauamrane 2010). The Program sets out to gain a deeper understanding of changes occurring in nature due to human interventions and the repercussion of these changes on the entire system (biosphere). An essential element of the Program is its focus on education and information that is required to understand and better manage the impacts of changes within the system. Put simply, the Program aims to achieve "a sustainable balance between the conflicting goals of conserving biological diversity, promoting economic development, and maintaining associated cultural values" (UNESCO 1996, p. 3). The objective is fulfilled by experimentation and testing on model sites called the Biosphere Reserves.

> Biosphere Reserves are sites designated by UNESCO with the mission of "maintaining and developing ecological and cultural diversity and securing ecosystem services for human wellbeing" (UNESCO, 2008, p. 8) in collaboration with a suitable range of actors, often including local communities and scientists. They are promoted as "sites of excellence" and "learning sites" in this regard (UNESCO, 1996) (Schultz, Duit & Folke 2011)

The Biosphere Reserve concept aligns with the adaptive governance approach of management as these landscape-scale Reserves are used as model sites for experimentation and learning through the trialling of innovative interventions that deal with emerging problems (Nguyen, Bosch & Maani 2009). The learning laboratory concept in a biosphere reserve framework refers to either a physical space for learning and research, and is also defined as 'a process, or a setting in which a group can learn together' (Nguyen, Bosch & Maani 2011, p. 52).

The management of a biosphere reserve is based on three principle functions; efforts that harness biological and cultural conservation, promotion of sustainable development and opportunities for learning and capacity-building (UNESCO 1996). The third principle is guided by efforts to contribute towards research, education and long-term monitoring. The principal functions of the biosphere reserve are executed through processes of capacity-building, environmental education, community engagement, integrated land management, regional planning and development (Matysek, Stratford & Kriwoken 2006). These are implemented through the process of zoning. Three distinct zoning categories have been defined for a Biosphere Reserve:

- **Core area**—where conservation of resources is governed by legislation. This is similar to a national park. It is an undisturbed area which has a legal protection status.
- **Buffer zone(s)**—is outside the core area. "Uses and activities are managed in ways that protect the core zone. These uses and activities include restoration, demonstration sites for enhancing value addition to the resources, limited recreation, tourism, fishing and grazing, which are permitted to reduce its effect on core zone" (Ministry of Environment and Forest 2007).
- **Transition area**—is an area outside the buffer zone that allows for learning and education through the implementation of innovative demonstration activities.

Activities are undertaken to meet the sustainable development goals of local population in the area (Price, Park & Bouamrane 2010).

Biosphere Reserves provide a framework that allows for the holistic integrated planning and management for bioregions at a landscape level where processes of human and environment interactions occur over multiple temporal and spatial scales (Brunckhorst 2001). They are the only model for landscape-scale management that takes into account sustainable resource use and resolution of conflicts to facilitate and engage stakeholders on such a large scale (Matysek, Stratford & Kriwoken 2006). This framework allows communities to own and take responsible actions for managing their natural resources. This is in contention with the sectoral approach to management where responsible 'parties' — both public and private sectors—manage their own patch in isolation or are "being excluded from ownership and responsibility for managing nearby public land in a wider context" (Brunckhorst 1999, n.p.). The biosphere reserve program provides the mechanism to coordinate socio-economic and environmental initiatives and enhance research, knowledge and the capacity of the stakeholder at different scale to adapt to future uncertainties (Brunckhorst 2001).

Consequently, a bioregional or biospheric perspective of resource management can help to provide the 'big picture' across scales. According to Garmestani et al. (2009), " a basin-wide governance institution to deal with system-wide problems and processes and coordinate efforts of spatially differentiated parts is needed (p. 1053). A critical element of an adaptive policy paradigm is the continuous monitoring of the policy to assess the utility. Biosphere Reserves can serve as instruments to provide the foundation for testing and trialling policies at a given scale. Garmestani (et al. 2009) suggest that it is essential to recognise the valuable attributes of nested systems and their stakeholders, and identify sustainability issues residing within a Panarchy. Biosphere Reserves for regional scale management, in principle, can provide a framework that strengthens connectivity between institutions at various scales—local, national and international—to address sustainability issues of SES. In addition, they are sites for testing innovative governance:

> Biosphere reserves constitute innovative approaches to governance at multiple levels. Locally, biosphere reserves are a potent tool for social empowerment and planning; nationally, they serve as hubs of learning for replication elsewhere in the country; internationally they provide a means of cooperation with other countries. They also provide a concrete means of addressing international obligations such as Agenda 21, the Convention on Biological Diversity, the Millennium Development Goals, the Plan of Implementation of the 2002 World Summit on Sustainable Development and

the UN Decade of Education for Sustainable Development (UNESCO 2005, n.p).

2.8. A catchment-scale management framework—opportunities and challenges for managing SES

International focus on water and sustainable development was substantiated during the Dublin Conference on Water and Environment in 1992. The conference recognised the conflicts in water management as a result of overuse. As one of the four Dublin principles, this landmark conference, emphasised that "water development and management should be based on a participatory approach, involving users, planners and policy-makers at all levels" (Hooper 2006, p.4). This all-inclusive, participatory management of water resources requires that water governance should involve participation at vertical and horizontal scales.

Catchment scale management models address three main principles for management; a holistic approach to management enabling integration of land, water, biodiversity and community resources at a water catchment-scale; engaging communities in planning and management; and balancing between resource use and conservation (Williams 2010; Williams 2012; Dale et al. 2014).

Conventionally, water resource management has been managed rather administratively through its natural boundaries (Hirsch et al. 2005). Frameworks such as the Integrated Water Management, Integrated River Basin Management and Integrated Catchment Management define a more contemporary approach to water management (Ingram 2008; Moss & Newig 2010; Grigg 2012) These frameworks advocate the understanding that activities in one part of the catchment may influence people and their environment in another part of the catchment and because of this there is interdependence between different water users which needs to be taken into account when managing at a river basin or catchment-scale for a broader understanding of SES. These frameworks focus on ecological scales of a catchment and challenge managers and decision-makers to amalgamate two different scales to manage resources sustainably, (i.e., the ecological and administrative scales including local, district, regional, state and national) (Moss & Newig 2010). According to (Hirsch et al. 2005) the biggest challenge within catchment management frameworks is to match scales. The challenge exists in "combining the local scale management with decision-making at greater scales in a way that addresses catchment-wide social and ecological interconnections that do not become separated from these local mechanisms for accountability and participation" (Hirsch et al. 2005, p. 9). Furthermore, "without scale sensitivity to what commonality of interest and the commons themselves mean and imply" there is a tendency to move from a shared resource management to mainstreaming dominant views of influential interest groups (Hirsch 2006, p. 112).

Adoption of catchment-scale management of water resources acknowledges that the decision-making process needs to be more decentralised. Hirsch et al. (2005) identifies two critical benefits of a participatory approach prescribed by the catchment-scale management framework. Participatory catchment management programs help ease bureaucratic and centralised decision-making processes and allow ownerships of decisions.

Catchment scale management in Australia emerged as a means of improving natural resource management. Challenges of developing consensus at a regional level were considered as a critical problem due to the inherent complexity of SES and different perceptions and understanding of NRM priorities (Williams 2012). Integrated catchment management can provide opportunities for managers to address issues of economic growth, urbanisation, weather extremes and sustainable landscape management (Williams 2012).

In NSW Australia, integrated catchment management dates back as far as 1948 when a Hunter River Flood Mitigation Committee was formed to manage floodplains and propose integrated solutions for the next 20 years (Williams 2010). In the 1980s, NSW became the first state in Australia to institutionalise total catchment management. The enactment of the Catchment Management Act in 1989 led to the establishment of catchment models and the subsequent reforms in NSW (Williams 2010). Initially the state was governed by 43 Catchment Management Committees which were up-scaled to 18 Catchment Management Boards. Further reforms led to 13 amalgamated Catchment Management Authorities (CMAs) based on the rationale that it would provide economy of scales, better regional integration of national resource management, community participation and have statutory power which the previous catchment-scale models did not possess (Hirsch et al. 2005). The catchment-scale framework varies between different states in Australia; Victoria, for instance, also have a CMA model but unlike NSW, it focuses on floodplain management.

While catchment-scale models have been implemented to increase integration and participatory approaches to natural resource management, significant challenges exist to gain the maximum benefits of implementing such frameworks. Issues of boundaries, different ideologies, and interests of stakeholders and the varying degrees of roles and responsibilities of organisations involved are central to achieving effective catchment-scale management (Martin & Lockie 1993). Empirical studies in the Hunter Valley NSW suggest that a fragmented approach to generating information based on biophysical phenomena exists, which is synthesised at inappropriate scales (Martin & Lockie 1993). Catchment scale dry land salinity management in the Hunter Valley provides an example of how catchment-scale management fails to be effectively implemented. Martin and Lockie (1993) argue that in case of the Hunter Valley, information acquired was not effectively processed or stored in a way that could be utilised by the catchment committees. The situation was further exacerbated due to a lack of integration between different information sources and furthermore, the information that was available was localised and could not be used to make catchment-scale decisions (Martin & Lockie 1993, p.78). This is often a limitation when assessing regional or catchment-scale risk analysis (Chen et al. 2014). Catchment scale models require an approach to generate information that moves away from the expert-centred approaches. It needs to provide a catchment-scale perspective and at the same time have utility for local communities involved to ensure participatory decision-making processes to manage catchment (Chen et al. 2014, p. 80).

Flood management at catchment-scale has increased recognition in regions tackling climate change. “Catchments are a whole system; rivers are highly linked and flooding in lowlands may be a result of local conditions and activities upstream affecting surface run-off” (Wentworth 2014). In the UK, this framework has gained significance in the past decade, where catchment-wide integrated management is viewed as practices that reduce flood risks and provide wider benefits in improving water quality (Wentworth 2011). Catchment scale flood risk management requires information to be generated at a relevant scale. In the UK, development of regional opportunity maps have helped to identify areas with the potential to reduce risk through soft measures (Wentworth 2014).

In Australia, best practices, principle and guidelines recommend more catchment-wide flood planning that goes beyond the local jurisdictions.

> Flooding needs to be considered from a catchment-wide perspective in order to manage effectively the result of existing development and the cumulative effects of future development on storm water and mainstream flooding. This perspective includes both the upstream and downstream implications of proposed land use development and floodplain management activities (Commonwealth of Australia 2000, p. 7).

For flood risk assessments, GIS mapping is an appropriate tool commonly used (Chen et al. 2014). In most cases in Australia there has been generally little understanding of flood behaviour due to lack of information and historical data (Tinnion 2013). Flood modelling has been done individually within local government boundaries to assess and mitigate local impacts. Catchment-scale flood modelling that takes into account wider impacts, including rural communities, are rare in Australia. The first catchment-scale modelling was commissioned by the Queensland Reconstruction Authority for the Condamine Balonne catchment in Queensland, after the 2011 floods (QFCI 2012). The application of a catchment-scale model in Condamine Balonne catchment revealed that having a flood model for an entire catchment can show previously unknown flood behaviour, increase understanding of regions where there is little to no flood information and help prioritise funding for detailed flood studies in regions that are more flood-prone, help improve emergency management and direct regional land use planning (Tinnion 2013).

In line with Queensland, other states in Australia are also moving towards reforms in flood management. In Victoria, where catchment-wide flood risk management is carried out through CMAs, recent reforms focus on linking regional scales to a more systematic, state-wide approach which takes into account total risk management rather than focusing on individual processes (Ronon 2009). In NSW, for the past two decades, flood risk management is predominated by developing individual flood risk management plans for target areas at the local government level. More recently, Richmond River County Council have made progress in implementing a catchment-based approach to flood management in the Richmond River catchment in northern NSW (Caddis et al. 2012). It has been anticipated that a catchment-based model for the Richmond River that encompasses five LGAs will provide an advanced flood warning system, ensure consistency in information and existing flood data which will increase its utility for multiple users including local managers (Caddis et al. 2012).

There is a need for a wider acceptance of catchment-scale flood risk management, in particular, under the prevailing climate change conditions. In the Netherlands, an attitude of acceptable uncertainty is being practised where initiatives are trialled 'without accruing proof of effectiveness' (Wentworth 2014). In the UK and Australia, however, funding are prioritised for flood risk management with the expectation that the initiatives will provide a positive outcome (Wentworth 2014, Worley Parsons 2009). Such approaches to management inhibit an 'openness to learning' culture. It leads to a compartmentalised governance, a lack of long-term monitoring of flood risks, and scales mismatch, where local information and scientific models are used to generalise impact on large scale and hinder the implementation of catchment-scale integrated frameworks for resource management (Wentworth 2014).

Despite the challenges such frameworks present, holistic models such as these are used to tackle critical problems of natural resource management. According to Martin and Lockie (1993), local participation, which is a significant component of integrated catchment-scale management, serves to help people get involved in environmental decisions regionally, and at the same time help link what they value locally in their district. Incorporating local knowledge ensures a more integrated perception of the catchment. It not only helps to broaden the perspectives of local communities but also provides a more integrated understanding for decision makers who represent more centralised institutions (Martin & Lockie 1993). Principles of adaptive management require a better understanding of human and ecological interactions; hence, frameworks that view SES as linked interconnected systems to address resource management issues provide opportunities for adaptive management under climate uncertainties.

2.9. Coping with Socio-Ecological-System's resilience, adaptation and future unpredictability through biospheric and catchment scale frameworks

The management of natural resources presents a governance challenge which requires political will to support adaptive policies, scientific inputs to promote research and knowledge along with logistical support through established institutions. Frameworks like the Biosphere Reserves and water catchment-scale management bring together key elements that are essential for an adaptive response to future uncertainties. It emphasises an interdisciplinary approach to research, values nature conservation and advocates education and monitoring as tools for improving understanding to inform management actions (Ishwaran, Persic & Tri 2008). The design allows for a context-specific management and governance regime that takes into account socio-economic values and the needs of specific areas.

Advocates of bioregional, landscape or ecosystem scale approaches to management argue that ecological integrity and biodiversity conservation is possible if protected areas are linked with its surrounding landscapes and corridors (Batisse 1997). A "landscape-ecological approach will be able to maintain the value of protected areas if the effects of climate change lead to vegetation shifts" (Batisse 1997, p. 14). The Biosphere Reserve concept provides the framework for managing SES at a regional scale. The zoning of areas into Core, Buffer and Transitional categories aid in maintaining the connectivity of ecological assets to social dimensions of development spread at regional and landscape scale. Similarly catchment-scale management helps to synthesise knowledge from a wider community and provides a broader understanding of social, economic and ecological systems within a catchment (Lawrence, Bennett and Barchiesi 2003).

The Biosphere Reserve follows the 'learning by doing' principle of an adaptive management paradigm. Learning requires the testing of concepts, values and assumptions against real-life situations. Ishwaran and colleagues (2008) argue that the gap between policy and practice is accounted for by the absence or lack of data, information and knowledge; hence, "the ability of knowledge to serve as an improvement of conservation and development relationships is the fundamental rationale for the Biosphere Reserve" (Ishwaran, Persic & Tri 2008, p. 12). In an environment that is continuously changing, there is a need to utilise knowledge generated from scientific research, monitoring and on-ground practice to direct policies that are adaptive to uncertainties. While sharing insights into the current policy issues ,Levin and others (2012) argue that super-wicked problems like climate change require a rethinking of the process by which policies are developed and implemented —a change in paradigm that allows for policy to unfold and mature temporally and spatially and influence 'path-dependent trajectories'. The spread of Biosphere Reserves and Catchment-oriented management scales help to extend knowledge networks across local jurisdictions. They help to provide context-specific experimental sites to test policy implementation for sustainable development at various scales (Nguyen, Bosch & Maani 2011). The concept of 'learning laboratories' helps to bring together scientific, experiential and indigenous knowledge systems. It provides a systematic process to identify problems, issues, and drivers, and defines interdependent relationships through the development of conceptual models and causal relationships of a complex system (Nguyen, Bosch & Maani 2011). This process is essential to identify knowledge gaps, support key research areas and identify appropriate policy intervention.

Lawrence, Bennett and Barchiesi (2003) recommend a catchment-scale adaptive management framework which prevents managers locking into implementing strategies pre-dominated by the reductionist scientific approaches. They suggest six critical phases for adaptive management at water-catchments scale. This would require management of SES through instituting regional processes for information generation and delivering, agreed upon by different stakeholder groups in the catchment. This would be in addition to gaining a common vision and objectives for the catchment followed by the establishment of a dynamic data analysis and communication source equipped with a rigorous monitoring and evaluation process.

The concept of learning laboratories also relates to SES resilience. SES resilience is characterised by the ability of a system to sustain its functional capacity when faced with disturbance; the ability to self-organise and the capacity to learn and adapt (Folke 2006). The ability of the system to 'self-organise', is a characteristic that requires a network of formal and informal institutions that supports a learning environment for adaptation. For this to happen, Baldwin and Chandler (2010, p. 638) argue that "systems and processes are needed to foster dialogue to build a shared understanding of diverse perspectives and common ground". A framework that allows for international and national drivers to ensure ‘top-down’ political commitments and ‘bottom-up’ support to implement context-specific interventions. These regional frameworks provide such opportunities.

The relationship between adaptive capacity and resilience is yet again described from different perspectives. Adaptive capacity is more often linked with the learning ability of a system to cope with perturbations or ‘a collective capacity of the human actors in an SES to manage resilience’ (Gallopin 2006, p. 301). Social capital is essential for SES to adapt to change (Folke 2006). Ishwaran (and others 2008) argue that the gap between policy and practice exists due to the absence of human institutions that are a precondition for effectively utilising the available knowledge. Adger (2003, p. 392) emphasised that ‘social capital is a necessary “glue” for adaptive capacity, particularly in dealing with unforeseen and periodic hazardous events’. The ability of communities to act collectively depends on the strength and availability of institutional mechanisms. Bonding and networks within and outside the community serve as strengths for the communities to deal with vulnerabilities and increase chances of coping with climate change and recovery (Adger 2003). Adger also argues that the process of adaptation to climate change resides within the communities at risk. Different communities will respond to climate change in different ways depending on their vulnerability status, strength of social networks and availability of institutions, based on their available resources they will opt for different strategies. Hence adaptation is a context-specific process that should develop from the ‘bottom up’. In doing so, the threat of climate change is internalised by communities from a global to a local issue whereby the communities take on the responsibility of ‘making decisions’ and getting involved in mitigation and adaptation processes, thus enhancing their adaptive capacity. The learning laboratory concept of the Biosphere Reserve allows for the testing of context-specific interventions and possible solutions for climate change adaptation that can guide resilience strategies and policies (UNESCO 2008, Madrid Action Plan). Catchment scale management also allows for cross-sectoral planning and integration. The Biosphere Reserves demonstration sites can be used to identify and maintain carbon sinks such as wetlands and forests, generate economies and support local enterprises that are eco-friendly and introduce innovative technologies that can improve lifestyle patterns. Close engagement with communities and an approach that supports local governance can allow for collective action and strengthen social capital that is central to the application of these two frameworks.

In addition to the establishment of testing laboratories as learning sites, and the enhancement of social capital to increase adaptive capacity and social resilience, these frameworks help maintain ecological resilience and help improve resource quality. One of the essential elements of complex adaptive systems is their capacity to sustain heterogeneity and diversity through processes of local interaction and dispersal. This gives an ecological system non-equilibrium and non-linear characteristics that enable “change as the system evolves and develops” (Folke 2006, p. 257). According to Levin (1999 cited in Folke 2006) maintenance of biological diversity is essential for complex adaptive systems to self-organise and to allow systems to cope with perturbation and re-organise.

In order to perform these functions, the Biosphere Reserve implementation process is informed by key strategic documents; the more recent being the Madrid Action Plan (MAP). The framework lays emphasis on the role of Biosphere Reserves as knowledge-generating systems for improving understanding about natural systems and sustaining resilience. It also focuses on building cooperative alliances between stakeholders and developing mechanisms for the integration of local knowledge, scientific research and policy to improve adaptation to change. As learning sites for sustainable development, the MAP identifies specific tasks that require agencies to link Biosphere Reserve activities with international, regional and national program programs and strategies in order to foster an integrated planning process (UNESCO 2008, Madrid Action Plan).

2.10. Introduction to the case study region: The Sydney basin bioregion

The Sydney Basin is one of the major bioregions in the state of New South Wales. “A biogeographic region, or bioregion, is a region in which the boundaries are determined by vegetation cover, and the earth’s physical features and climate” (Commonwealth of Australia 1999). The establishment of bioregions within Australia underpinned the understanding that management of natural resources cannot be bounded by man-made state jurisdiction and that a greater level of awareness is required to realise the connectivity and interdependence of larger systems for sustainable management (Hutchinson et al. 2005). Thus the classification of Australian land as bioregions was characterised on the basis of common attributes through a system termed

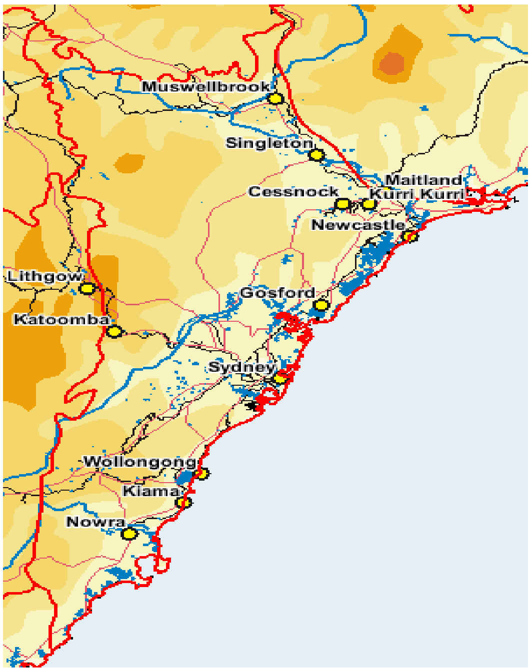

Figure 2.4. Sydney Basin Bioregion (Australian Natural Resources Atlas 2009)

the Interim Biographic Regionalisation of Australia (NSW National Parks and Wildlife Service 2003).

The Sydney Basin bioregion extends from Batemans Bay in the south, including the cities of Nowra and Wollongong on the south coast, and extends as far as Nelson Bay, in the Hunter region on the Northeast of NSW, close to the city of Newcastle (NSW National Parks and Wildlife Service 2003). Within the Sydney basin, the bioregion encompasses Cessnock in the North, and in the west Mount Victoria and Katoomba in the Blue Mountain World Heritage Area.

Apart from being a bioregion, the Sydney Basin is significant not only for its natural heritage but its rapidly growing, multicultural, human population.

In terms of natural heritage, the Sydney bioregion has an abundant supply of natural resources. The Greater Blue Mountain Area, in the west of Sydney, is a globally significant World Heritage Site. It hosts the highest concentration of Eucalypt vegetation in the world (Hammill & Bradstock 2006). This place is home to a wide range of threatened and rare fauna and flora and was formed through the integration of seven National Parks.

In close proximity to the Sydney metropolitan region are two major water resource catchments: Botany Bay to the South of Sydney that drains two major rivers, the Cooks and Georges, and to the west the Hawkesbury-Nepean Catchment that supports extensive agriculture and other industries (CSIRO 2007). A significant portion of the Hawkesbury-Nepean Catchment is occupied by the Greater Blue Mountain World Heritage Area. It presents an interesting case study to examine the issues of managing complex catchment systems.

2.10.1. Challenges to water resource management in the bioregion

The naturally controlled release of water from the valleys and creeks of the Blue Mountains World Heritage area supports the peri-urban agricultural and expanding urban growth of the Sydney Plains. This, however, also presents a challenging environment for sustainable development. With a considerable percentage of land bounded by conservation efforts, the challenge of striking a balance between sustainable resource conservation to meet the growing population demand and the development needs has become critical.

As urbanisation and growth in the bioregion continues, the region’s integrity to function and maintain its resilience is in jeopardy. Urban growth within the Blue Mountains area, limited by its close proximity to rugged bushland has increased exposure to bushfires and ecological damage. The development and urbanisation in the Western region of Sydney is more likely to put pressure on the Blue Mountain's natural resources (Blue Mountain City Council 2004) and that of the Hawkesbury-Nepean catchment (CSIRO 2007). The estimated increase in population in the Sydney Metropolitan region of NSW also implies that the security of future potable drinking water for this growing population will be critical (Regional Development Australia-Sydney Inc. 2011). About half of this growth will occur in the west of Sydney's suburban areas and a further 113% increase in the population is anticipated to occur by 2036 in the south-west sub-region of Sydney (Regional Development Australia-Sydney Inc. 2011).

The increasing expansion of urban areas around the metropolitan region has implications for the natural water systems and flows. The Georges River, in the southwest of Sydney, is a densely populated area and with the increased urbanisation, the catchment has been subjected to different types of pollution that potentially degrade the water quality of this catchment. Main pollution sources include stormwater, increased level of turbidity, nutrient inputs, weeds and introduced species (Georges River Combined Councils' Committee 2012).

The Hawkesbury-Nepean Catchment supplements the water supply for Sydney and its surrounding suburbs (Cheney, Nheu & Vecellio 2007). The demand for water within this catchment is primarily for domestic use, irrigation, recreational and industrial use. With an expanding population, the catchment is at risk of increased pollution, deteriorating water quality, stormwater management issues (Fisher et al. 1992) and increased settlement along the riverine corridors (Cheney, Nheu & Vecellio 2007).

Figure 2.5. HNC boundary with sub-catchments in the region (Hawkesbury Nepean Catchment Management Authority 2006).

The future management concerns are focused on effective mechanisms for water resource governance to meet the challenges of changing geographic and demographic trends in the Sydney Basin bioregion. This situation also needs to be looked into from the perspective of climate change.

2.10.2. The Hawkesbury-Nepean catchment

The Hawkesbury-Nepean region can be categorised as hilly terrain with only 10% of basin classified as flat (NSW Office of Water 2013a). This river system supports agricultural, farming and oyster industries and serves as a major drinking water supply to the Sydney metropolitan area (NSW Office of Water 2013b; Plant et al. 2012). The Hawkesbury-Nepean Catchment covers an area of 22,000 km^2 (Warner 2014). It is one of the major river systems in the NSW (Gillespie et al. 2002). The region forms a complex network of vital sub-catchments (Figure 2.5) that augment flows into the Hawkesbury-Nepean River systems (Warner 2014; Hawkesbury Nepean Catchment Management Authority 2006).

The Hawkesbury Nepean system is divided into two sections; the fluvial (Nepean) and the tidal (Hawkesbury) system. The Fluvial section forms the Nepean River that flows in the northern direction from its headwaters in the Illawarra Plateau past Penrith city (Markich & Brown 1998). Critical to the system is the Warragamba Dam. Its catchment encompasses Wollondilly and Wingecarribee Rivers in the South of the catchment and Nattai, Kowmung and Coxs River in the West (Turner & Erskine 2005). Downstream of Warragamba Dam, the Nepean River forms the Hawkesbury River at its confluence with the Grose River (Pinto et al. 2013). The Hawkesbury River, thus formed, flows in the north-east direction and passes through the cities of Richmond and Windsor which are the largest urban settlements on the river. As the river flows north it is joined by the Colo River that drains the Northern part of the Blue Mountains. Further down its flow, the Hawkesbury River is joined by the Macdonald River and the river continues to flow in a north-east direction where it opens into the sea at Broken Bay (Markich & Brown 1998).

The flows in the system have been impacted by a number of factors. One of them is the development of these in-stream structures. In addition to the changes in the flow due to in-stream structures, the River system is impacted by a number of external factors (Pinto et al. 2012). For instance, the Hawkesbury River System is severely impacted due to low flows and storm water pollution (Diamond 2004; Warner 2014). The floodplains have been cleared for development. The region is impacted by increased urbanisation in the Western region resulting in development of impervious surfaces that are impacting the system's hydrology (Pinto 2013). The South Creek in this region is a highly degraded system impacted by storm water pollution and water extractions and future developments (Rae 2007). In addition to urbanisation and development, the in-stream flows are influenced by the Sewerage Treatment Plants' discharge in the system (Department of Environment and Climate Change NSW and the State of NSW 2009; Plant et al. 2012). The influence of these multiple factors adds to the complexity of sustainably managing this catchment.

2.10.3. Climate change impacts in the Hawkesbury-Nepean Valley

The IPCC Report (Pachauri et al. 2014) indicates that frequency and duration of extreme weather events such as heatwaves has increased over most land areas in Australia. The Australian climate has changed over the past 50 years with increased sea level rise, increased average temperatures and change in patterns of rainfall in South-East and South West of Australia (GHD Pty Ltd 2012).

The future climate change trends in the Hawkesbury-Nepean catchment indicate a warmer and drier climate. These anticipated climate changes would increase the risk of bushfires. In addition, climate change assessment reports (CSIRO Australia 2007; NSW and Department of Environment Climate Change and Water 2010) indicate that there is a likely increase in extreme rainfall events.

Planning for Climate and Natural hazards Risk Assessment Report for the Hawkesbury region identifies the Hawkesbury LGA at risk of wild fires due to changes in temperature and rainfall patterns; increased risk of flooding due to rainfall and sea-level rise; and vulnerability to heatwaves and storms due to climate change (GHD Pty Ltd 2012).

Another Climate Change Vulnerability Assessment study (Eco Logical Australia 2010) of the Hawkesbury-Nepean catchment identifies the Blue Mountain swamps as highly vulnerable to climate change. Climate change relevant impacts on the swamps system is anticipated to be from increased temperatures and the high risk of bushfires resulting in an overall decline in suitable habitat; changes in rainfall patterns can result in drying and channelisation of these swamps; storm water flows can increase due to increase in summer flows that will likely impact these swamps (Eco Logical Australia 2010) According to the report, lack of data on micro-climate and hydrology limits the determination of the extent of these impacts on swamp eco-systems (Eco Logical Australia 2010).

2.10.4. Flooding problem in the Hawkesbury-Nepean catchment

Unique topography

Historically NSW has been a flood prone region since European settlement. The Hawkesbury-Nepean Valley has been identified as a high flood risk region. While describing the flooding history of NSW, Keys (1999) explains that in 1810 the colonial government took measures to mitigate flood impacts by allocating regions in the Hawkesbury as areas for urban development. These included Richmond, Wilberforce, Castlereagh and Pitt Town. However these were later subjected to flooding in the massive 1867 flood. This was the largest flood episode since European settlement (Sydney Catchment Authority 2010).

The estimated economic loss of $1.5-2.5 billion under a 100 year Average Recurrence Interval[3] (1% AEP) flood has been calculated (Ribbons 1997). Ribbons (1997) has emphasised the need to rethink planning and development in the region. The Hawkesbury-Nepean Flood Damages Assessment report shows the extent of areas in the Hawkesbury-Nepean region that can possibly be flooded in the event of a large flood (Molino Stewart Pty Ltd 2012). This is also the case due to the unique topography that creates backflows in the region. In a high water event downstream of the Warragamba dam, large amounts of water spread in the wide floodplains at Penrith and then the much wider floodplains at North Richmond which is then forced to pass through a narrow gorge. Failure of large amounts of water to pass through a narrow outlet to the sea causes the water to back flow into the Richmond and Windsor areas. This back flow is dangerous due to its depth rather than its velocity. The 1867 flood event reached a level that was 3 metres higher than the development today and even two metres higher than the flood planning levels today. The probability of maximum floods is expected to be several metres higher than the flood planning level in Windsor. Bewsher (et al. 2002), elaborates that statistics by Sydney Water indicate that an incident such as a maximum flood can completely inundate the cities of Richmond and Winsor and can cover an area of 300 km^2. The regions of Richmond, Windsor, Penrith and others are growing urban centres and are at risk to the Hawkesbury-Nepean flooding due to increased runoff. Hence an episode of heavy rainfall over a period of just a few days can cause severe flooding in the Hawkesbury-Nepean region (Gillespie et al. 2002).

The dynamics of the Warragamba dam

The Warragamba Dam was developed in 1960. It is the largest water supplying dam in the world. About 80 % of the Sydney's drinking water supply is provided by this dam. This dam impounds Burragorang Lake which receives its primary inflows from Cox, Wollondilly, Nattai, Wingecarribee and the Kowmung Rivers (Sydney Catchment Authority 2010). A few

[3] The long-term average number of years between the occurrence of a flood as big as or larger than the selected event. For example, floods with a discharge as great as or greater than the 20 year ARI flood event will occur on average once every 20 years. ARI is another way of expressing the likelihood of occurrence of a flood event (Catchment Simulation Solutions 2013).

metres below the dam, the Warragamba River flows into the Nepean River which flows through Penrith, Richmond and Windsor (Molino Stewart Pty Ltd 2012).

The construction of the Warragamba Dam was a result of an extensive drought in the 1930s and 1940s (Sydney Catchment Authority 2010). The topology of the area characterised by the narrow gorge, through which the Warragamba River flows, provided the ideal opportunity to store a large amount of water using a dam.

Since its construction, the dam has been periodically upgraded and civil works continue. An increase in the dam wall was suggested in 1995 which was overruled by the then government. Instead other mitigation measures were adopted through the construction of spillways and an improvement in evacuation plans. In recent times, this decision has been criticised as inadequate to reduce the flood risks in the Hawkesbury-Nepean area (Saulwick 2013)

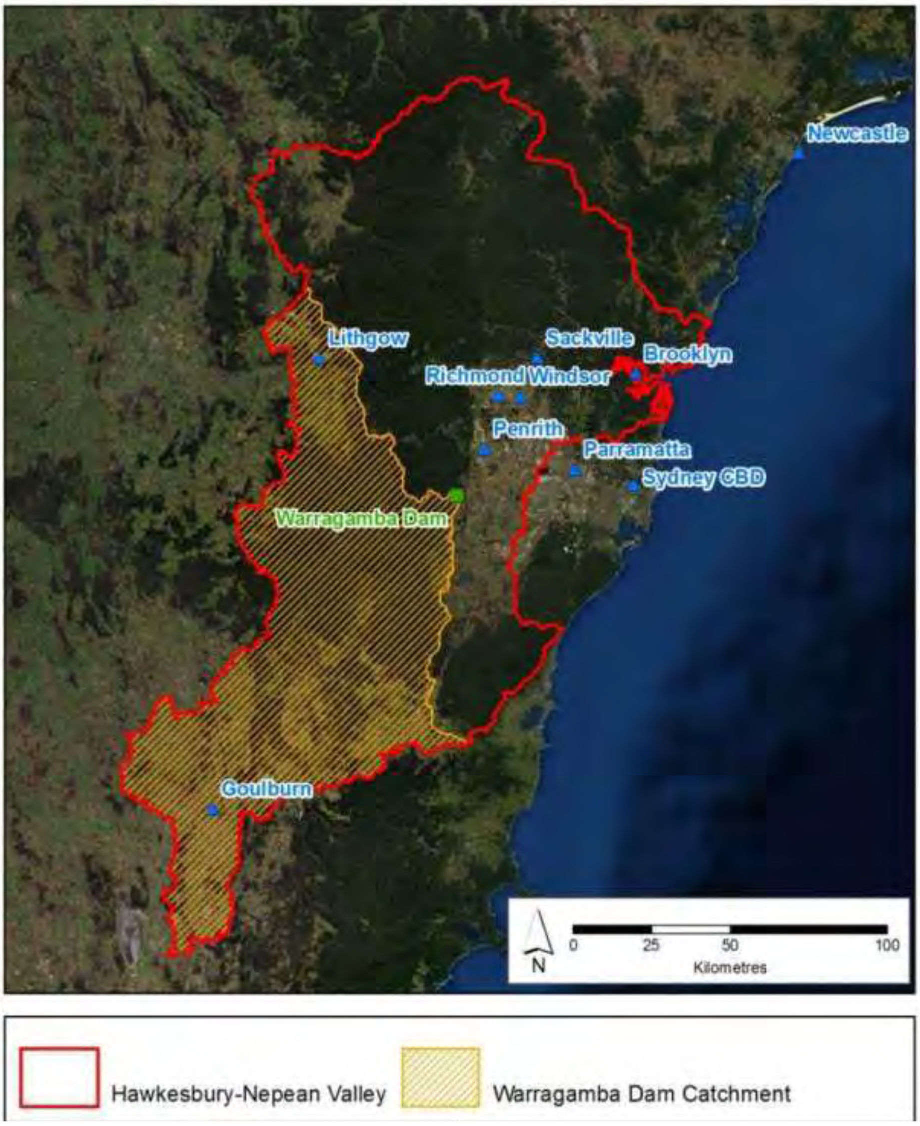

Figure 2.6. Showing the Catchment areas of Warragamba Dam and the Hawkesbury Nepean Valley (Molino Stewart Pty Ltd 2012)

Frequent wet weather events in the Sydney region have sparked concerns about the overflow of Warragamba Dam. In order to mitigate the potential risk of floods in the Hawkesbury-Nepean valley, the possibility of increasing the dam wall to 23 m is under consideration. Hence, the chances of a catastrophic flood have been central to recent debates to increase the dam wall. The issue became more prominent with the warnings and later the actual overflows of the Warragamba Dam in March 2012. The dam overflowed for the first time in fourteen years and experts fear that a major flood in the region may have catastrophic outcomes that could be worse than the Queensland flood of 2011 (Hawke 2013).

The following graph represents the water levels in the dam since 2002. The Y axes show the capacity of the dam over the years (X axes). Recent records show that the water levels have been rising and had reached maximum capacity in 2012. In 1998, 1000 gigalitres flowed into the dam in matter of weeks; if the same event occurred with the current capacity of the dam, the situation would result in a catastrophic flooding event (Researcher, pers. comm., March 2013).

Figure 2.7: Capacity of the Dam over time (Sydney Catchment Authority 2013)

The option of increasing the height of the dam wall to curtail flooding risks downstream opens up a range of issues in relation to how eco-system values are perceived. More importantly, it provides an opportunity to critically examine how issues of scale can be undermined by government taking short-term, reactive decisions as opposed to an adaptive thinking paradigm. The context of this problem becomes more complicated under the extreme weather conditions in the region. The problem that requires attention is how the increase to dam wall will address variability due to climate change and whether the investment in the development of the wall, which is a significant amount, will justify the long-term benefits of this decision?

Development in the floodplains

The NSW Floodplain Management Manual (2005) provides the legislative framework for managing flood risks in the Sydney bioregion. The framework places responsibility on councils to have systems in place for addressing flood issues in their respective jurisdictions. It is also the council's responsibility to review development applications and take into account flood risks in the proposed development area. The acceptance of any development is based on a Floodplain Risk Management Plan (Bewsher, Maddocks & Grech 2002).

The planning for this particular floodplain region requires contextual specification. According to Bewsher (et al. 2002) the 100 year flood level (1% AEP) used for planning and development in NSW is generally acceptable as there isn't much difference in the 100 year flood levels and Probable Maximum Floods[4] (PMF) level. This however is not the case in the Hawkesbury-Nepean floodplains where urban centres are situated in regions that can have several story-height differences in the flood planning level and the PMF. This is an issue as impacts of larger floods have not yet been considered by planning authorities in the region, nor the potential impact they present.

A 2002 survey has identified that most of the councils have not conducted floodplain risk management studies. Most councils in the Greater Sydney area have 'no formal policy relating to overland flow risks' (Bewsher, Maddocks & Grech 2002, p. 4). In addition, the development proposals are reviewed on an ad-hoc basis and crudely defined on a floor level standard against a 100 year flood (1% AEP). Bewsher (et al. 2002, p. 10) indicate that in most cases when approving development proposals the broader floodplain risk management issues are often ignored. The situation is further exacerbated due to the 'bath tub' effect when flood water causes the water to flow back into the catchment. The narrow gorges of this catchment prevent the water from leaving this catchment as rapidly as it entered. With increased development and under flood conditions, it is likely that the backflow will trap people, hindering evacuation by creating flood islands (NSW Office of Water 2014).

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[4] 'The Probable Maximum Flood (PMF) is the theoretically largest flood resulting from a combination of the most severe meteorological and hydrologic conditions that could conceivably occur in a given area (LaRocque 2013)

Councils have a greater level of responsibility to address development in vulnerable regions of the catchments but have limited resources to investigate flooding problems that may result from development (Bewsher et al. 2002). Hence the rapid development of the region can potentially increase flood risks to the communities. Chapter 5 of this thesis elaborates on this issue and the prevailing flood management in practice by the councils, and the consequence of such management.

2.10.5. Extreme weather conditions influences on the resilience of the Sydney basin

The state of NSW faces a challenging future in terms of climate change. As a result of a persistently dry climate, the water resources have been under stress during the past decade. Future climate projected for NSW indicates a decrease in the levels of rainfall, and an increase in frequency of extreme weather events (Engineers Australia 2010). The water sector has also been classified as a ‘high risk category’ (Regional Development Australia-Sydney Inc. 2011, p. 13) under the climate change projections. NSW climate change projections also indicate higher temperatures are expected to increase evaporation levels, resulting in short-periods of intense rainfalls and storms during summers (NSW and Department of Environment, Climate Change and Water 2010). Sea level rise and increased storms are likely to cause coastal inundations and increase coastal flooding. Localised flooding due to climate change and flood-producing rainfall events are difficult to predict and require more sophisticated climate modelling (NSW and Department of Environment, Climate Change and Water).

> The vulnerability and exposure of people and property to flash [and] riverine flooding through all regions of New South Wales is significant and widespread. It is generally expected to increase along with the increasing development density in growth areas and changing community profiles; however, the vulnerability of individual locations to flooding depends on specific factors and needs to be addressed by flood investigations in specific catchments and locations (NSW and Department of Environment, Climate Change and Water, p. 12).

In addition, the future drier climate has been predicted to increase the risk of high intensity bushfire incidents (Regional Development Australia-Sydney Inc. 2011). In the Blue Mountains, situated in the west of Sydney, about 400 bushfire incidents have occurred over twenty-eight years (Worboy & Gellie, 1989, cited in Dragovich and Morris 2002a; Dragovich and Morris 2002b). This means that on an average about fourteen fire incidences occurred each year. Bushfires affect the water quality and catchment hydrology and can have severe impacts downstream (Brown 1972; Prosser & Williams 1998; White et al. 2006; Morris et al. 2008; Blake, Wallbrink & Droppo 2009). For instance, the city of Melbourne faced a 30%

decline in water yield as a result of the 1939 Victorian bushfires—the impacts of which continued for about 50 years (White et al. 2006). Dragovich and Morris (2002b) have described an increased rate of sediment transfer in the Sydney region after a bushfire event due to the loss of vegetation cover.

The Blue Mountains form a "sequence of benches and cliffs producing a stepped topography" (Dragovich & Morris 2002b, p. 1310) that provides a temporary storage of sediments which can be released intermittently following a bushfire event (Dragovich & Morris 2002a); this may result in prolonged water quality problems. This has implications for the adaptiveness of water policies and management plans to sustain a continuous supply of water for a highly urbanised region.

Most of the large-scale bushfires have been attributable to ENSO-related droughts especially in eastern Australia which is highly influenced by the naturally occurring climatic variability (White et al. 2006). With climate change, the Sydney region is faced with increased wildfire incidents in the region (Hammill & Bradstock, 2006).

It is anticipated that the Sydney region will be under constraint due to climate change impacts upstream resulting in low water storage levels (CSIRO 2007). The CSIRO (2007) report highlights that low stream flows in the Hawkesbury-Nepean catchment are to be expected. The Hawkesbury Estuary and wetlands in the catchment will also be negatively impacted due to low flows and reduced runoff (CSIRO 2007), whereas in the northwest region of the State, a 20% increase in runoff is to be expected as a consequence of climate change (Engineers Australia 2010).

Extreme weather events and an increase in sea level rise are likely to result in economic loss of coastal infrastructure and increase vulnerability of communities (Regional Development Australia-Sydney Inc. 2011). Whetton (et al. 1993) claim that with an increase in flooding and extreme weather events, the socio-economic damage will substantially increase resulting in further downstream impacts. The damage, due to floods, poses a greater threat and loss in urban areas in Australia.

Altered climatic effects resulting in floods are known to create hypoxic aquatic environments (Whitworth, Baldwin & Kerr 2012). Whitworth et al. (2012) state that the impacts of unexpected floods and drought regimes due to climate change in Australia calls for a 'whole-of-system approach' for managing the waterways.

2.10.6. Management gaps in the Sydney Basin

The governance of resources calls for management at various scales and across jurisdictional boundaries. For effective governance and planning it is essential to gain an understanding of what is contained within its landscape—at a state, regional, ecosystem and species level (NSW National Parks and Wildlife Service 2003).

Water resource management in the region is carried out by a network of agencies with overlapping responsibilities. The agencies have an independent *Decision Support System* that informs their management discourse within their jurisdictional boundaries. Much of the attention is focused on meeting annual targets as per the individual Catchment Action Plans with very little, if any, attention to collaborative learning opportunities and integrated management across catchments.

A sectoral approach to management has limited capacity to deal with social and ecological complexities and their inter-relatedness at landscape scale (Brunckhorst 2001). SCA has little control over land management practices as most of the land within their catchment jurisdiction is privately owned. Hence management requires strong stakeholder participation. The Hawkesbury-Nepean Catchment Management Authority in its annual report indicated that the challenge to engage in and convince landholders of on-ground initiatives is difficult (Hawkesbury-Nepean Catchment Management Authority 2008).

The Sydney Basin although recognised as a bioregion, lacks the mechanisms to manage the region as a whole. There is a need for a state-wide network that allows for an exchange of information, innovation and knowledge that directs the management of the entire bioregion to build the adaptive capacity of SES against a rapidly changing and unpredictable environment. This requires a "holistic goal-setting, together with collective decision-making and networked partnering" (Brunckhorst 2001, p. 20).

Integrated water resource management across boundaries becomes essential in an area like the Sydney Basin where climate change impacts upstream can influence downstream water management objectives.

Knowledge gaps exist in research and institutional capacities to cope with a rapidly changing environment. One of the challenges identified in the Infrastructure report card was the stakeholder's lack of understanding of climate change on water resources to guide the development of infrastructure (Engineers Australia 2010). The report card provides information on the quality and the provision of infrastructure. Prosser and Williams (1998) have indicated that research and monitoring gaps exist in assessing the impacts of runoff and erosion, as a result of fire, at the catchment-scale. White et al. (2006) emphasise the need for an in-depth understanding of how catchments respond to bushfires, knowledge on the frequency of weather events and the appropriateness of managing water supply catchments. Blake et al. (2009) highlight the need for “better predictive capacity” (Blake, Wallbrink & Droppo 2009, p. 653).

2.10.7. Implications of the management gaps in the Hawkesbury-Nepean case study region

In the Hawkesbury-Nepean catchment, the future patterns of growth, urbanisation and climate change projections highlight some serious potential changes in the hydrology of the region that may threaten the sustainability and resilience of this system. The Hawkesbury-Nepean region of NSW highlights common issues of resource management at a catchment level in the Sydney Basin. Hirsch (et al. 2005) describe complexity in managing this catchment and its socio-political dimensions of conflict between community and scientific- based approaches to its management as well as tension created due to multiple interests upstream and downstream in addition to accelerated development of its floodplains.

The catchment supports the Sydney metropolitan region which is an important business hub in Asia-Pacific and Australia (Regional Development Australia-Sydney Inc. 2011); the Greater Blue Mountain World Heritage Area makes up substantial portion of conservation in the form of wetlands, national parks and biodiversity reserves. Its governance and sustainable planning is challenged by a number of factors: piecemeal management of natural resources at catchment level with poor, if any, integration between catchment management; jurisdictional boundaries; compartmentalisation of sector-wise knowledge management; ineffective information-sharing; and the absence of an information and knowledge management network at a catchment/regional scale (See Chapter 4 for details). The governance of this catchment is further challenged due to the projected increase in future demographic trends, land limitation and increased level of surface water pollution. The impacts of these factors are further intensified when faced with climate changes such as increased threats of bushfires, extreme weather resulting in low stream flows, sea level rise and floods posing threats to water quality and quantity, along with downstream impacts and the increased vulnerability of floodplain communities and their properties.

This catchment, with its complex problems and conflicting goals of development and conservation, presents an ideal case for an in-depth study of the management gaps as discussed above and a review of a regional scale management strategy through implications of the Biosphere Reserve and Catchment-scale management frameworks that can help to address these issues and recommend opportunities to improve SES resilience and its adaptive capacity.

2.11. Conclusion

In summary, this chapter highlights some of the major challenges that threaten the sustainability of Socio-Ecological Systems (SES). Exploitation of environmental resources coupled with extreme weather conditions as a result of climate change have potentially threatened the capacity of SES to cope with abrupt changes. Consequently, a detailed examination of barriers that create system vulnerabilities has been discussed. An in-depth review of literature has helped to identify two main classifications of barriers to SES adaptive capacity; the natural environmental barriers that are inherently complex and unpredictable and the socio-political barriers. The socio-political influences are characterised by a prevalent rigid governance paradigm that values scientific knowledge, implements top-down policies and strategies and undermines inclusive participation and perceptions.

As social and ecological systems are interlinked, this classification of barriers has a profound influence in weakening the systems' positive resilience and its subsequent capacity to absorb damage and readjust to change. Two frameworks, the Biosphere Reserves and the Water Catchments Scale of management provide opportunities for a more system-thinking and integrated management approach. In order to understand the suitability of these approaches, an in-depth examination of the Hawkesbury Nepean catchment is presented.

A typical example of a SES faced with the barriers and issues of system resilience and adaptive capacity are described in this chapter. The next chapter will explain how the analysis of the problem was addressed and what methods were used to generate information and draw conclusions.

Chapter 3: Methodology

3.1. Introduction

This chapter explains why a particular methodological approach and discourse was used. It also elaborates on how research questions and the subsequent analysis chapters of this thesis are linked.

3.2. Research design

In line with the different methods used in this research, a mixed-method approach was undertaken. "Mixed methods involve combining or integration of qualitative and quantitative research and data in a research study' (Creswell 2014). Hence two different forms of data are used to draw connections from the whole. According to McCusker & Gunaydin (2015, p.541) "mixed methods designs can provide pragmatic advantages when exploring complex research questions". Mixed method approaches have been used in a number of published research studies in environmental and other fields. Islas (2012) used the mixed methods approach to study visual perceptions of people towards landscapes affected by fire regimes; Wauters and Mathijs (2013) used qualitative semi-structured interviews that formed the bases of a quantitative survey to determine the socio-psychological factors that influence farmer's conservation decisions; and in other research fields, Matos Marques Simoes & Esposito (2014) used a combination of qualitative and quantitative methods to determine the influence of communication on change management.

According to Creswell (2014, p. 218) a mixed method approach can aid in analysing the following:

- Comparing different perspectives drawn from quantitative and qualitative data.
- Helping to develop a better measurement instrument by collecting qualitative data and then administrating the instrument to a sample.
- Understanding experiential results by incorporating individual perspectives.
- Developing a more complete understanding of the problem through the combination of both qualitative and quantitative data.

A convergent, parallel mixed method form of this approach was deemed most suitable for this research as there was a need to merge different data sets to help interpret and analyse the research problem (Creswell 2014).

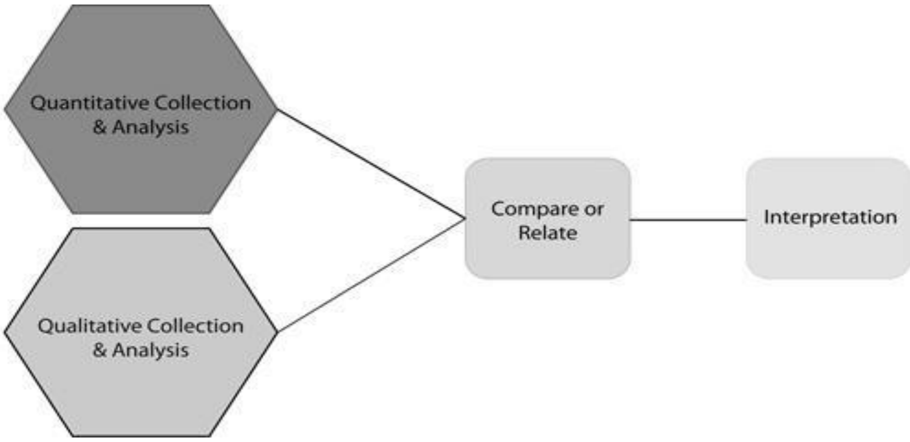


Figure 3.2. Convergent parallel mixed method (Sauro 2015)

The convergent parallel mixed method design (Figure 3.2) requires the collection of qualitative and quantitative data which is analysed separately and then the results are compared to identify conformities and nonconformities. The assumption is that both these different data sets provide different types of information (Creswell 2014).

Both qualitative and quantitative approaches present valuable discourses to address the research questions of this study. For instance, in order to determine the barriers to flood management, it was essential to identify key informants involved in flood management, implementation of policies on-the-ground and risk assessors in the research study area, and to carry out discussions with them through semi-structured interviews. This was done to address the second research question: *What barriers exist in flood risk management in the Hawkesbury-Nepean region?* It was also essential to conduct these discussions with experts and managers involved in managing regional/catchment-scale models outside the research study area in other regions of Australia to address the first question of this research: *How can biospheric and catchment-scale frameworks improve flood risk management issues in the Hawkesbury-Nepean Catchment?* The reasons for selecting key informants for this study were similar to Pinto & Maheshwari's (2014) work on the multi-perspective analysis of river health in the Hawkesbury-Nepean catchment where key informants were selected based on their expertise, knowledge and ability to provide different viewpoints pertaining to their research study. In addition, examining how perceptions of decision-makers and other agencies involved differs and what it means for flood risk management in the Hawkesbury-Nepean Catchment required a more qualitative analysis. In both these situations, semi-structured interviews provided a viable form of data collection.

The use of semi-structured interviews was suitable because it provided flexibility. It banks on the idea that "the relationship between ideas and data is very likely to change during the research" (Curtis & Curtis 2011). Further, "a significant advantage of semi-structured interviews is the opportunity for previously unknown information to emerge" (O'Keeffe et al. 2015, p. 8226). The flexibility was critical as the key informants identified held different positions and control with regard to flood management; therefore, the semi-structured interviews enabled modification in accordance with the informant. This tailoring according to Curtis & Curtis (2011) creates depth in data gathering. Information gathered for this research revolved around the identification of barriers to flood management and identifying suitable management opportunities to address these gaps. Semi-structured interviews were useful to understand the flood management situation through the perspectives of individuals involved. Semi-structured interviews can also provide important information about the drivers that influence a management regime and the motivations behind participant decisions (O'Keeffe et al. 2015).

For a different audience, however, a different approach was required. For instance, in order to assess perceptions of the resident community, a more economically viable and practical approach was necessary. Consequently, due to the sheer number of resident communities, a more suitable form of research instrument to conduct the analysis was adapting a quantitative approach via survey implementation. Survey research is an approach that collects data through sampling from the population and uses statistical analysis (Curtis & Curtis 2011). Bryman (2012) argues that quantitative methods such as surveys also help to determine meaning in a social setting. A major part of this thesis deals with understanding risks to manage them. Johnson & Covello (2012, p. viii) argue that "risk is not an objective reality, instead, the perception of risk is a social process" hence risk perceptions are not always based on scientific reasoning. A number of research studies have made use of surveys to assess attitudes, values and perceptions of communities to address particular research queries (Snyman 2014; Wei et al. 2014; Franklin et al. 2014). Bryman (2012, p. 617) elaborates that the "widespread inclusion of questions on attitude in social surveys suggests that quantitative researchers are interested in matters of meaning". Hence under this premise, a multi-method approach was found to be most suitable for this research study.

The above section establishes the methodological approach to this research and elaborates on the reasons for their use; the following section provides a more descriptive account of the specific methods used in this thesis.

3.4. Descriptive account of the methods used, sampling and data collection

This section provides a summary of the methods used. It should be noted that specific details on the different methods used are discussed at the beginning of each analysis chapter, (i.e., chapter 4 – 9) of this thesis. This was carried out for two purposes; to provide a clear understanding of how the content of the chapter was derived and also because several interviews were conducted at different occasions with the same individuals of a respective organisation and there was the need to clarify which interview data was used to do what analysis. Therefore, the respective information is provided under the section 'method of inquiry' at the start of every chapter.

3.4.1. Semi-structured interviews

According to Maxwell (2013, p. 88), less structured approaches "focus on the particular phenomena being studied and may differ between individuals…and require individually tailored methods". A less structured approach such as semi-structured interviews was used as the dominant method of addressing the research questions. The previous section provides justification for using this method. This section will focus on the design and sampling of this method.

One of the more popular techniques in qualitative research is snowball sampling (Rubin & Babbie 2009). Since this research explored barriers to flood management, it required identification of key participants who possessed an in-depth understanding on how floods are managed and also had the experience and expertise to comment on different aspects of flood management in the Hawkesbury-Nepean catchment. As an outsider to the management and governance systems of NSW and particularly to the Hawkesbury-Nepean catchment, it was essential for the researcher to gain the support of participants to identify other suitable candidates for interviews who were best suited to provide insights to address the research questions. Snowball sampling was useful because it involved identifying individuals who presented the purest or the most clear-cut instance of a phenomenon under study (Watkins & Gioia 2015, p.62).

As per Pinto & Maheshwari (2014) and (Tongco 2007) there is no specific cap on the number of key informants that should be used to address research queries. "The number of key informants in past studies generally varied from 12 to 339 and there are no particular traditional statistical tests required for the analysis of interview data" (Pinto & Maheshwari 2014, p. 1062). Pinto & Maheshwari (2014), however, emphasised that in such studies the key informants selected should be able to address most aspects of the problems under study for a comprehensive and in-depth analysis.

The key informants selected for this research study were individuals who were directly or indirectly involved in flood management or represented an important interest group that was likely to be influenced by flood management policies. These can be broadly categorised as strategic planners, flood managers/engineers, flood risk assessors and researchers.

The following tables (Table 3.1 & 3.2) provide the information on sample size and estimated distribution of target interviewees per different categories.

Table 3.1. Information on the key informants selected for the study

Interview Categories	Number of Interviews
Council Representatives HN* & others	12
Real estate, HN	2
Insurance Groups HN	5
Catchment Management Representatives in Victoria and HN region	5
Emergency and hazard control entities, HN and other regions	4
Strategic planners, flood managers, team leaders and other experts	16
Researchers, HN and Noosa, Qld.	7
NOOSA Biosphere representative	5
Total Number of semi-structured Interviews	56
*Hawkesbury-Nepean	

Table 3.2. Distribution of interviewees across the analysis chapters

Interviews per chapter	Number of Interviews/responses
Chapter 4	11
Chapter 5	12
Chapter 6	19
Chapter 7	178*
Chapter 8	9
Chapter 9	5
*Community survey	

Although the questionnaire for the semi-structured interview was tailored so that relevant questions were asked of the interviewee based on their professional experience in the subject matter, some broad themes were identified. These themes initially emerged as a result of document analysis for the literature review of the study area and were later modified as more understanding and information was acquired from initial interviews. The questions focused on developing an understanding on the involvement of different agencies in flood management in the Hawkesbury-Nepean; identification of governance and management challenges and also on eliciting competing views from experts. In addition, as part of the interview, experts' opinions on enhancing flood risk management were also sought.

To address the second research question of identifying barriers to flood management the following themes were defined:

- Role of the agency (to be interviewed) involved in flood management
- Coordination mechanisms, information access and exchange for flood management
- Issues of risk management and risk assessment
- Management challenges and knowledge gaps
- Views on defining acceptable risks, community engagement and potential role of regional organisations in flood management.

Additional agency specific questions involved discussion on issues of LEPs, development in the floodplains, issues of pollution and flash floods.

In order to address the first research question, the information analysed from the second research question formed the basis of designing the semi-structured interviews. The following were the broad thematic categories.

- Role of the agency (to be interviewed) involved in flood management
- Flood management process; management at regional/catchment-scale
- Coordination with other agencies and engagement with communities
- Knowledge management and information collection process
- Perspective on NSW model for flood governance

More area-specific questions dealt with learning-laboratory concepts, the community-based governance model and political issues in the existing governance model.

A semi-structured questionnaire sample is included as Annexure I. As discussed, details on the length of the interview and what categories of interviewees were used for each analysis are explained at the beginning of every analysis chapter. The ethical considerations for conducting semi-structured interviews are discussed in section 3.6 below.

3.4.2. Survey

Communities are one of the key interest groups in the study area as they are the ones affected by flood risks and policies that mitigate these risks. As discussed in section 3.3 above, a community survey was conducted to assess members' understanding of flood risk and evaluate their expectations and perceptions. Chapter 7 presents a detailed account on the design of the survey, target audience and elaborates on the need for this analysis (for details, see section 7.3 of Chapter 7).

The survey was developed as a self-completion questionnaire administered through three channels; postal, internet and supervised, as discussed by Bryman (2012). A purposive sampling process was used instead of random or probability sampling as the purpose of the survey was to assess understanding and perspectives of resident communities that are residing close to either the Hawkesbury or Nepean Rivers with a moderate to high flood risk. Residents who can provide useful information for the study were therefore selected. Purposive sampling "invites the researcher to identify and target individuals who are believed to be 'typical' of the population being studied" (Davies 2007). The purpose of this type of sampling is that the selected population is closely related to the problem under study and enables researchers to study different phenomena of the problem (Marton 2013). Survey questionnaire is provided as Annexure II.

3.4.3. Document analysis

Document analysis was carried out to gain a better understanding of the problem area and the governance processes involved in flood management. According to Bryman (2012, p. 110), a review of literature in interpretive research is carried out to develop an understanding of a particular subject rather than accumulating knowledge. In line with this purpose, documents such as flood studies, flood management, flood review reports and other relevant documents were examined. This process also helped to identify any gaps in the problem area. Curtis & Curtis (2011), argue that the 'finding the gaps' approach for reviewing secondary sources is useful for maintaining originality in one's research work.

Another purpose of conducting the document analysis of the organisational reports was to triangulate information that was later also acquired via semi-structured interviews. Triangulation "implies combining together more than one set of insights in an investigation" (Downward & Mearman 2007). This process helps to develop a better assessment of the explanation that one develops and reduces the risk of biases by avoiding the use of any particular method to investigate research issues (Maxwell 2013, pp. 128, 102).

The documents that were reviewed were available on the public domain and were easily accessible via electronic media. Some council reports which were not available publicly were shared by the interviewees during the data collection process. Chapter 5 of this thesis is predominantly developed through this research method. It helped to provide a detailed situation analysis of the study area and issues of flood management in the region. More particularly, a review of flood studies helped to identify the extent of information available to the public of flood risks. These reports were viewed to develop an understanding about flood assessment processes, identify risk areas, review the problems of flood risk and identify whether the report acknowledges threats to increase flood risk in certain development regions. These reports were also reviewed in the context of the language used and the level of technical information provided to assess the general usefulness of these reports for the resident communities. They were also viewed on the basis of how the flood-plain development manaual five-step process of flood management is in place and what mitigation measures are prescribed among other things.

3.5. Data collection and analysis

For data collected through semi-structured interviews, a thematic analysis, which is a qualitative descriptive approach, was used. It is defined as "a method for identifying, analysing and reporting patterns (themes) within data" (Braun & Clarke, 2006, p.79). The data was collected through audio recording and then transcribed verbatim. Audio-recordings have been found to provide more information which could have been missed through note-taking and helps the researcher to concentrate on the discussions without getting side-tracked (Davies 2007). This descriptive form of analysis draws heavily on interview transcripts allowing the data to somewhat "speak for themselves" (Glesne 2011, p.208). It helps to determine what is going on and the information tends to provide a range of details and description of the phenomenon under study, thus portraying a richer analysis (Glesne 2011).

The final scripts of the transcribed data were transferred to an Excel sheet which comprised broad themes taken from the questionnaire and emerging themes from the interviews. Through this thematic analysis it was feasible to identify common issues that emerged from the interviews and provide a more detailed and complex account of data as indicated by Vaismoradi et al. (2013). This data collection method was suitable where there was an assumption that the data acquired was an accurate reflection of the reality as understood by the interviewee (Sandelowski 2010) and where it helps to determine the actual behaviour, attitudes and underlying motives of the people under study (Vaismoradi et al. 2013).

For the survey analysis (see Chapter 7 for details), open-ended questions were transcribed on Excel sheets and their content analysis was carried out. Content analysis is an approach that collects and analyses data from different communicated sources which includes books, and other written and digital forms of communications (Curtis & Curtis 2011), in this case, survey questionaries. It is well suited in an exploratory work which helps to report on common issues mentioned in data (Green & Thorogood 2004, cited in Vaismoradi et al. 2013). It aids in the identification of difference and similarities in context which are expressed through coding the data into categories and themes (Thyme et al. 2013). Content analysis differs from thematic analysis as it allows for qualitative as well as quantitative analysis of the data (Gbrich 2007). “Content analysis uses a descriptive approach in both coding of the data and its interpretation of quantitative counts of the codes” (Vaismoradi et al. 2013, p. 400). For content analyses, coding is a critical step. “Coding is the process of organising the material into ‘chunks’ before bringing meaning to those ‘chunks’” (Rossman & Rallies, cited in Creswell 2003, p. 192). Guidelines provided by Bryman (2012) were used for coding.

In addition, a more quantitative analysis of the survey data was carried out through SPSS software. It is the most widely used software for quantifying research data, is practical and provides accurate results for the most common statistical tests for surveys without the need for computer program-coding of unique formulas (Bryman 2012). Each participant’s response was coded, based on the themes of the questionnaire. The data were coded based on the location of the respondent or the organisation he/she represents. For instance, in the community survey analysis chapter (Chapter 7) if the respondent was from Windsor and was the seventh respondent from that region then he/she was coded as Windsor Resident 7, July 2014. The dates were used to ensure accuracy of the data and were in relation to when the interview took place. Where there was a need to compare perceptions of individuals from different organisations as in Chapter 6, the respondents were coded based on their association with a particular organisation. So an interviewee from a council will be represented as Council Group, interview 8, July 2014. When the number of interviewees were less and there were fewer organisation in the region that would have made their identity visible, as was the case for Chapter 8 and 9 then no particular reference was given in terms of location or organisation. In these circumstances, the interviewees were numbered numerically and identified only with the date at which the internview took place for instance interviewee 8, July 2014.

3.6. Ethical considerations

In social research, ethical concerns pertain to subject wellbeing, informed consent, confidentiality, privacy and issues of deception (Schutt 2006; Bryman 2012).

In the current research, ethical considerations based on the above premises were carefully taken into account. In addition, as per the UNSW policy, the research topic was reviewed by the Human Research Ethic Committee (HREH) and formal ethical approvals were obtained from the committee. Since there were two general categories of respondents, (i.e., the experts and professionals engaged directly or indirectly in flood risk management and the residents of the Hawkesbury-Nepean catchment), two ethical approvals were obtained. The approval forms are included as Annexure III for reference.

The university's approved standard forms were used to address ethical concerns highlighted by Schutt (2006) and Bryman (2012). Since a snowball sampling or purposeful sampling technique was used for this research study, initial contacts were made through an introductory email to the respective agency. The email provided a brief introduction to the research and explained the purpose of the research. In addition, the email included a participation information sheet on the University's letterhead. The participation information sheet also outlined information on confidentiality and disclosure of information and consent of the participants (see Annexure IV – Participation information sheets). Furthermore, at the time of the interview, the participants were briefed on the purpose of the study. They were also informed that they have the right to revoke their consent at any stage during or after the interview, in case of a change of mind (See Annexure IV, p.4).

A verbal consent to record the interview was also acquired in addition to including the option in the participant consent form (See Annexure IV, p. 3). The interviewees were also informed that the data were the property of the researcher and would be kept in a secure location with password protection.

For the face-to-face, online and postal surveys, a similar process was followed. The information sheets were modified to attract the attention of non-technical participants from the resident community (Also, Annexure IV). The information sheet along with the questionnaire were posted to the residents and were also shared prior to conducting face-to-face surveys. It also formed the introductory section of the on-line survey form.

The published work as a result of data gathered from the respondent was shared with the participants. In addition, prior to publication, the relevant chapter was shared with the participants to record any feedback or concerns that they may have had.

To maintain the confidentiality of the data, pseudonyms were used while transcribing and incorporating the data in the analysis chapter of this thesis and the relevant publications. Seidman (2013) provides detailed procedures on maintaining confidentiality in data gathering, collection and analysis and these were used as guiding principles during the conduct of this research.

3.7. Linking methods with the research questions

Table 3.3 provides a matrix that links research questions with methods and analysis chapters. The method has been adapted from Maxwell (2013). It has been carried out to present a coherent research design and to demonstrate how different elements of the research are integrated.

Table 3.3. Matrix linking methods and research questions

Research questions	How to address this question	Sampling decisions (how this information can be obtained?)	Data Collection methods (what kind of data will answer these questions?)	Who needs to be contacted for access?	Data analysis	Relevant analysis chapter
1. What are the characteristics of a good governance system?	To identify examples and research evidence of good governance models in NRM and FRM. To determine criteria for healthy/good governance systems	Litrature review	Published reports and research articlas on the subject	Desk research	Online document analysis	Chapter 2, 8 & 9
2. How can biospheric and catchment-scale frameworks improve flood risk management issues in the Hawkesbury-Nepean Catchment?	To determine opportunities, strengths and weaknesses of these frameworks for resource management.	Agencies in Victoria and QLD: CMA, Noosa biosphere, Councils, state agencies; research institutes engaged in Noosa BR research	Interviews, Email correspondence & Document review online.	Managers – infrastructure, Planning and Policy, floodplain specialists, Emergency management coordinators, Noosa shire councillors. Management	Audio taping, Transcription coding, Review of reports on Noosa Biosphere and its amalgamation, Noosa sustainability institute as a learning laboratory, and	Chapter 8 & 9 discuss the strength and weaknesses of these frameworks.
	To determine implications of such frameworks for the case study region.					Chapters 8 & 9 also discuss the implications of these frameworks for flood

Research questions	How to address this question	Sampling decisions (how this information can be obtained?)	Data Collection methods (what kind of data will answer these questions?)	Who needs to be contacted for access?	Data analysis	Relevant analysis chapter
				team of Noosa Biosphere.	governance mechanisms of flood management in Victoria.	management in the NSW.
	To recommend a conceptual framework, to be implemented at a regional scale, that utilises the existing institutional arrangement of the Hawkesbury-Nepean catchment for improving flood risk management.					Chapter 10, provides a conceptual framework to improve existing gaps in the flood management of the Hawkesbury-Nepean catchment.

Research questions	How to address this question	Sampling decisions (how this information can be obtained?)	Data Collection methods (what kind of data will answer these questions?)	Who needs to be contacted for access?	Data analysis	Relevant analysis chapter
3. What barriers exist in flood risk management in the Hawkesbury-Nepean region?	To examine the current trends in flood management in the region.	Council reports, Online search on flood history and past management issues; Review of published scientific literature Council representatives	Interviews with experts and reports	Floodplain coordinators, engineers, emergency managers,	Audio recording transcription and analysis of reports	Chapter 5 provides a situation analysis of flood management in the case study area
	To examine institutional gaps within the existing flood risk management of the catchment.	Research Institutes Council members Existing regional scale agencies involved in environmental advocacy and management.	Interviews	Flood managers Strategic planners Climate change and fire/flood researchers	Ongoing analysis, categories and thematic analysis	Chapter, 4 and 5 specifically identify gaps and mal-adaptive practices.

Research questions	How to address this question	Sampling decisions (how this information can be obtained?)	Data Collection methods (what kind of data will answer these questions?)	Who needs to be contacted for access?	Data analysis	Relevant analysis chapter
	To examine issues of scale and determine the perceptions and approaches to managing floods in the region	NSW Planning and Development sectors; insurance groups; flood managers; real estate agencies; NRM groups and local environmental networks; local resident communities of the Hawkesbury-Nepean catchment.	Interviews, community survey	Experts in planning, development and emergency management; flood risk assessors; and local communities	Thematic analysis and qualitative assessment through SPSS.	Chapter 2 sets the context of issues of scale which are intermittently discussed throughout this thesis, more specifically from chapter 4, 5. Scales are further discussed along with perceptions as barriers to management in chapters 6 & 7.

Chapter 4: One Catchment, One System: The Blue Mountains of the Hawkesbury-Nepean Region

4.1. Introduction

A central characteristic of Social Ecological Systems (SES) is their embedded nature. The Panarchy framework describes how systems behave, function, and respond to changes triggered by internal and external influences. One of the main arguments this thesis makes is how often institutions and governing bodies lack understanding of such influences and their relationships to improve management practices, especially issues of scale.

The ability of a governance framework to address local problems and link essential elements of micro-scale with larger macro-scale objectives is critical if institutions and natural systems are to succeed in adapting to a changing climate. The subsequent chapters of this thesis will focus on addressing this problem from a flood management perspective; however, this chapter highlights the ecological significance of this catchment and sets the background context for the environmental values of this region where flooding is a risk. In doing so, it demonstrates the vulnerability of this SES to unexpected shifts and the potential to lose positive resilience. This is the only chapter, in this thesis, that focuses on ecological components of this system and its vulnerabilities.

This chapter presents a micro-scale case study on the hydrological significance of the Blue Mountains. A focus on hanging swamps as an example demonstrates the integral value of the Blue Mountains in relation to the entire catchment. More particularly, it explores factors that influence the surface water hydrology [5] of the Blue Mountains, how this influences downstream hydrology, and how major shifts in these systems can be triggered under future climate change trends. It identifies factors that can impact the Blue Mountains ecosystem with the potential to adversely influence the catchment flow regimes. Consequently, it draws attention to the lack of understanding of an appropriate scale of management, the critical value of understanding the system as one operational entity, and demonstrates how state-level policies undermine this. The second part of this chapter highlights the governance challenges to indicate that sustainability of natural systems is closely embedded in the way these systems are governed by state and regional entities.

[5] To avoid confusion, the term Hydrology in this chapter is mostly used to mean impact on surface water resources.

4.2. Method of inquiry

The information collected for analysis was based on initial examination of online documents to develop an understanding of hanging swamps in the Blue Mountains region. In addition, detailed semi-structured interviews were conducted with representatives from academia and local agencies involved in hanging swamp research and management. A total of 11 interviews were conducted with representatives from the Blue Mountain City Council, Sydney Catchment Authority, and Office of Environment and Heritage. The majority of interviewees were researchers and academics associated with the University of Wollongong, University of Technology, Sydney, and University of New South Wales. A discussion forum entitled Winter Circle forum held by the Blue Mountain World Heritage Institute on July 6th, 2013 also provided additional information to supplement discussions in this chapter. The presentations at the Forum highlighted issues of climate change in the Blue Mountains and potential impacts of fire and intense weather on sensitive ecosystems.

In most cases face-to-face discussions were held, whereas in certain situations telecommunication and in rare cases email discussions were carried out.

4.3. The Blue Mountains in the Hawkesbury-Nepean region

The Greater Blue Mountain World Heritage area is predominantly a forested landscape on a sandstone plateau (UNESCO World Heritage Centre 1992-2015).

It is situated to the west of the Hawkesbury-Nepean catchment about 60 km from Sydney, Australia (Chapple et al. 2011). It was recognised as a World Heritage Site in 2000 and covers over one million hectares of reserved parks and protected areas that support unique and diverse fauna and flora (Department Of Environment and Climate Change 2009). The region is dominated

Figure 4.1: Blue Mountain World Heritage Area shows the spread of the Blue Mountains and its close proximity to the rapidly developing Sydney region (Australian Government, Department of Environment and Water Resources 2007).

by a diverse range of Eucalypt forests. The Blue Mountains were named due to the blue haze reflected by light as a result of Eucalypt oil dispersed in the surrounding atmosphere (New South Wales National Parks and Wildlife Service 1998).

In order to identify factors that can potentially influence the hydrology of this catchment there is a need to examine the potential impacts of extreme weather conditions and other factors on the ecosystems of the Greater Blue Mountains region.

For this purpose the hanging swamps of the Blue Mountains are taken as case example. Particularly to examine the degree of interconnectivity in the following ecological relationships, the:

- role of hanging swamps in maintaining the hydrology of the catchment,
- vulnerability of these systems to urbanisation,
- impacts of fire on hanging swamps and its implication on the system's hydrology and flow regimes, and
- potential impact of future climate change trends on hanging swamp habitat.

4.4. Significance of hanging swamps as critical hydrological systems

Upland Swamps [6] are found across New South Wales especially on the Blue Mountain, Woronora and the Boyd plateaus (NSW Department of Education and Communities 2011). The Swamps of the Blue Mountains constitute dense communities of shrubs and sedges situated on high sandstone escarpments that receive greater than 1000 mm average annual rainfall (Young & RAL 2000). These swamps cover an area of 900 ha in the Blue Mountains Local Government Area (LGA). They occur where aquifer zones intercept upper slopes or in poorly drained environments and are common along cliff tops (Commonwealth of Australia 2014). They are situated on the urbanised ridgelines hanging at the edge of slope (Carey 2007) forming the periphery of Blue Mountain City Council.

According to the director of the Colong Foundation cited in The Sydney Morning Herald:

> "These swamps provide water [and] are essential to the wellbeing of the World Heritage Area downstream, and are listed as national heritage and also support nationally thereatened species' (Hannam 2016).

[6] 'Upland swamps are vegetated freshwater wetlands occurring in shallow basins located in low hills or mountains. This wetland type includes shallow marshes, sedge swamps, "hanging" swamps, wet heaths and peat swamps' (New South Wales, Department of Education and Communities 2011).

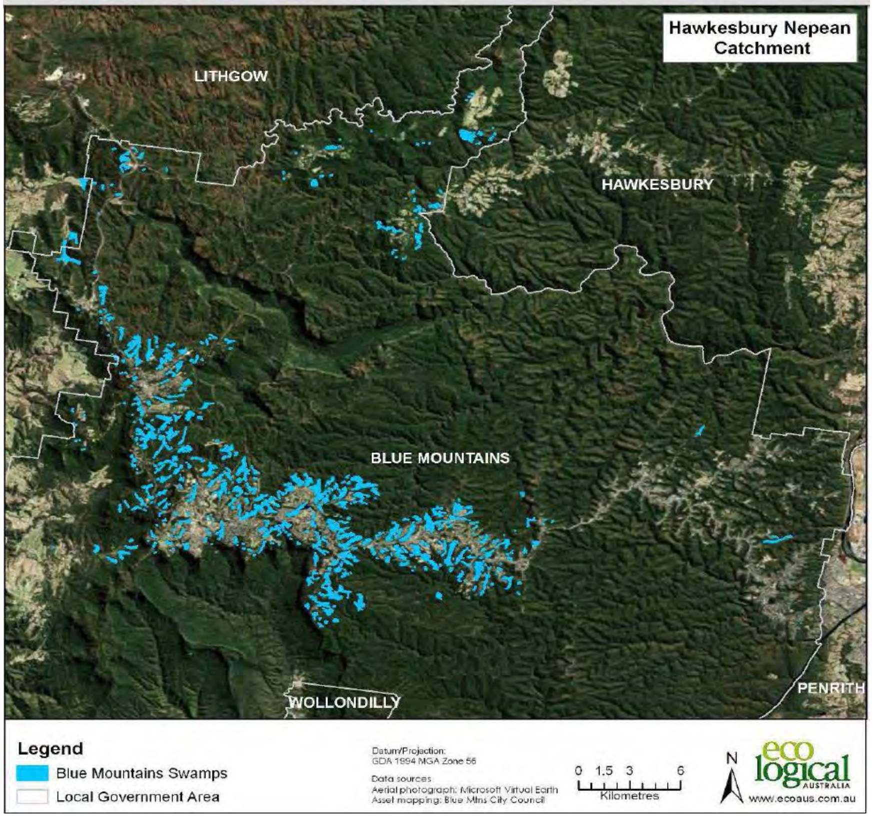


Figure 4.2: Spread of Hanging Swamps in the Blue Mountain City (Eco Logical Australia Pty Ltd 2010)

These swamps have been listed as threatened ecological communities under Environmental Protection and Biodiversity Conservation Act 1999 (Blue Mountains City Council 2004-2005). These swamps are under threats due to erosion, development, runoff, fertilisers, ground water extraction and weed invasion (Blue Mountains City Council 2004-2005). The flows from the Blue Mountains swamps, supplements Sydney's largest water supply catchment, the Warragamba catchment that provides 90% of drinking water supply to the Sydney region.

The hydrological properties of upland swamps play a crucial role in the sustained supply of high quality water to Sydney, Australia largest population centre (Keith et al. 2006 p. 6).

Studies on upland swamps demonstrate their role in regulating flows and improving the quality of water downstream. According to Keith et al. (2006) upland swamps play a vital role in maintaining certain hydrological functions in the catchment they occupy:

> [They] regulate flow rates of their discharge streams by slowing and prolonging the discharge of water runoff from precipitation events, mitigating

the severity of downstream floods and increasing the reliability of downstream flows during dry spells' (p. 4).

> These swamps are important functionally for one they act as a filter because the sediments that are in them are highly organic so they can bind up the material that runs through. They tend to spread the flow out…over a long period and it is a way of reducing the variability of flow volumes that is useful for the biodiversity of streams' (Interview 1, May 2013).

The surface water may also be linked with ground water through hydrological processes (Sarker et al. 2008). Swamps have water retention and slow release capacity that helps to balance out water in the landscape. For instance, in the absence of swamps, water entering a catchment after a rainfall event will run down more rapidly. Swamps can serve as natural barriers to hold water on land and reduce the variability of flow volumes for biodiversity of streams (Interview 1, May 2013). **"**Hanging swamps act like massive sponges, soaking up water and releasing it gradually to provide life–sustaining moisture for downstream ecosystems" (Blue Mountains City Council 2004-2005).

4.5. Factors influencing vulnerability of the swamp ecosystems

The following sections provide brief descriptions of factors that have a negative impact on swamp ecosystems.

4.5.1. Vulnerabilities of the swamp ecosystems against temperature variations

Threats to upland swamps can be processes that tend to reduce vegetation density or disrupt the root mat. This has the potential to release pollutants, increase acidity of streams, and may result in excessive flushing of swamp sediments. The hanging swamps are potentially more sensitive to disturbances and can erode easily (Chalson & Martin 2009) and have lower organic matter accumulation rate than valley swamps and swamps situated along waterways (Chalson & Martin 2009).

Swamps in the Hawkesbury-Nepean Catchment are highly sensitive to the climatic conditions in which they function. A discussion with a landscape ecologist at the University of Technology, Sydney, on swamps at Barrington Tops and in Blue Mountain World Heritage Area, helped to elaborate the complex and sensitive nature of these habitats. Each group of swamps scattered throughout this landscape support a unique fauna – '[their] ecosystem harnesses a high level of endemism' (Interview 2, May 2013). This makes them highly sensitive to changes in climate. The temperature within swamps may differ from temperatures outside the swamps a few hundred meters away. What this indicates is that for assessing future temperature projections a more refined scale of data collection is required that would provide more precise projections of temperature variations.

This is in contrast to the current practice where research and management discourses make use of a more standard method of climate projections available at online sites such as Bioclim or Worldclim (Interview 2, May 2013). The data collected in these is through meteorological stations which have a standard design and are placed at a standard predetermined height above ground. The use of this data against elevation defines a causal relationship where increase in height results in decrease in temperature. This may be interpreted as the higher the area above sea level the cooler climate it will experience. However, the accuracy of temperature just above the ground varies dramatically with the average temperature captured by metro stations (Interview 2, May 2013).

Increase in temperatures in these swamp systems will potentially lead to some form of disruption of ecological processes. There is currently a lack of understanding in terms of how subtle changes in temperature variations would impact on these vulnerable ecosystems. Fine scale data is essential for better management decisions and for assessing the impacts on other component in the landscape, such as the changes to fluctuation in the flows that may cause alterations to the hydrological functions of these systems. Currently, there is limited use of temperature-sensitive data to understand the impacts on swamp ecosystems.

4.5.2. Vulnerability of swamp ecosystems to urbanisation: Issues of runoff and sediment release

A key threat to these swamps is development of impervious surfaces and storm water runoff from urban areas. Increased development and lack of storm water management can lead to disruption in the hydrological functions of swamps resulting in reduction in aquifer recharge, increase in overland flows, erosion, and channelisation of swamps. According to Keith et al. (2006) such impacts are localised but can impact larger scales as a result of changes in the precipitation/evaporation ratios due to climate change and changes to vegetation or peat deposits.

One of the major issues faced by the Blue Mountain City Council (BMCC) is the urban runoff. Prior to development, most of the rainwater (about 80%) was held-up within the natural landscape with rainfall producing an average of 4-6 runoff events per year. Now with increase in clearing and development works about 85% is accounted as runoff (Interview 3, May 2013). This water is wasted and not used for replenishing the hanging swamp system or groundwater recharge.

A major issue of the urbanised catchment above the hanging swamps (Katoomba) is the increase in velocity and flow of runoff that impacts the landscape. The land in these catchments have sandstone escarpment and increase runoff carves through the sandstone.

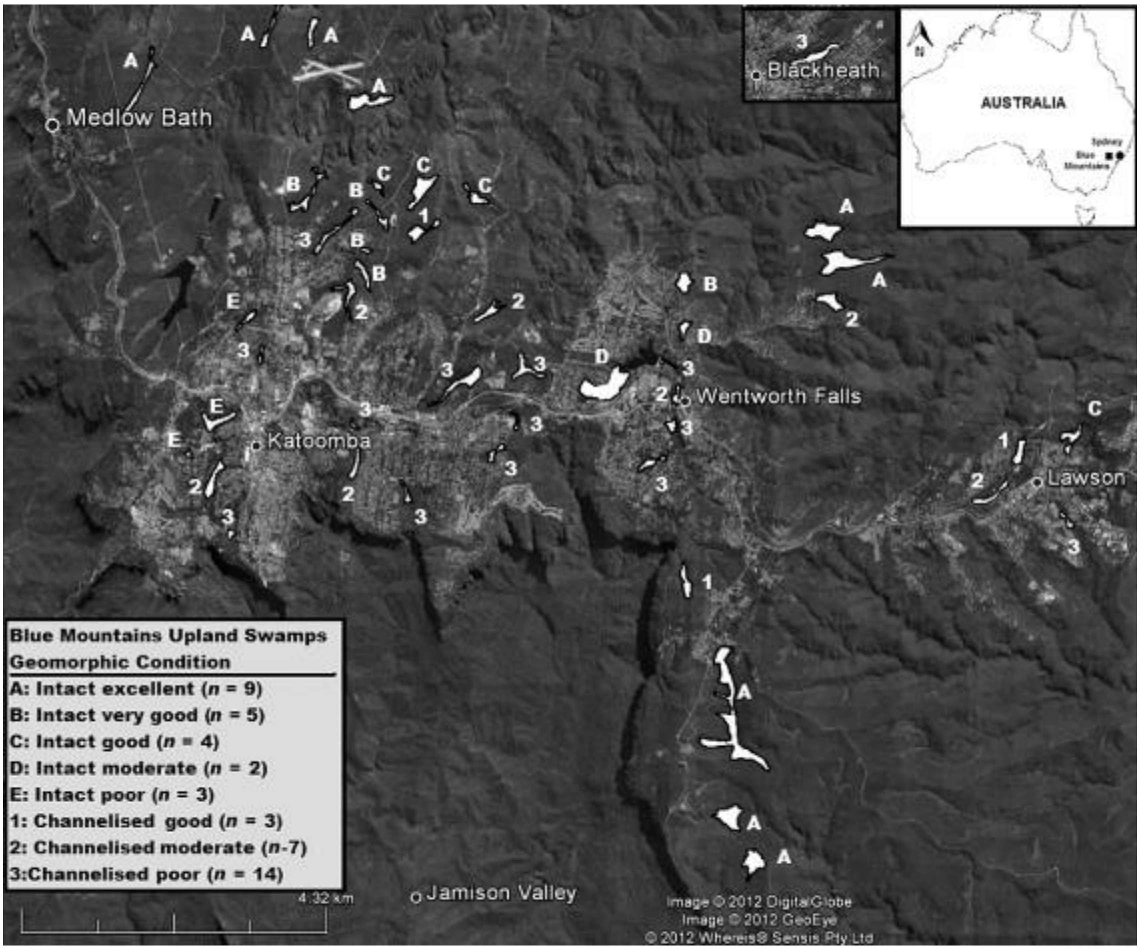


Figure 4.3: Swamp communities in Katoomba and surrounding area of the Blue Mountains. Most swamp communities are categorised as channelised moderate to poor conditions (rating 2-3 in the figure) with mostly intact but in poor conditions (Kohlhagen, Fryirs & Semple 2013).

According to BMCC staff, the increase in development has led to an increase in the runoff ‘we are experiencing up to 120 runoff events following rainfall’ (Interview 3, May 2013). This increased level of flow and variations in velocity changes the in-stream flows and has the potential to damage the soils of the hanging swamps and the system’s hydrology. Discussion with one of the BMCC representatives further elaborated that the possible changes experienced are deposited sediments in areas that potentially impact biodiversity such as filling-up pools. Research conducted by BMCC demonstrated that even a 5% increase in the impervious surfaces, which are connected to storm water and waterways, could result in a dramatic decline in the biodiversity index results (refers to the quantitative measure of different species). Further development works by the *NSW Roads and Maritime*

Services in the Katoomba region mean more incidences of sediment release into these systems can be expected (Interview 3, May 2013).

In addition, increase in impervious surfaces has increased impermeability of the landscape that prevents water retention on land and facilitates groundwater recharge which is vital for vulnerable systems like the swamps. This problem is likely to continue in the light of the current ambitious development plans where about 7,000 dwellings are to be established in the next few decades within the Blue Mountain LGA (Gold & Merson 2013). More on this is discussed in Chapter 5 in relation to flood management. The issue of development and urbanisation in the Blue Mountains region is closely embedded with the conflicting interest of State level agencies to expand and develop the Western region of Sydney potentially undermining the World Heritage Status of the Blue Mountains. Section 4.6 discusses some of the issues demonstrating conflicting interests of state and local agencies that can adversely influence the management of the fragile ecosystems of the Blue Mountains.

4.5.3. Vulnerability of swamp ecosystems to fire hazards

A research study on the Woronora Plateau, NSW, indicated that over geological time occasionally swamp sediments were flushed down to the valley as a consequence of bushfires followed by heavy rainfall events (Young 1982). In some cases flushing of sediments from these swamps has been accounted to subsidence associated with the extraction of coal from beneath the rock profile (Interview 1, May 2013). This process has been found to change the topology of the surface creating 'nick points' – a point of rapid erosion that has the potential risk of flushing sediments during heavy rainfall (Interview 1, May 2013).

The potential damage to swamps from fire is well described by Keith et al. 2006:

> Fire regimes characterised by very short or variable fire intervals and peat fires may pose particular threats to upland swamps in the Sydney Catchment areas' (p. 6).
>
> Damage of swamps due to fire regime may result in 'changes to the swamps vegetation and soils [impacting the] hydrological functions of swamps, particularly through accelerated oxidation of organic matter and increased exposure of their unconsolidated sediments to erosion during heavy rainfall events' (p. 6).

Through an initial discussion with researchers engaged in upland swamp studies, it has been observed that swamps on the South and South west of Warragamba catchment have been a greater focus of these studies than the hanging swamps of the Blue Mountains;

West or North West of the region. Discussion by one of the fire experts suggest that the extent of impacts of fire on hanging swamps has not been studied extensively (Interview 4, June 2013).

> Part of the issue is that we don't know how frequently fires burn the soil or substrate. [A number] of research suggest that fire burns most of the biomass at the bass and since swamps have a lot of moisture it does not reach that critical level. So when they do get burned it is quite superficial but that is not always going to be the case. What we don't have information, or a handle on, is how often fire is severe enough to burn the substrate. When the substrate does get burn that is when we have disruptions to water cycling, water retention and also the whole functioning of the ecosystem, but we don't know how common that is partially because people have been mapping, documenting or studying only recently. Most of the work is in grey literature (Interview 4, June 2013).

A recent PhD study (unpublished) looks at the impact of wildfire on vegetation in the Sydney Catchment. The research suggests that there is little evidence of the impacts on catchment hydrology during post-fire events. One of the reasons described is that the pattern of regrowth of vegetation differs from one region to another as growth occurs from seedlings emerging from burned tree barks which tend to have very little impact on water as compared to seed germination after a fire impact as was the case in Melbourne fires of 2009 (Interview 5, April, 2013).

Another explanation provided by a researcher at the University of Wollongong, with regard to impacts of wildfire on vegetation is that the local forests in the catchment have been dominated by Eucalyptus species which have a fast regeneration cycle and the water-use cycle of trees is normalised after five years, hence there is minimal impact on water yield on the catchment. However, the researcher further elaborated that threats under dry climatic conditions would lead to burning of organic matter. If fire becomes more frequent there are species and plants in the swamps that can be knocked down. Future scenarios of increase drought with increase fire will potentially be deleterious to some of the swamp ecosystems (Interview 6, April, 2013). A five year regeneration rate is considered to reduce impact on the catchment, provided that the region does not experience extreme climate conditions.

During the *Winter Circle Forum* hosted by the *Blue Mountain World Heritage Institute*, at The Australian Museum in July 2013 Professor David Keith observed that beliefs that swamps don't burn are wrong. Upland peaty swamps [in the Blue Mountains and Sydney Basin] are actually very fire prone. He further elaborated that these swamps have a very dense, well aerated rapidly drying layer of fuel – a meter or two meters thick. Usually, in cases of fire, 'the entire lot will burn' whereas the adjacent woodland would have a lot of heterogeneity in terms of what burns and what doesn't. The swamps are one part of the landscape that is also exposed to other types of fires such as the substrate fires. Their peaty soils can combust under certain circumstances which can have long lasting impacts on swamps affecting their vitality, erosional and hydrological characteristics.

The impact of fire on surface water and their influence downstream of the catchment is a less researched area especially in the upper Blue Mountains region. This might be due to perceived low risk of fire impacting large catchments in the region. It could also be due to the lack of knowledge and understanding of how these systems will respond under extreme weather conditions or that the hydrological functions of swamps in the Blue Mountain catchment are less recognised and hence less researched.

As a fire ecologist from one of the NSW State Agencies stated:

> There are several reasons that suggest it will not happen, the catchments are really big. The fires are quite patchy. There is so much vegetation buffer and the length of unaffected water quality. So it gets moderated in the rest of the catchment. Also, there isn't any convincing evidence that it is likely to become more of a problem. All the work done so far on looking at the potential impacts of predicted climate change on fire regime are very complex and uncertain and for what has been done so far it looks like for every changing factor that makes fires looks like more frequent, severe and intense there is another factor that counteracts it. [Fire impacts] gets moderated in the rest of the catchment. That is why fire impacting the water catchment is not a significant issue in the Blue Mountains. Unless there is a heavy rainfall event shortly after a big fire...it can [be an issue] in a particular spot but catchments are so extensive that it gets evened out (Interview 4, June 2013).

The vulnerabilities of the hanging swamp ecosystems depends on a number of factors that are directly or indirectly tied to the rapidly changing climate creating novel conditions for natural systems. The following section describes the potential impacts of climate change that would more likely lead to drastically changing environment testing ecosystems thresholds.

4.6. The potential impact of future climate trends on the Blue Mountains ecosystems

Discussions with researchers and management representatives were carried out to outline a general understanding of the likely trends of climate change for the Hawkesbury-Nepean catchment in general and Blue Mountains ecosystem in particular. This section summarises the potential impacts of climate change and the likely consequences of increasing vulnerability of the hanging swamps.

4.6.1. Unpredictability in forecasting rainfall events

The Australian climate is an extremely variable one due to impacts of climatic phenomenon of El-Nino, la-Nina and Southern Oscillation. Minor changes in these events can topple the predicted climate change trends and can result in dramatic climate shifts in the region (Interview 6, April 2013). In addition to El-Nino, the Indian Ocean Dipole phenomenon also creates extreme weather conditions in Australia (Cai et al. 2013). According to 'The Conversation' the influence is bound to strengthen under climate change (Cai 2013). Variable climate and future uncertainty further adds to the complexity of assessing climate change impacts and management decisions that needs to be taken into account for natural resource management.

> Nobody knows the impact of global warming on the Sydney basin. [What] we do know is that, on average, it will be warm. We do not know what will happen to rainfall irrespective of what you might read. We do not know if it will increase or decrease. Beyond the projection of 10 days we move to a statistical forecast which gives you 50% accuracy. If you move beyond that then you reach the decadal scale that will tell you what will happen in 10 years. At this point in time there is no skill in southern hemisphere that can provide decadal predictions. Reason: much less data, and complex influences of la Nina, El-Nino and Southern Oscillation...minor changes in that can change the projections dramatically. Australia has the most variable climate on earth and NSW is most variable in the Australian system. There are no observable trends in rainfall and I don't think there will be any observable trends in rainfall for decades across the Sydney Basin. There will be in southern Victoria and in the tropics but [Sydney Basin] is very dynamic in terms of its climate variability. It will be a long time that accurate predictions can be gained. The only information that resource managers can get is that it will get warmer, slight increase in evaporative demand but not massive (Interview 7, May 2013).

The Director of the Climate Change Research Centre, at the University of New South Wales, elaborated that the future climate change trends show warmer conditions in the western part of the Sydney Basin as compared to the eastern region. The far west side of the basin, up to the mountains is expected to experience warmer weather conditions. There is anticipated to be a stronger temperature contrast from east to west of the basin. "In case of Hawkesbury-Nepean there is a known risk of heatwave and bushfire and increase rain. We think that global warming can intensify global rainfall events" (Interview 7, May 2013).

Historically large floods have hit the Blue Mountains region. The 1867 flood reported to have inundated a number of suburbs in the catchment. A boat could be taken from Riverstone to the Blue Mountains, a distance of 15 miles during this flood event (Howes 2012). The majority of the Blue Mountains 60 sub-catchments, however, are not highly flood prone and are more inclined to frequent localised flooding. Developments in the past 20 decades have resulted in increased frequency of such floods (Maunsell Australia Pty Ltd 2008). Regions such as Lapstone, South Glenbrook South Blaxland, and Jamison creek catchments of the Blue Mountains region are subjected to rapid and intense flooding of short durations. Storm events of 2001, 2003, 2005 and 2010 have caused flooding in these regions (Maunsell Australia Pty Ltd 2008; Cardno Wiling 2005)

The western encampment of the Blue Mountains which includes the South Leura regions have 205 properties that are flood liable in a storm event and 25 are directly in the flood path (Maunsell Australia Pty Ltd 2008). These flood events have occurred at a 5yr Average recurrence interval instead of a 100 yr (Maunsell Australia Pty Ltd 2008). Due to the change in frequency of the flood events flood assessment guidelines indicate the need to evaluate storm events of 20, 50 and 100 year ARI storm events while developing flood risk management plans (AR&R 1987).

4.6.2. Increase in fire hazard weather

A global trend in climate change scenario presents increased levels of fire risks (Clarke, Smith & Pitman 2011). The McArthur Forest Fire Danger Index (FFDI) (See Figure: 4.4 for more details on FFDI) is one of the commonly used guides to determine fire weather conditions in Australia (Clarke, Lucas & Smith 2013). The index takes into accounts a combination of factors that include temperature, wind speed, drought effects and humidity (Clarke, Smith & Pitman 2001).

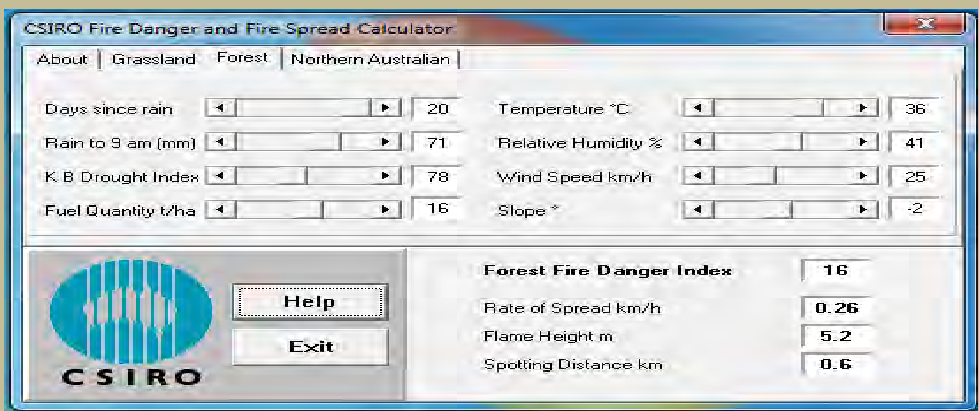
Figure 4.4: McArthur Forest Fire Danger Index

McArthur Forest Fire Danger Index has been designed to forecast fire incidents in eucalypt forest and grasslands. The index divides fire thresholds into five categories (see table below for details). The fire index rating falling between 0-5 means that the chances of fire burning is low or if it still burns, it can be controlled without difficulty. Whereas a rating index of 100 presents an extreme fire danger scenario where fire is likely to burn fast and impossible to control.

Table 5.2: FFDI values for each fire danger rating class (Luke and McArthur 1986 cited in CSIRO 2009).

Fire Danger Rating FFDI range	Low	Moderate	High	Very High	Extreme
	0-5	5-12	12-24	24-50	50+

CSIRO provides an 'easy to use' Forest Fire Danger Meter to assess the degree and chances of burn under given conditions. The Forest Fire or Grassland Fire Danger Index is determined by information provided in the first section and the Index is automatically generated. A print screen shot is provided below;



A UNSW climate change research scientist emphasised that climate change projections in this region translate into an expected higher risk of bushfire (Interview 6, April 2013). Bradstock (et al. 2009) using a modified FFDI predicted 'a 20-84% increase in potential[ly] large (≥ 1000 ha) fire ignition days in the Blue Mountains and Central Coast regions' of the Sydney Basin. A different investigative approach to determine climate change impacts on fire were used by Hasson et al. (2009) which also showed increase fire weather events from one every two years to two major events per year by 2100. Figure 4.5, below shows the number of days per month with a FFDI above 40 for the Sydney Region. According to this, extreme FFDI is 'projected to increase strongly by 2100 with a more intense peak and a full-month-longer period of activity'

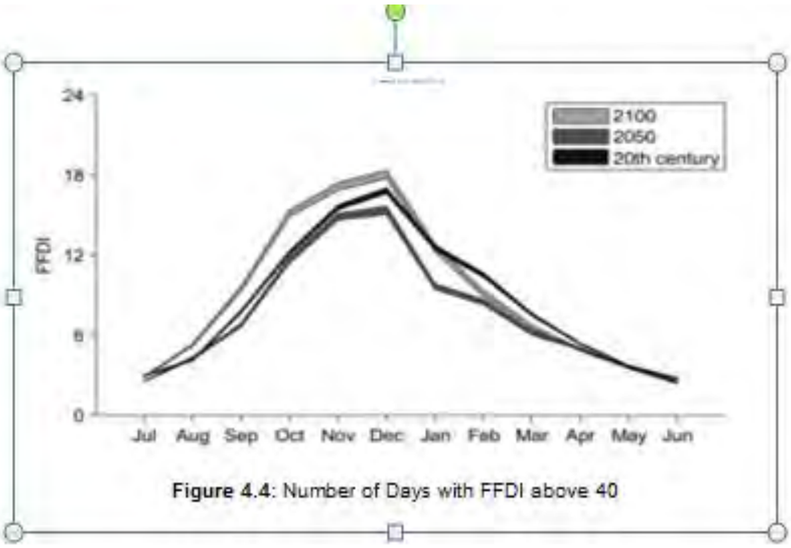


Figure 4.4: Number of Days with FFDI above 40

Figure 4.5: Number of days with FFDI above 40 (Clarke, Smith and Pitman 2011, p. 558).

A presentation by a representative from the Fire Ecology Unit, a NSW state agency, during the Blue Mountains Circle forum, summarised the impacts of fire in the Greater Blue Mountain World Heritage Area as: 'greater level of 40+ FFDI days, an early start to the fire season and more frequent and large uncontrollable fires to be experienced in future under the climate change scenario (Interview 4, June 2013)

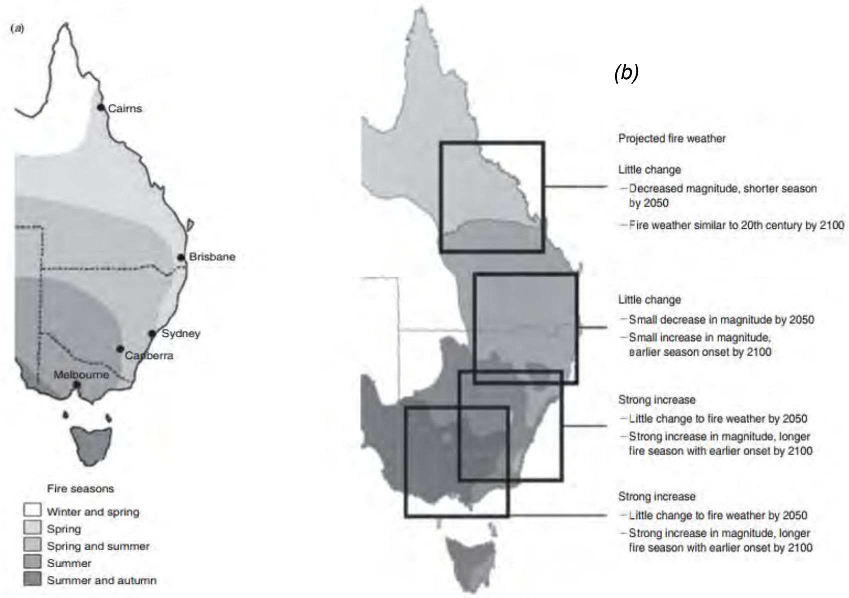


Figure 4.6. (a) Fire seasons in the South East region of Australia and NSW; (b) Likely impact of fire in the region due to climate change during 2100 and 2050.

A warmer future climate with unpredictable and intense rainfall events can have a number of potential impacts on the Blue Mountain ecosystem creating high variability in natural systems that can alter hydrological functions. According to one of the interviewees:

> the future weather conditions when measured against fire models, present a trend in increased burned area in the Sydney Basin. Warmer hot windy days will tend to make fire spread more rapidly and it is anticipated that such days are more frequent. Such conditions can burn somewhere between 15 to 100,000 hectares of land which in some cases could be entire catchments and in large catchments it can be a fairly large portion to be impacted. Highly complex spatial patterns of fire exist but individual fires can have significant impacts on individual catchments (Interview 6, April, 2013).

In summary, a likely scenario of future climate change can have a number of potential impacts on the Blue Mountain ecosystem affecting its hydrological processes. Through discussions with a number of professionals a general understanding of the perceived trends can be determined. Although the exact implications are not known, a general prediction indicates more rainfall in summers and drier winters. In a likely scenario where bushfire events are followed by rainfall, the temporary removal of vegetation cover can expose the surface to erosion. The substrate of swamps is highly organic and there is a potential risk of bushfires burning the peats. If this happens, peat can burn for a long time under the ground. Intense rains during summer potentially indicate more runoff after fire events due to the soil hydrophobicity that would prevent water from infiltrating the soil. A drier summer also means a hard dry surface that would have less water absorption capacity, less infiltration and more erosion, resulting in increased runoff and increased potential to destroy the hydrological structures of these swamps (Interview 2, May 2013).

The likely chance of this happening is higher than anticipated. While talking to a Blue Mountains City Council staff member, it was learned that the possibility of extreme weather is far more frequent '1 in 100 [years] has become 1 in 5 years and those big events will happen more. They usually say that these events happen in 1 and 100, but I have been here for ten years and we had ten of them' (Interview 2, May 2013).

A report titled 'Angry Summer' indicates that in the summer of 2012-2013 temperature, rainfall and flood records were broken across Australia.

> Extreme weather events dominated the 2012/2013, Australian summer, including record-breaking heat, severe bushfires, extreme rainfall and damaging flooding. Extreme heatwaves and catastrophic bushfire conditions during the Angry Summer were made worse by climate change (Steffen 2013, p. 1).

This is the *likely* scenario that can result in erosion, increase the level of storm water runoff causing damage to swamp structures, and subsequently, alter the hydrological regimes of an ecosystem such as the Blue Mountains. There are, however, a number of factors at play that require an understanding through research to assess their collective impacts on the swamps of the Blue Mountains.

An analogy of the functioning of these swamps can be of glaciers. Glaciers hold a massive amount of water and maintain sea levels through this enormous storage. Climate change has resulted in rapid melting of these water storages which has threaten to increase sea level rise with potential risks of flooding in low lying and coastal communities around the world.

The hanging swamps of the Blue Mountain are like glaciers of this landscape. Their role is recognised by the BMCC as:

Hanging swamps are a feature of the Blue Mountains water cycle. They act like massive sponges, soaking up water and releasing it gradually to provide life sustaining moisture for downstream ecosystems (Blue Mountain City Council 2010 cited in Gold & Merson 2013, p. 35)

The slow release of water from these swamps provides a balance in the system. The need is, however, to determine how this balance is at risk from urban expansion in the Metropolitan Urban Area (Chapter 5 discusses the development in the Blue Mountains region), extreme weather conditions that may result in increased temperatures, dry conditions, and an increases in fire frequency. Lack of research and understanding on how increases in impervious surfaces and climate change will influence the water holding capacity of the hanging swamps and what will be the immediate and long-term impacts downstream on the flow regime of this catchment is not recognised in regional planning. The situation is more likely exacerbated when institutions fail to recognise the vulnerabilities of these systems and the absence of managing this system as a single interconnected Social-Ecological-System. This situation is consistent with the concerns highlighted by Sarker and colleagues (2008) in terms of the sustainable use of common pool resources. They argue that there is a missing link in recognising the socioecological interdependence between different users. Consequently, there is a need to recognise within- boundary and cross-boundary externalities that influence common pool resources.

4.7. Governance challenges

The above sections of this chapter focus on the ecological complexity of this system. This is demonstrated through streamlining factors that can potentially threaten the hanging swamps ecosystems. The following section identifies some of the governance gaps that could result in institutional failures to understand, manage and facilitate the system's ability to adapt to abrupt changes under extreme weather conditions.

4.7.1. Agencies need to *talk* to each other – within and outside their specialist disciplines

Wyborn and Bixler (2013, p. 64) argue that 'without forums to connect different cross-scale actors it is hard to imagine how the theoretically proposed benefits of learning and experimentation across a nested governance system could be maximised.' Discussions with individuals from state and regional level agencies engaged in NRM in the Blue Mountains region provided an understanding that departments are compartmentalised into specialised fields. For example in the NSW Office of Environment and Heritage (OEH)[7], there is a Fire Ecology Unit that deals with fire management; NSW Office of Water is responsible for managing flows, surface and ground water resources and flood management; whereas swamps and vegetation management comes under the NSW Parks and Wildlife. The management of swamps is further divided into areas that come under the national reserve to

[7] The name of the department has changed a number of times. It was previously known as the Department of Environment and Conservation and the Department of Environment and Climate Change (DECC) which was later changed to The Department of Environment, Climate Change and Water (DECCW). During the course of this thesis it was recognised as the OEH.

be managed by NSW Parks and Wildlife Department and regions outside to be maintained by the Blue Mountain City Council (BMCC).

This process of compartmentalisation to manage resources is also embedded in research disciplines and among practitioners representing these organisations. A very relevant observation was noted in the *Winter Circle Forum* hosted by the *Blue Mountain World Heritage Institute* in June 2013. The theme of the forum pertinent to the issues discussed in this chapter. The panel representatives, well known for their discipline specific work on fire regimes, swamp conservation, water quality and flow management in the Sydney Basin, discussed the trends in future fire regimes, nature of fire threats to the Blue Mountain swamps and issues of sewerage treatment plants in the region. However, despite these interlinked themes related to the Blue Mountains ecosystem, there were no deliberations on how the discipline specific research integrates to assess collective impacts of these factors on the hydrology of the Blue Mountain system and how that will influence the entire catchment or region. Experts were able to express their views on their specialised disciplines rather than address cross-disciplinary impacts. This may be partially because of the complex relationships between these factors or the absence of data for such analysis. It could also be because research on swamps and fire impacts has recently gained much attention as discussed in the previous sections on fire behaviour and impacts (see section 4.5.2 above). Lack of available data and complexity could be the primary reasons to undertake management research on a piece-meal basis. This suggests that institutional interests are governed by the way different departments are set-up and required to perform in their specific disciplines. A cumulative impact analysis would most certainly require researchers and practitioners to collate scientific information, define relationships, collect substantial evidence for causal relationships for inter-disciplinary research. This is possible only if agencies involved see the value in assessing such impacts and provide the necessary resources and financial support to become involved. The compartmentalisation of agencies into specialised disciplines is, in fact, a reflection of how the prevailing culture of governance perceives inter-related problems of NRM.

Another observation on this was made while interviewing staff from some of the agencies. In order to manage data, recorded for the purpose, the questions asked were divided into specific interrelated themes:

1. Future fire trends and its impact on the system
2. Issue of sediments and runoff in the Blue Mountains
3. Impact of fire on swamps

4. Impact of extreme weather conditions on the Blue Mountain system's hydrology

The themes identified required responses from agencies on the work that they have been doing and their understanding on the future trends in potential changes in the system. It was observed that there were gaps in establishing linkages. For instance work undertaken on fire intensity and severity did not take into account its impact on the hydrology of the region.

> None of the work I have been doing myself and in my team is looking at bushfire and its impact on water flows or water quality. We have been concentrating on the frequency, severity and extent of the fire and building-up details on the fire history of the world heritage area…,the exact history of fire and the extent of impact on hanging swamps haven't been put together yet. Most of the research on fire impacts have been to deal with particular animals in the hanging swamps but not on impacts of fire on hanging swamps and on water regimes (Interview 4, June 2013).

A recent article published in The Morning Hereld Sydney titled 'very fragile system' at risk from coal mininig in Sydney water catchment' highlight the implication of mining exploration on swamps. A representative from Colong Foundation emphasised that the swamps are very fragile systems that can be upset by very small changes and it is difficult to predict them (Hannam 2016). Another representative from Labor's planning also highlighted that "Planning and policy decisions such as proposed offsetting changes cannot be made without recognising that the swamps are an important part of the water catchment and damage to them must be avoided" (Hannam 2016).

For a region to be holistically managed it needs to break through the disciplinary boundaries in which governance of NRM is taking place.

4.7.2. Conflicting state-level interests and local NRM objectives

The Hawkesbury-Nepean region is governed by a large network of agencies, Chapter 8, figure 8.4, identifies those involved in flood management. Broekhans & Correlje (2008) argue that in flood management, governance is often fragmented, complex and may be driven by political economic interests. Chapter 6 & 7 of this thesis discusses different stakeholder perceptions and emphasis on disconnect in the values and interests of different groups.

Councils as statutory agencies

At a local level, councils serve as focal agencies to manage their Local Government Areas (LGAs). Due to their local focus they are more in-tune to the issues surrounding NRM in their respective regions. Some of the council representatives interviewed, felt that councils should be given regulatory powers to be able to influence decisions that pose a risk to NRM in their LGAs. The representative indicated that in the economic interests of the state government, quite often local interests and concerns are ignored (Interview 3, May 2013). Since the council has no legal standing to pass regulations, state government often by-pass councils to obtain regional development objectives (Interview 3, May 2013).

The council's lack of a statutory role has its disadvantages especially when conservation becomes less of a priority against achieving development objectives. In this context, for the Blue Mountains region which is also a designated World Heritage Site, increasing accessibility of land for development presents a challenge to conservation objectives. Ambitious development plans outlined in the Sydney Metropolitan Strategy (NSW Government 2014) suggests the extension of more impervious surfaces, with little emphasis on the use of Water Sensitive Urban Design (WSUD) (Interview 3, May 2013). These decisions can have detrimental impacts on water quality and quantity.

Undermining context specific LEPs in future development strategies

Councils have been managing development through its Development Control Plans (DCPs) and Local Environmental Plans that has helped to scrutinise proposed development in terms of its likely impact on the environment. These plans also set a requirement to have Water Sensitive Urban Design (WSUD) in place. With the new planning system issued by the NSW Planning and Infrastructure Department, a number of changes took place to accelerate development in the region – with environmental issues taking a back seat. The new growth strategy will increase the housing by 180,000 in the Sydney Basin (Smart Consulting 2013). To expedite development, the process of approving development plans will primarily be the State's responsibility. Certain provisions in the new plan, such as reduce approval time for submitted applications and pre-approval of 80% of development proposals, may increase the chances of overlooking environmental aspects of development. These actions will potentially reduce the regulatory power of the councils.

> We [were] working on DCPs that had a statutory requirement to put WSUD in any development that is approved. We were trying to come up with the WSUD floor plan. The NSW government got rid of all the DCPs. We do have a very strong LEP that restricts building on hanging swamps—can't build near waterways, can't build where there is endangered community. The state government is changing all that and they just released their white paper and they are going to try to speed-up development. The State government wants to by-pass us. Council has no legal standing. The LEP will be put into a new format and it will be called Local Plans so the word environment will be removed. They want to change the planning legislations so they can build,

and local community will not have any say. That is the biggest challenge - a culture of denial where climate change doesn't exist (Interview 3, May 2013).

With increased development and reduced measures to minimise developmental impacts on the environment, chances are that issues of runoff, sediments release, storm water impacts will exacerbate in future with a likely impact on the system's hydrology. Experiences in the past, where local level issues have been ignored to implement State interests have accounted for such outcomes, as discussed below.

Case example: Lessons from the past

The Blue Mountains Sewage Tunnel system was developed in 1995. The nearly 40 km tunnel was constructed to divert sewerage waste away from the natural reserves of the Blue Mountains to a more central treatment plant at Winmallee (Wallis 1995) prior to its discharge into the Hawkesbury-Nepean River System. The construction of the tunnel was conducted under the management of Sydney Water Board, and was built as a build-own-operate-and-transfer public infrastructure scheme (a scheme which enabled a third party – private entity to operate and maintain the facility during a given concession period) by the State government that by-passed the council's scrutiny.

Figure 4.7: Positioning of the Blue Mountains Sewage Tunnel (Wallis 1995)

The construction was leased by the Sydney Water Corporation so there was no accountability for monitoring environmental consequences. The lack of involvement of the council and absence of their statutory role also reduced the opportunity to highlight any potential environmental risks presented as a result of this large scale development. Consequently at the time of development, no systematic study was conducted to monitor the impacts of the tunnel scheme on the local water table or stream base-flows.

In 2003, a study was conducted, to assess the impacts of tunnel drainage on the ground water levels and stream base flow for Katoomba-Wentworth Falls region. The study revealed that groundwater drawdown was most severe in the central and west of Katoomba. The base flow to stream and cliff was reduced by approximately 50% due to inflows to the drainage tunnel (Interview 8, May 2013). The study also revealed that there were chances of significant water loss due to tunnel drainage and pumping of water through bores. This had the potential to cause environmental stress surrounding urban areas in the long term (Interview 8, May 2013). Since the ground water system supports a number of sensitive ecosystems such as the hanging swamps, reduction in base flow and ground water levels can increase vulnerability of these systems during drought conditions or periods of low rainfall. Further studies conducted by the Blue Mountain City Council revealed that the tunnels intercepts groundwater and resulted in the drop of nine meters.

Regional agencies are in a position to provide context specific inputs to large-scale projects that can potentially disrupt landscape ecology. The Sydney Metropolitan Strategy facilitates a more flexible plan for development that by-passes any existing LEPs and DCP. This new arrangement reflects the priority of state government and conflicts with the NRM goals of the local council.

A study by Gold & Merson (2013), argues that the Blue Mountain City Council LEP provides certain provisions for environmental protection that are not considered in the NSW Government's Standard Instrument (SI-LEP) template. According to the report the council's existing LEP provides greater level of protection to native vegetation that is not included in zoning, and storm water management. The report also states that the provisions for storm water in the Blue Mountain City Council LEP allows for protection of swamps whereby it prevents intensification of storm water flows and reduces risk of swamp channelisation.

The report concludes:

> Should climate change bring a stressful, hotter, and drier climate to the Greater Blue Mountain World Heritage Area, any weakening of development controls at the hands of the current SI-LEP would only serve to exacerbate the impacts of such change (Gold & Merson 2013, p. 38).

The examples above suggest the significance of context-specific management of resources and the need to accredit local agencies in planning and management for natural resources. These examples represent the governance challenges and their complexity in managing the critical systems in the Blue Mountains which are threatened by development and extreme weather events. The concept of holistic management that recognises the interdependence and interrelationships between social and ecological systems as defined by Hollings requires forums for collaboration and communication (Wiering et al. 2015).

4.8. Conclusions

This chapter identifies a number of factors that can trigger changes in the landscape to create conditions that can potentially influence variability in the hydrology of the Blue Mountains system and its subsequent impacts downstream. In doing so, it emphasised the connectivity between different scales of governance. The bio-physical impacts are amalgamated within a complex governance regime that cultivates a number of management challenges. Although catchment-scale frameworks provide meaningful physical boundaries (Cunningham 1986), significant constraints exist in co-coordinating and integrating institutional approaches. Grumbine (1991) and Day (1988) identify different organisational interests and ideologies as keys to such constraints.

Management of the Hawkesbury-Nepean catchment has become contentious due to upstream and downstream interests and pressures of development (Williams 2012). Through examining the hydrological value of the swamp ecosystems in the Blue Mountains, it was noteworthy to find a mosaic of conflicting interests and priorities of agencies. These conflicting interests and priorities for conservation tend to deter whole-of-government thinking.

The function of swamps is well known through documented literature and generally well understood. There has been work done on the swamps of Woronora, Boyd plateaus in NSW and recent work carried out on impacts of wildfires on vegetation in Kowmung and Nattai Rivers. The hanging swamps of the Blue Mountains, however, have not been a central focus, despite threats due to climate change that can potentially cause massive sediment and runoff issues in Katoomba, Blue Mountain City Council LGA. Knowledge gaps exist in terms of the Council's capacity to calculate the amount of sediments trapped or released downstream. Assessment of effectiveness of urban sensitive design is futile if not measured in terms of their role in controlling runoff and sediment washing downstream. Limitations in knowledge also exist in terms of flow rate increases after a heavy rainfall, how much of this is accounted for as runoff due to increase in impervious surface, and how the hanging swamps are impacted by it?

There is a general understanding that the future climate change scenario will result in more extreme weather conditions. There is also a general understanding that more rainfall events during summers are expected that can possibly lead to increase level of erosion, frequent episodes of flash floods in localised areas, and higher risk of bushfires. Despite these realities, definite conclusions on the exact consequence of these factors on the Blue Mountains are difficult to define primarily because the Blue Mountains region is a rugged and complex area, and the factors triggering impacts such as fires and extreme weather patterns are non-linear and uncertain. What are also lacking are the research aspects to determine cumulative responses to these risks on the eco-system as a whole. Compartmentalisation of institutions into smaller units fails to address interrelated conservation problems and does not encourage a holistic or catchment-scale analysis to determine ecological and environmental consequences. The main reason for the lack of such thinking and planning model is the governance framework that relies heavily on working towards organisation-specific objectives that restrict building capacities that are beyond immediate responsibilities, Chapter 5, provides more information on overlapping goals and objectives and the lack of incentives for integration. There is a general attitude that what goes beyond the boundaries of a particular council's governance area is the responsibility of another.

A lack of information and research is further complicated by a new reform system of governance that intends to discard local context through standardisation of Local Environmental Plans for the sake of expediting urban expansion in a region already under stress. How the parallels of a new governance regime and a rapidly changing climate will influence the hydrology of the Blue Mountains is a challenge that needs to be addressed by researchers and practitioners.

In this chapter management gaps are identified by examining the value of hanging swamps and potential vulnerabilities to this system,. The issue of scale in managing SES is critical. There is a need to determine appropriate scales of management. Processes that link scales need to be identified and recognised to foster interventions at different levels i.e. from catchment-scale to local sub-catchment level, and from state to regional and local. This chapter has discussed issues of scale and the lack of linking between different environmental components of a catchment-scale system. The following chapter will focus on practices adapted at a local scale taking flood risk management as central to the discussions in this thesis. It lays emphasis on how local context overrides the whole-of-system thinking approach when managing floods in the Hawkesbury-Nepean catchment.

Chapter 5: Flood Management Practices in the Hawkesbury-Nepean Catchment

5.1. Introduction

This chapter provides another dimension of scale. It examines the flood management practices in the catchment—providing a more micro-scale focus. In order to determine maladaptation in the existing system of flood governance, it is essential to understand the processes involved in its management and how factors such as development can create problems of flood management.

Councils are the main authorities for flood management, planning and development for their respective Local Government Area (LGA). The Hawkesbury-Nepean region is subjected to an ambitious development agenda to be undertaken during the next few decades. Development is more likely to transform the landscape of this region. The councils approve development under the premise that new development maintains pre-development flow regimes. Therefore development will continue as long as measures to counteract additional flows are implemented. Does this principle rationalise opening access to additional land for intensive development? Do the councils have an effective flood management mechanism that can allow natural systems to accommodate urban expansion and climate change impacts? This requires the examination of areas targeted for future growth in the region; explores planning and development processes carried out by the council; and determines their feasibility. This chapter assesses the current flood management practices in the region with specific focus on the four councils; Blue Mountains City Council; Liverpool City Council; Penrith City Council and Hawkesbury City Council. More particularly this chapter examines the following:

- patterns of growth and development in these four councils
- consequence of development to flood risks
- flood management processes in the Hawkesbury Nepean Catchment
- gaps in flood management in the Hawkesbury Nepean Catchment
- barriers to adaptation processes in flood management

5.2. Methods of inquiry

The information collected to analyse this is based was predominantly based on document analysis such as council reports, review of development plans and flood studies. In addition, semi-structured interviews were conducted with the local and regional agencies and individual academic representatives possessing in-depth understanding of urban planning in this region. Since the primary focus of this chapter is to identify the current flood management practices and elaborate on the problems that urbanisation and weather extremes will pose to this catchment, the targeted interviewees selected were mostly representatives from local councils. For this purpose, technical engineers, flood managers and strategic planners from councils, mostly from downstream of the Warragamba dam were selected for interviews. These included individuals from Penrith, Camden, Liverpool and Hawkesbury city councils. In addition, representatives from Western Sydney Regional Organisation of Councils (WSROC), Floodplain Management Association (FMA) and State Emergency Services representatives were also interviewed to gain a regional perspective on flooding and regional scale management of this catchment. Information-gathering through personal communication (emails) was also carried out for brief data inquiries and acquisitions.

The councils were selected on the following premise that the council Local Government Area (LGA) is:

- one of the regions focused on future development targets
- either in close proximity to the Hawkesbury-Nepean water system or is one of the river cities with high flooding potential
- providing a unique ecological environment that can be adversely impacted by the proposed development agendas
- an essential hydrological system that supports critical tributaries
- a part of a regional body to assess their potential to undertake regional action.

The councils thus selected generally cover most if not all of the above criteria. In addition, a review of flood-studies was also carried out to develop an understanding about how flood risks are determined and management plans developed. For this chapter discussions with twelve representatives were carried out in addition to seven personal communications.

5.3. Planning and development in the Hawkesbury-Nepean catchment

Reforms in NSW's planning and development have led to the development of the Sydney Metropolitan Strategy. The Strategy has set growth targets that will accelerate development in the western region of Sydney. For the Hawkesbury-Nepean River system, this adds another dimension of complexity to manage this catchment. With a total of 180,000 dwellings planned in this region, the challenge to manage the increased runoff and overland flows resulting in the expansion of hard surfaces becomes critical. Climate change presents another challenging dimension that state and local agencies need to consider while planning to accommodate massive expansion of this flood-prone region.

The Sydney Metropolitan Strategy has identified two growth centres in the west of Sydney as part of its mandate to expand development and foster urbanisation. The development of these centres is administered by the *NSW Department of Planning and Infrastructure* through the *Growth Centre State Environmental Planning Policy (SEPP)*. The development in the growth centres is a staged process where first the precinct identified for future development in the growth centre undergoes environmental, infrastructure and housing assessments. According to the process outlined in the Sydney Growth Centre program report (NSW Government 2010a), several studies are conducted to assess a range of environmental, socio-economic, and cultural impacts prior to releasing a Precinct for development. Next, these assessment reports are used to develop an Indicative Layout Plan followed by the Development Control Plans (DCPs) for the Precinct under review. After submission, these plans are reviewed and approved by the *Minister of Planning*. The approval of these plans results in the annulment of any existing Local Environmental Plan (LEP) and DCPs for that particular Precinct. Consequently, when development applications are submitted to the local council they are reviewed under the *NSW Department of Planning and Infrastructure's Growth Centre SEPP*. Issues of the standardisation of LEPs have been discussed in the previous chapter.

5.3.1. Growth centres

The development in the west of Sydney is primarily being undertaken in the two main regions of growth called the Northwest Growth Centres and the South West Growth Centres (see figure 5.1). These Centres are characterised as underdeveloped land covering an area of about 27,000 hectares (NSW Department of Planning and Infrastructure 2011). The Growth Centre planning was initiated in 2005 through the precinct planning process. The development is planned to continue for 25-30 years and is anticipated to accommodate 180,000

The North West and South West Growth Centres in the context of the Sydney region.

Figure 5.1: Growth Centres (NSW Department of Planning and Infrastructure 2011)

new dwellings in the region (NSW Department of Planning and Infrastructure 2011)

The North West Growth Centres (NWGC) includes Baulkham Hills, Blacktown and Hawkesbury. (Figure 5.1) Approximately 70,000 dwellings are planned for this region. Development in this region is divided into 16 Precincts. The South West Growth Centre (SWGC), situated in the southwest of Sydney, encompasses Liverpool, Camden and Campbelltown LGAs (Cardno 2011). It constitutes 18 Precincts with 110,000 new dwellings planned. The following section will discuss the potential risks urbanisation presents in these Growth Centres with regard to flooding.

5.4. Review of urban development and flooding problems in the four council LGAs

A detailed account of the four councils in the catchment is described below in terms of development plans and flood risks in the respective LGAs.

5.4.1. Urban development and flood risks in the Blue Mountains City Council

The previous chapter on the Blue Mountains signifies their value as an important hydrological system and highlights the potential threats to its ecosystem due to climate change and its likely impacts on the water resources, and the lack of research evidence to quantify such impacts. This chapter, however, focuses on the urbanisation issues from the flood management perspective. The Blue Mountains region, in comparison, is geographically different from the other three councils (Penrith, Liverpool and Hawkesbury) discussed in this chapter. Apart from being a World Heritage Site, the majority of this region forms the upstream area of the Warragamba Dam. This indicates that the mainstream flooding from the Hawkesbury-Nepean River systems would unlikely have a direct impact in the Blue Mountains LGA. Flooding, however, in the region may result from intense rains over short duration that can cause high flows and flood housing properties (Cardno Willing 2005). Hence, future urban development presents a challenge.

The steep and sloped topography of the Blue Mountains LGA also suggests that increased urbanisation can influence downstream water flows due to the increase in storm-water runoffs (Blue Mountains Conservation Society Inc. n.d.). A letter submitted to the Minister of Planning and Infrastructure by the *Blue Mountains Conservation Society*, highlights the detrimental impacts of urban growth in the area. In their submission, the Society emphasised that the new planning system in the White Paper, and as laid out in the Metropolitan Strategy, will open access to the natural reserve of the Blue Mountains for development and will cause urban sprawl.

According to the Metropolitan Strategy, the east of the Blue Mountains is targeted as an urban release area for housing development. There are about 7,000 new dwellings planned for the Blue Mountains LGA (Gold & Merson 2013). While in discussion with a staff person from the Blue Mountains City Council, it was noted that on average there are about 150 dwellings developed annually. Increased development is an issue primarily because of the physical space availability and also due to bushfire risks (Interview 1, August 2013). The lower Blue Mountains region bordering the Penrith City Council is identified as the Sydney Metropolitan Urban Area (Figure 5.2), targeted for future development. The development in the Metropolitan Urban Area of the Blue Mountains will be constrained by a lack of infrastructure and sewage waste disposal issues in additional to being instrumental for urban sprawl (Interview 1, August 2013). *The Blue Mountains Conservation Society* expressed that the Blue Mountains should be removed from the Metropolitan Strategy and should not be treated as a "high growth" area and its development plans should not be planned in line with those of the Penrith LGA (Blue Mountains Conservation Society Inc. n.d.).

Figure 5.2. Sydney Metropolitan Urban Area (Blue Mountains Conservation Society Inc. 2015)

While the Blue Mountains City Council does not agree with the development plans as per the reform Strategy and continues to criticise the implementation of a standardised LEP (discussed in chapter 4) and development in new release areas, an assessment of its current flood management practices helped identify the current state of management and the likely increase in management gaps due to the implementation of new development plans.

A discussion with the Council representatives provided information on the current governance gaps in terms of flood planning and management which is generally consistent with the on-ground practices adopted by other councils. This has been discussed in the later sections of this chapter.

5.4.2. Urban development and flood risks in the Liverpool City Council

The Liverpool City Council is surrounded by the Camden City Council in the South, Penrith in the North and Wollondilly and Blue Mountains in the west. Figure 5.3 shows the Liverpool location (inset) and water courses across the Liverpool LGA.

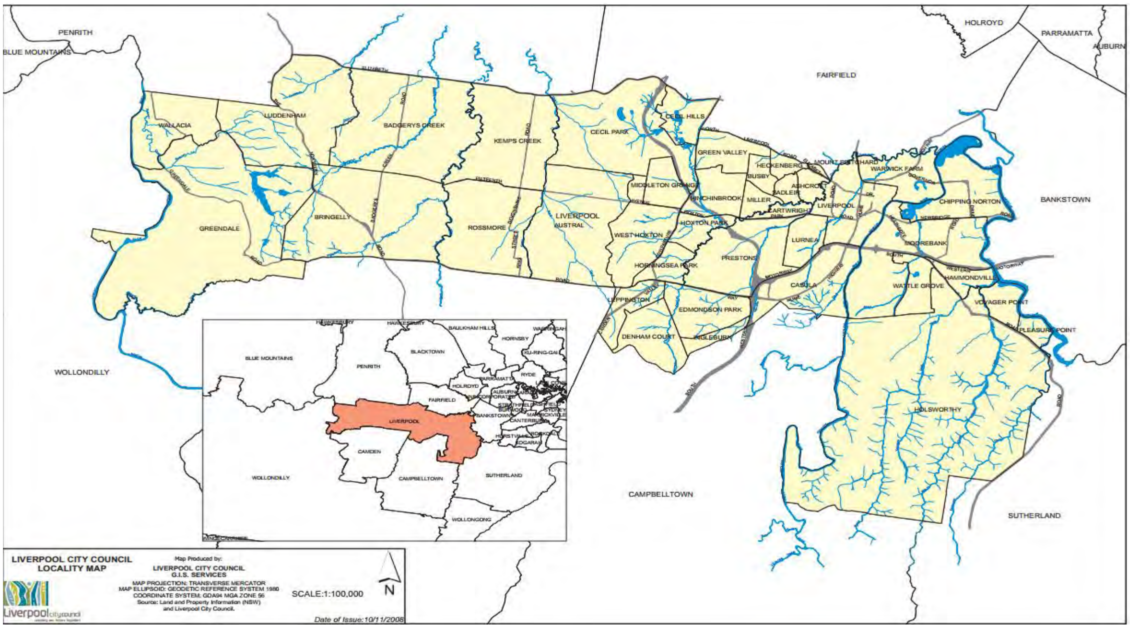


Figure 5.3. Liverpool City Council boundary map

Unlike Penrith and Hawkesbury LGAs, the Liverpool region shares a small portion of the Nepean River in the Hawkesbury-Nepean catchment. Risk of flooding directly from the Nepean River is of less concern. Flooding risk in the Liverpool LGA, however, is influenced by three other catchments/sub-catchments; the Georges River on the east, close to the Liverpool City Centre; Cabramatta Creek in the mid-west; and Austral Kemp Creek that flows into South Creek which is a major tributary of the Hawkesbury-Nepean catchment. The following maps (Figure 5.4) show the extent of flooding of these creeks across the council region at a broad scale. Nepean River forms the west of the LGA and is categorised as a low flooding area in the map below.

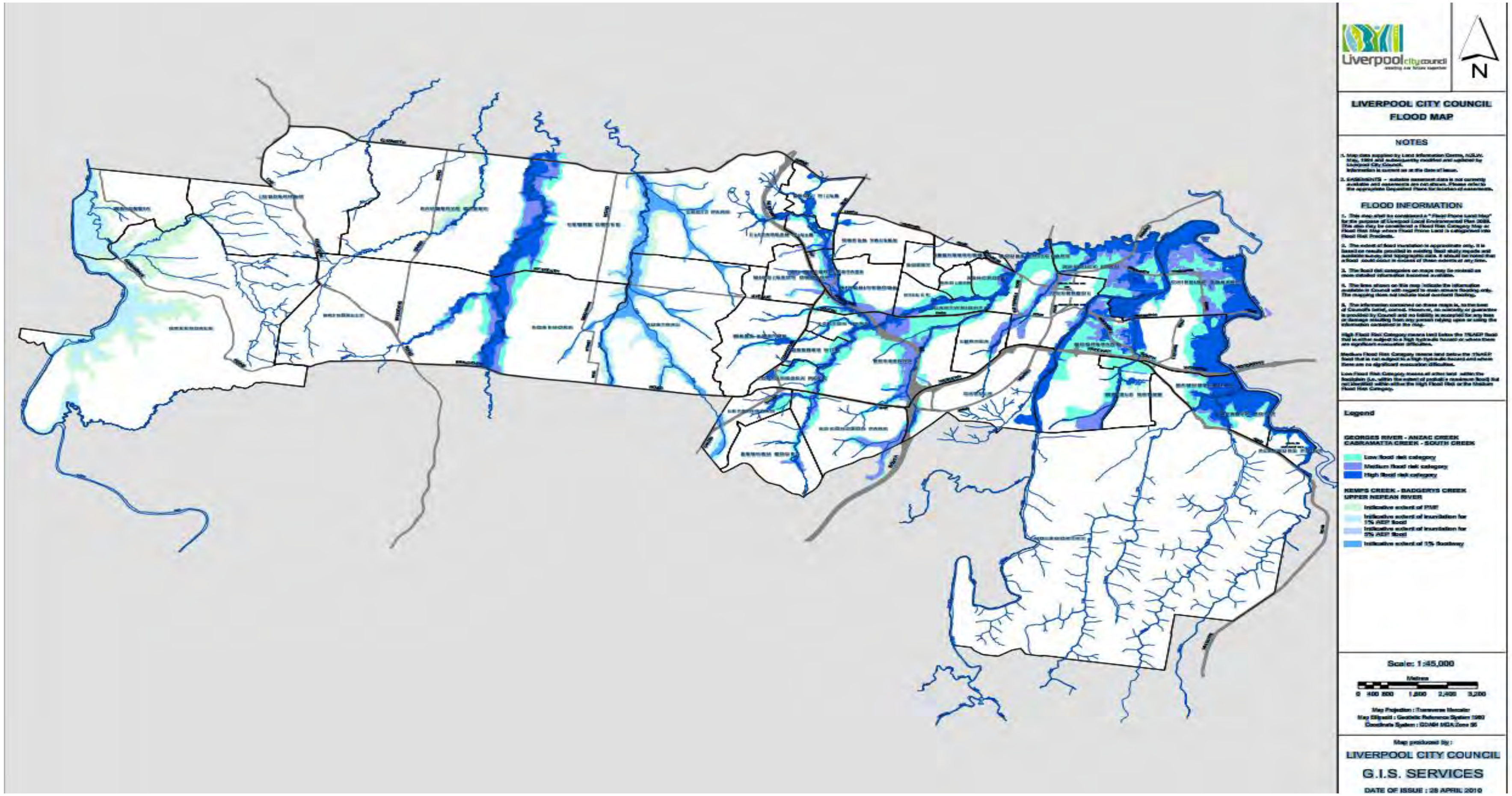


Figure 5.4. Liverpool City Council flood map (Liverpool City Council, per comm., 1, 2013).

For discussion purposes, Kemp creek in the Austral Growth Centre will be reviewed to assess flooding potential in the Growth areas. The flooding potential and issues of flood management in this particular area have been selected due to ease in acquiring updated information about these newly released precincts and to demonstrate how urbanisation presents a challenge in flood management in the Hawkesbury-Nepean catchment. An in-depth discussion to analyse the flooding issues has been carried out for these precincts (Austral and Leppington) in this section. The following map (Figure 5.5) shows the area under discussion, circled in pink within the South West Growth Centre which has an approximate area of 20.3 km^2 (Cardno 2011).

Figure 5.5. Austral and Leppington North in South West Growth Centre (NSW Department of Planning and Infrastructure 2011).

Within the Austral and Leppington regions, an estimated total number of 17,350 new houses are planned to be developed over an area of 2,025 ha (Smart Consulting 2013). The land is characterised as rural with small-scale farming. About 85% of the native vegetation has been removed from the area to allow development. Approximately 8,000 – 12,000 dwellings are expected to be developed in Austral and North Leppington area respectively (Cardno 2011).

The future development area in the Austral and Leppington region is dominated by three main creeks; Kemps, Bonds and Scalibrini creeks (Figure 5.6). The water courses are drained from south to north into Kemps Creek. The floodplain extends up to 500 m in the

Kemps and Bonds creek. Kemp Creek flows 2-2.5 km before joining South Creek, downstream in the west, which then flows towards north to join the Hawkesbury River at the Hawkesbury City Council Area (Cardno 2011). This shows how the water systems in the region are linked and their potential influence downstream.

The soils in this growth centre region are characterised by poor drainage soils and soils surrounding these creek systems pose a significant erosion hazard (Cardno 2011). The following map shows the region and the creeks passing through it.

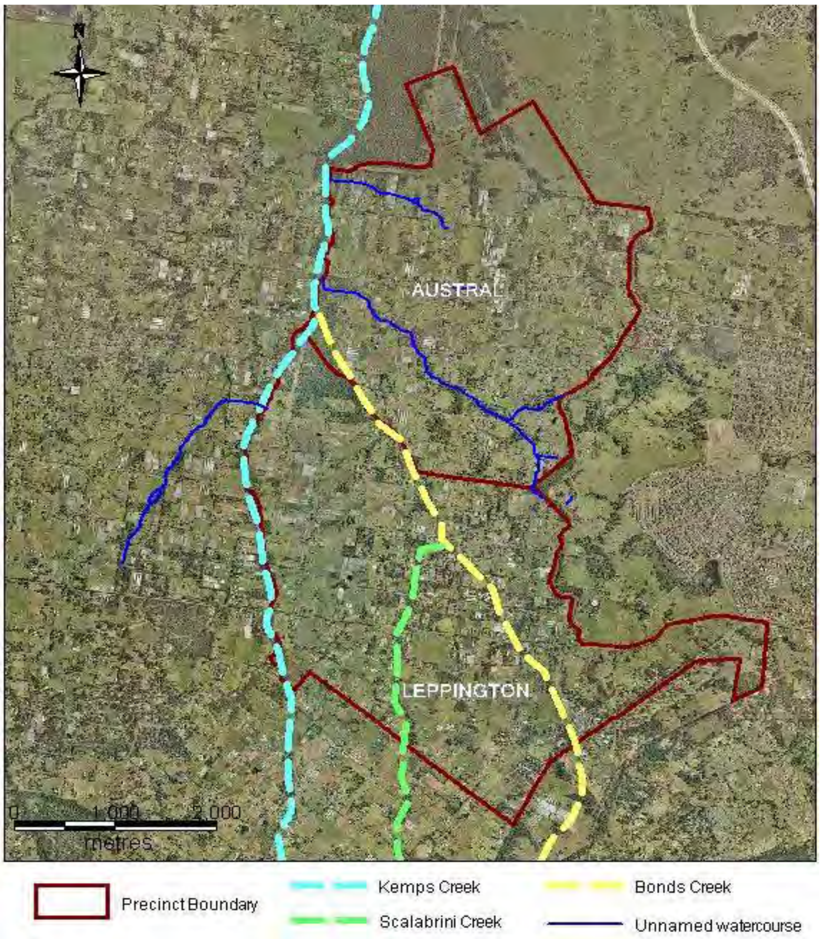


Figure 5.6: Important creek systems in Austral and Leppington Growth Centres (Cardno 2011).

Flood risks in the Kemps Creek floodplains

The floodplains constitute about 30% of the Austral land, a large area which consists of the Kemps creek area. The flood risk assessment highlights that the local communities are faced with flooding issues with limited capacity of the councils to make improvements to reduce impacts (Perrens Consultants 2003). The Austral landscape consists of small water channels with limited capacity to hold small floods that occur once a year. Hence more frequent floods or floods of high magnitude are more likely to flow over the wide floodplain areas (Perrens Consultants 2003).

Currently, the road system and low dwelling density in the area supports the rural nature of the area. The rezoned map, below (Figure 5.7), shows the extent of development planned in the Growth Centre with the majority of the area zoned as residential, industrial and commercial identified in shades of tan, (a majority), white and blue respectively.

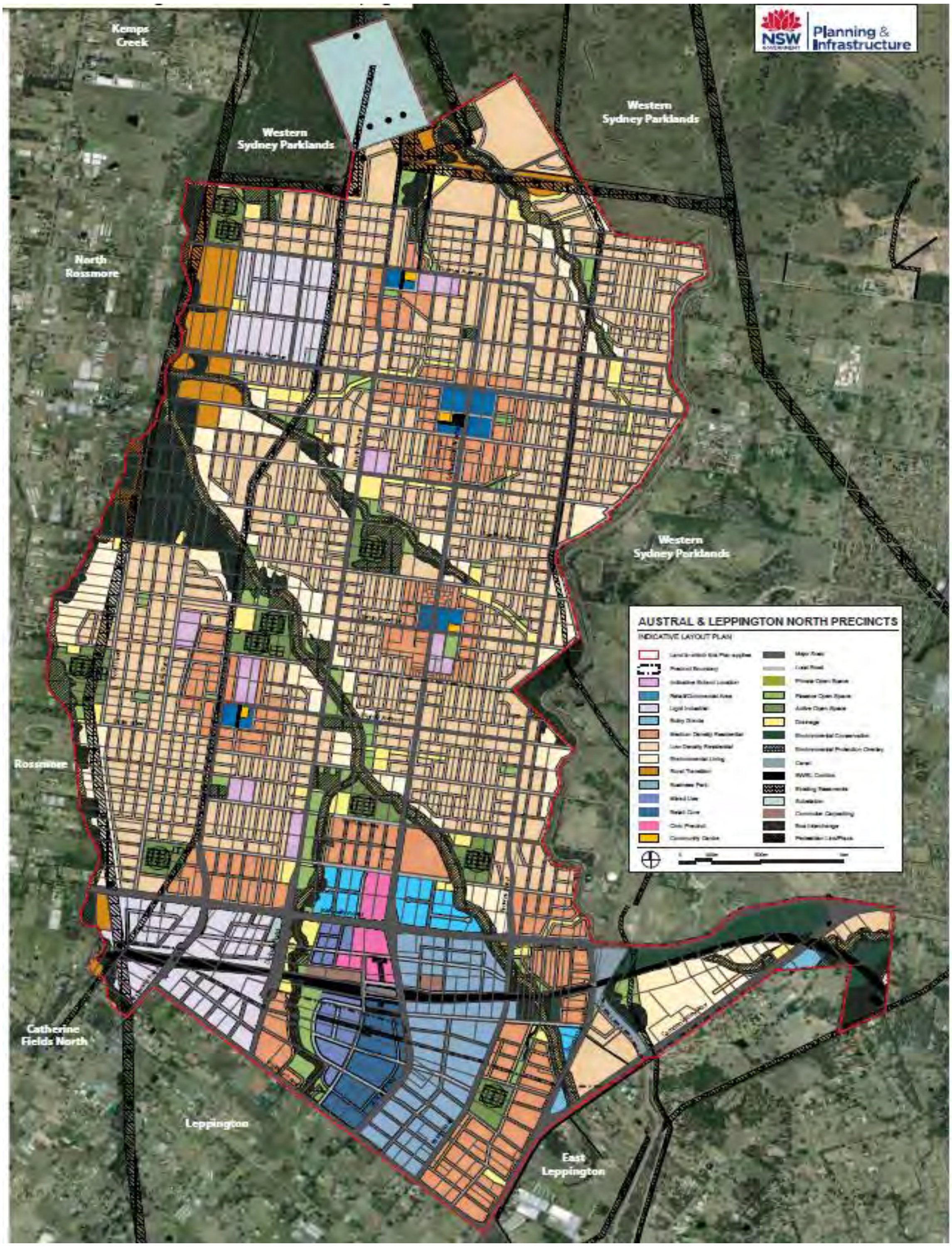
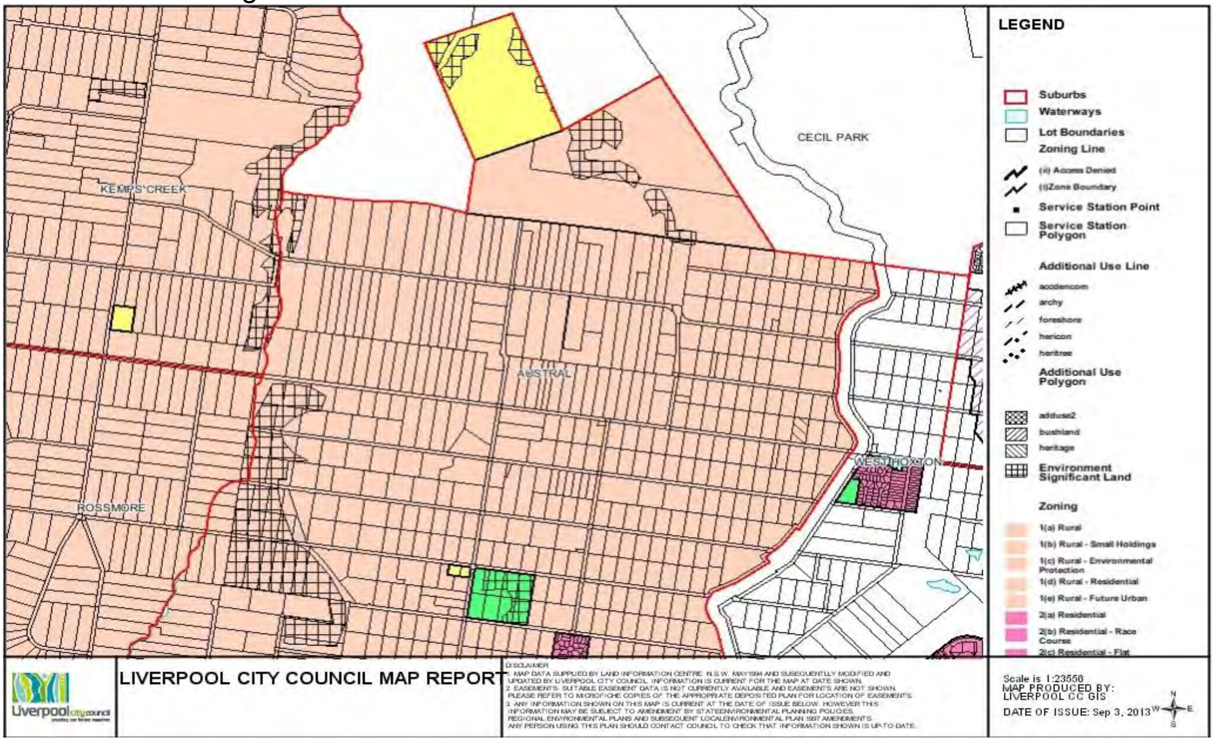


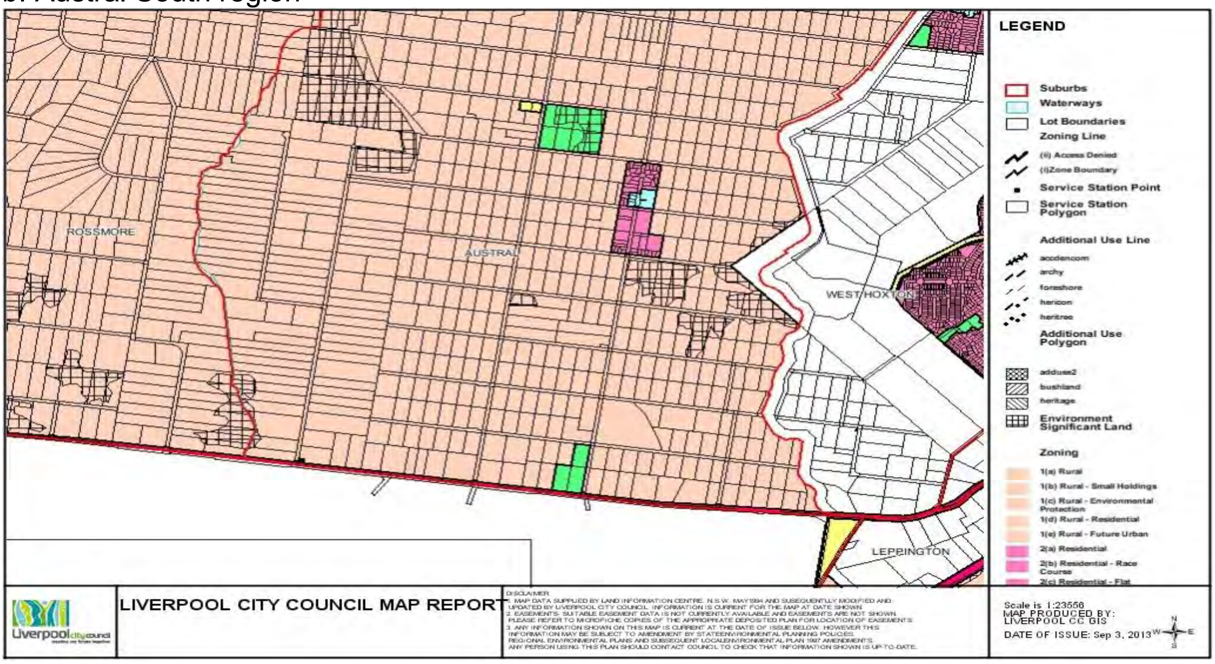
Figure 5.7. Re-zoned map for Austral and Leppington (Liverpool City Council, per comm., 1, 2013).

In comparison, the old zoning maps for Austral and Leppington as shown in Figure 5.8 below show rural area and small holdings in ‘light pink’ that form the entire landscape with residential area coloured as ‘hot pink’.

a. Austral North region



b. Austral South region



c. Leppington region

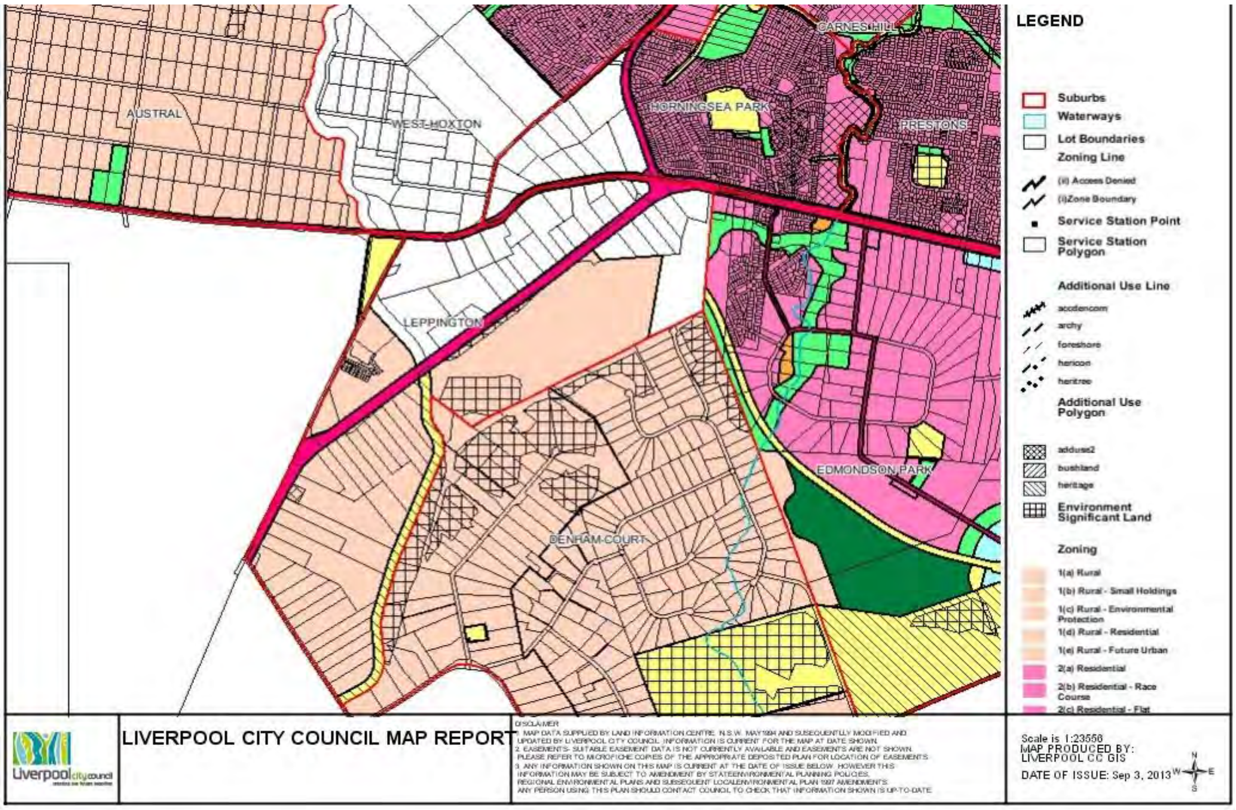


Figure 5.8. Old zoning maps (a, b & c).

The difference between pre-zoned and newly zoned areas illustrates the extent of transformation in this region as a result of implementing future development plans. The new rezoned areas will not only result in massive conversion of natural land to an urbanised centre but will also increase the amount of impervious surface area. This is likely to exacerbate issues of flooding and change the pattern of overland flows. Currently, three main structures have resulted in disruption in natural flows and have caused pounding upstream. According to the Austral Risk Management Study (Perrens Consultants 2003), these three major road infrastructures (Elizabeth Drive, Fifteenth Avenue and Bringelly Road structures) have significantly obstructed flows. The re-zoned map (Figure 5.7, above) shows a high concentration of development around Fifteenth Avenue and Bringelly Road which may cause further disruption in natural flows of the catchment system as explained in the Austral Risk Management Study:

> The low hydraulic capacity of the natural drainage system, coupled with generally low culvert capacity and a road layout which is not sensitive to flooding patterns has compounded problems, particularly those of access during flood periods (p. 12).

Heavy storms in April 2015 had also resulted in flooding of Thirteenth Avenue in this area (Chapter 8 provides more details about the storm impacts) highlighting the potential of future flood risks with increased development.

The Perrens Consultants (2003) study also highlights that about 61 of the existing dwellings are in the flood zone area close to the Bonds Creeks and Scalabrini creek. Looking at the most recent re-zoned map (2013), there is additional development planned (medium to light residential and industrial development) in close proximity to these creeks. This will undoubtedly exacerbate the flows in the Kemp Creek and will more likely 'mimic' the issues of overland flows as observed in the flood map (Figure 5.4 above) to the east of Liverpool. Additionally, from Figure 5.4 above, it can easily be recognised that flooding intensity is higher in the more developed eastern region of the Liverpool council as compared to the rural western region. The landscape will likely change with the development of the South West Growth Centre.

There is also a general assumption that as long as the new development is able to maintain pre-development drainage flows, the flooding problem will not exacerbate. Therefore, to counteract the issue of overland flows and as a flood mitigation strategy the Liverpool council plans to implement a massive detention basin in the region. At Cabramatta creek, which has a catchment area of approximately 74 km^2 (29 sq mi) there are around 20 of these detention basins (mostly developed). In comparison, in the South West Growth Centres, in the Kemp creek-Austral region which forms a relatively much smaller catchment area, it has been proposed to have 32 such detention basins. This demonstrates the extent to which flood patterns may be altered due to the development such that it would require a greater number of detention basins to ameliorate the impacts of altered flows in the region. This planning, however, does not guarantee the management of floods occurring at the probability of 1-in-a-100[8] years as there are no mechanisms in place to mitigate floods above 100 years.

Furthermore, there are plans to supplement the detention basin with a trunk drainage system in the Austral-Kemps area. This may, on one hand, resolve issues of local flooding but on the other hand, may result in increased flows downstream and in the main tributaries of south creek that could influence flows in the Nepean River already vulnerable to future

[8] 1% AEP flood is a flood that occurs on average once every 100 years. It is also referred to as the '100 year flood' or 1 in 100 year flood' (Liverpool City Council 2007).

extreme weather scenarios. A case example discussed in Figure 5.9 provides a critical reference to this.

Case Example: Cabramatta Creek Catchment

A brief account on Cabramatta Creek is discussed to demonstrate how flooding issues are challenged by a rapidly urbanised region and how similar conditions can be perceived when the West Growth Centres are subjected to similar patterns of development and growth.

The Cabramatta creek is one of the major tributaries of Georges River. It is also a catchment that has been substantially modified due to rapid expansion of urban growth where large areas of land have been re-zoned for residential and industrial purposes, in addition to the development of road infrastructure. These activities have inevitably impacted the flooding behaviour especially with expansion of new suburbs and development in floodplains. Consequently, in the past five decades there have been ten major flooding incidents that have resulted in inundation of land adjacent to the Creek and its tributary creeks (Brewsher Consulting 2011).

A large number of dwellings including commercial and industrial buildings have been developed in the catchment which is likely to be flooded above floor level in a 1-in-a-100 year flood event (Bewsher Consulting 2004 cited in Bewsher Consulting 2011). These buildings have been constructed just above the 1-in-a-100 year scenario. Climate change studies in the Georges River catchment suggest that increase in rainfall intensities will have impact on the Cabramatta Creek that will potentially increase the 100 year flood level.

The severe floods of the 1980s occurred as a result of major flooding in the Georges River. It inundated over 1,000 residents with an estimated damage of about 40 million dollars. The flooding occurred in Cabramatta and Prospect Creeks (Bewsher Consulting 2001). In response, as a ‘reactionary’ measure, detention basin strategy was adopted for Cabramatta creek to curtail the impacts of development to conditions that prescribe a predevelopment state. There are more than a dozen of these detention basins with about half a dozen planned to be developed

Similar patterns of development and application of flood mitigation options have been applied. However, the impact of additional development in new release area has not been considered for floods higher than 1-in-a-100 year nor the accumulative impacts of development in the entire LGA - waters and creeks are connected and influence flows in the main rivers. Creeks in the east of the Liverpool LGA such as the Cabramatta Creek represent the patterns of growth and development surrounding it. The flood map (Figure 5.4) provides a visual display of how the regions within the Creek’s catchment have higher flood risks. Similar patterns of development in the Growth Centres can raise potential flood risks and present a challenge to councils to deal with flooding scenarios.

Figure 5.9: Case Example: Cabramatta Creek Catchment

5.4.3. Development challenges and flood risks in the Penrith City Council

The Penrith LGA is situated west of Sydney, bordering Liverpool Council at the South, and Hawkesbury LGA at the North. It is recognised as the passageway that connects the urbanised Sydney and its sub-regions from the east of Penrith to the Greater Blue Mountains area in the West. The Penrith LGA

Figure 5.10. Location map of Penrith (Randolph & Holloway 2003).

covers an area of 407 km^2 that is predominantly rural landscape with development concentrated close to the city centre, forming a corridor expanded in a horizontal east-west direction close to major roads infrastructures (Randolph & Holloway 2003). (Figure 5.10) The region supports significant agriculture in the north and south of the LGA. While the region has slowly evolved to cater to increased residential pressures, it is anticipated that a more rapid development scenario is planned for this region in the next few decades. Among the four councils lying in close proximity to the Nepean-Hawkesbury River System, Penrith LGA is expected to accommodate the largest amount of urban dwellings. According to the Sydney Metropolitan Strategy 2036, it is defined as the Regional City which will be a primary focus of future development. The following table (Table 5.1) provides a brief comparison of expected development targets as outlined in the Sydney Metropolitan Strategy 2036 (NSW Planning and Infrastructure 2012).

Table 5.1. Expected development targets

Planned Development Areas	Development Targets
The Blue Mountains	7 000
Hawkesbury	5 000
Penrith	25 000

(NSW Planning and Infrastructure 2012)

Development plan for the Penrith LGA

Unlike Liverpool's urban development, where the majority of future planned development is being carried out in new release areas, development in Penrith LGA is planned to spread across a number of suburbs. The Penrith Urban study (2008a) identifies fourteen new urban release areas for development. Half of the planned development will take place in already urbanised/semi-urbanised regions whereas the remaining 50 percent of development will be targeted in new release areas. 'Infill' development will take place in a number of regions as shown below in Table 5.2.

Table 5.2. Infill Development Regions

Emu Plains	Cambridge Park	Werrington
Penrith City Centre	Kingswood	St Marys
Glenmore Park	Claremount Meadows	North St Marys
Cranebook	Werrington Downs	St Clair
Cambridge Gardens	Werrington County	

(Penrith City Council 2008a).

In addition, fourteen new release areas have also been identified for future development which include Penrith Lakes and areas surrounding and in between the regions of Werrington, Claremont Meadows and Kingswood. The two blue circles on the map below (Figure 5.11, below) outlines the regions designated for planned development that are also in close proximity to the major water systems (i.e., the Nepean and South Creek in the LGA.)

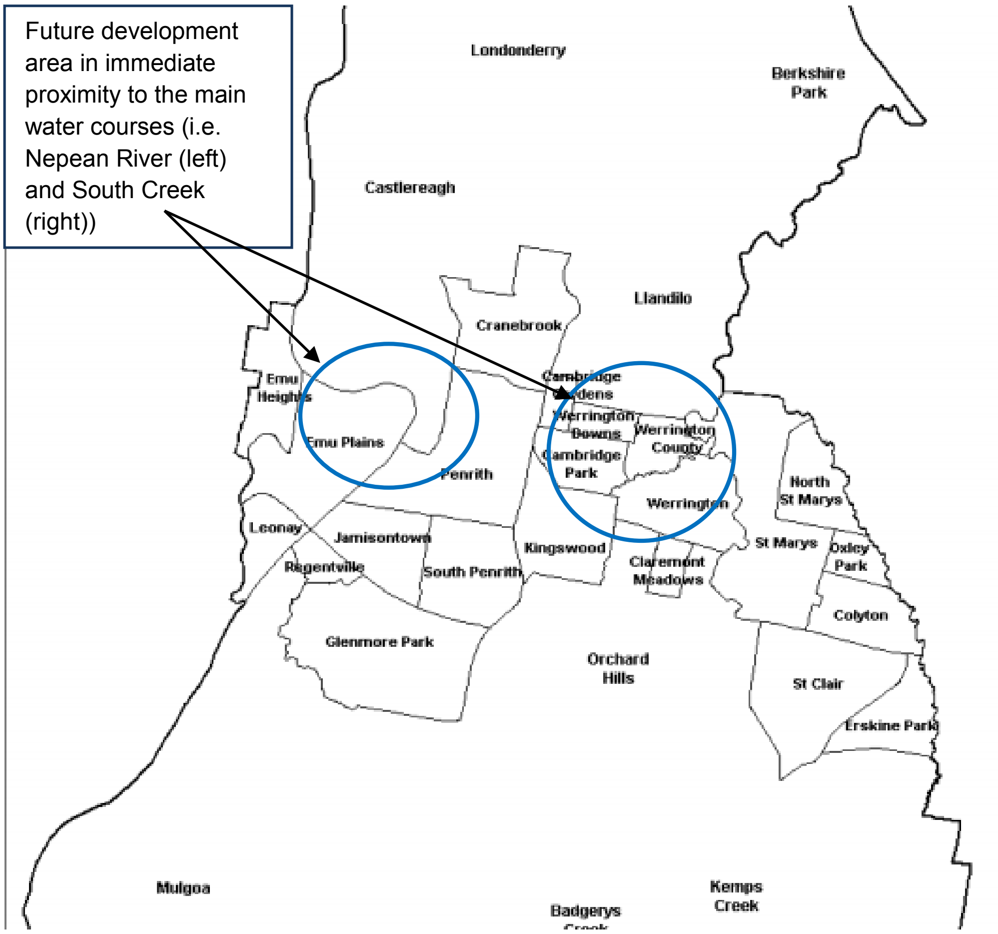


Figure 5.11. Penrith LGA (Penrith City Council 2008a)

Important water courses and flood risks

The Penrith LGA has two important water systems; the Nepean River System, in the west, and the South Creek System, in the east, and its tributaries. The image below (Figure 5.12), shows a vast network of watercourses spread across the Penrith region. The dark blue lines show catchment boundaries. The Nepean River on the west of Penrith (Far left: shown as solid dark blue colour) has a number of catchment systems flanked on either side which connect at several points close to the Penrith city centre (marked in red). The far right which forms the east side of the LGA is the South Creek System (circled in red).

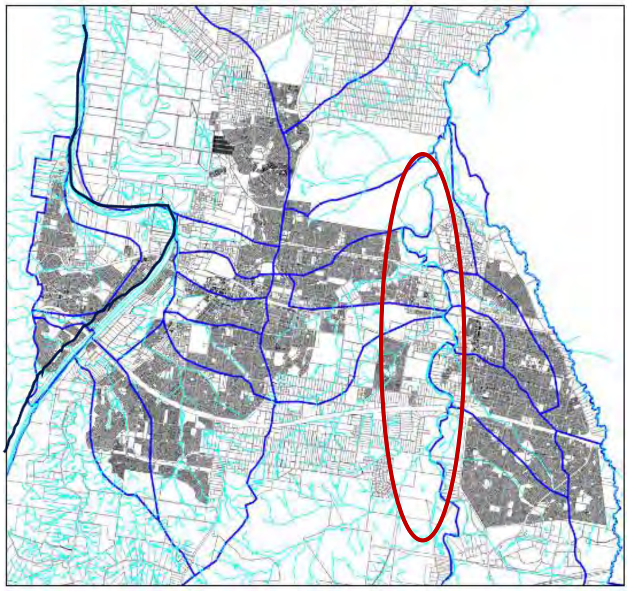


Figure 5.12. Network of water courses at the Penrith LGA (Penrith City Council 2008a).

The South Creek System encompasses a number of urbanised suburbs and New Release Areas in the Penrith LGA. The following figure 5.13, shows important rivers and creek systems in Penrith.

Figure 5.13. Rivers and Creeks in Penrith LGA (Penrith City Council, per. Com., 2, 2013)

Penrith LGA lies on a relatively flat terrain rising slightly from west to east. It is this flat terrain that increases the likelihood of flooding from these watercourses especially from the Nepean River System (Penrith City Council 2008a). "The suburbs of Penrith and Emu Plains straddle the high banks of the Nepean River in what is a typical picture of Australian suburbia - lots of brick houses, probably built around the 1960s and 1970s" (Mark 2012). According to Steven Molino (from Molino Stewart consultancy, with 20 years of experience in floodplain management) "a major flood today would probably destroy many houses in Emu Plains" (Steven Molino, cited in Mark 2012). Parts of Penrith and Emu Plains are all major urban areas and vulnerable to Hawkesbury-Nepean flooding (Howes 2012). According to a State Emergency Service representative, a major flood in the region will require evacuation of 70,000 people (Interview 2, December 2013).

> At some point we are likely to experience a major flood in Sydney. It will be deep, and it will affect a very built-up area… the primary floodplain is mostly located within the Penrith, Hawkesbury, Blacktown and Baulkham Hills local government areas (Howes 2012 p.1).

Several of the most severe floods experienced on the Hawkesbury-Nepean River have resulted from East Coast Low Pressure Systems. Among these was the highest recorded flood of June 1867 (Howes 2012, p. 7).

The extent of the 1867 flood is shown in the image below (Figure 5.14). When observed closely the magnitude of the flood indicates that a major part of Emu Plains and the Penrith city centre were inundated. When compared to a recent Google image (2013) of development in these regions (Figures 5.15 a & 5.15 b), the image shows that a number of residential properties could be at risk of flooding. A closer view (Figure 5.15 b) shows a section of urban development in Emu plains, indicating the close proximity of dwellings to the Nepean River. In a recurrent event, such as the 1867 flood (or floods larger than a 100-year event) the region will most likely be flooded with a much higher social and economic cost.

Figure 5.14**.** Extent of 1867 (100 year) flood

Figure 5.15a. Urban development at Emu Plains, west of Nepean River (Google Map 2013)

Figure 5.15b. Emu Pains, arrows indicating the possible overland flows from either side of the Nepean River (Google Map 2013).

Across the Emu Plains, on the east of the Nepean River, is the Penrith City Centre Precinct (See Figure 5.16 below). The Urban Study (Penrith City Council 2008a) characterises this City Precinct as an area of underdeveloped and undeveloped land. The report also signifies that the development in this particular region is constrained due to flooding complexities and future development should take this into account. However, the projected planning for the City Centre Precinct defines high density development surrounding Station Street and Mulgoa Road which is in close proximity to the Nepean River System. The existing development patterns as seen in the Google image above and the planned development close to the River System in the City Centre Precinct shows that the probability of another large scale inundation of the region is greatly underestimated or is considered to be perceived as an insignificant risk.

> Above the 100 year level, it is assumed, wrongly, by the general community that the land is 'flood free'… Most Councils do not have development controls above the 100 year flood level (Howes 2012).

With further development planned in the Emu Plains and City Centre region, accumulative impacts of urbanisation on flows in the Nepean River need to be assessed for flood risk and management. The arrows in the second image (figure 5.15b, above) indicate the potential for inundation from either side from overland and mainstream flooding.

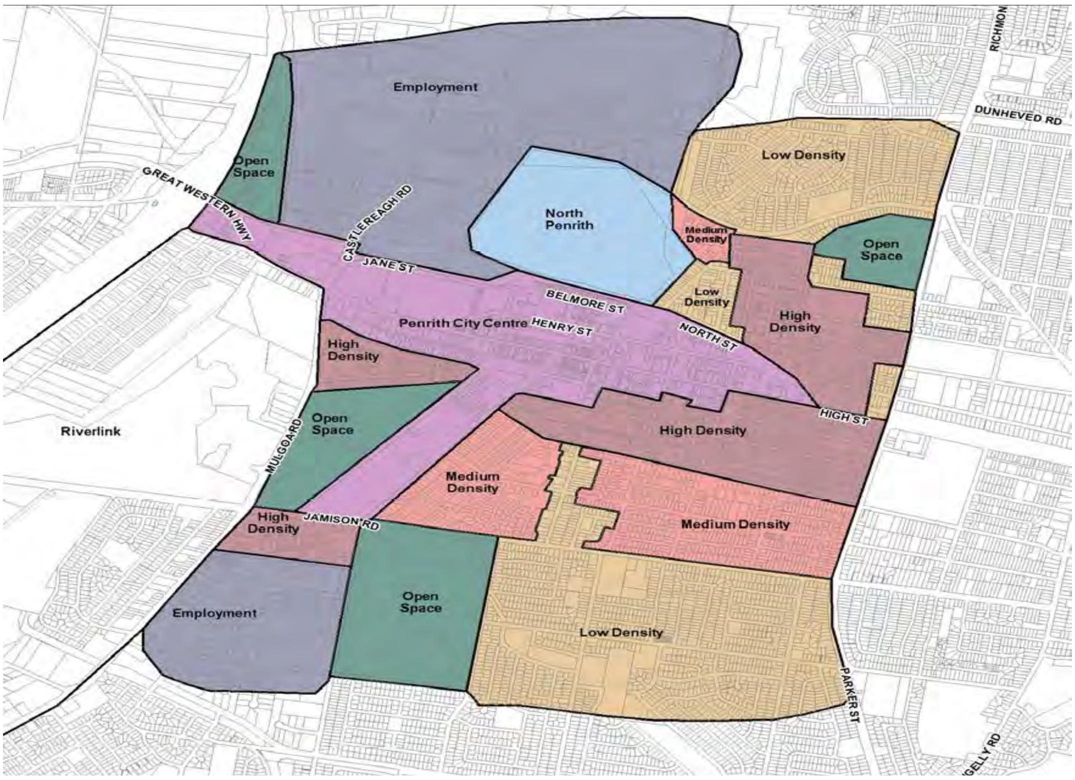


Figure 5.16. City Centre Precinct (Penrith City Council 2008a).

Flooding risks in the South Creek system

On the other end, east of Penrith, is the South Creek catchment which also has flood risk issues. Figure 5.17 shows the south creek and its floodplain, marked by the yellow dotted line, flanked on either side by rapidly growing urban regions where land has been identified for future infill development and new release areas between Werrington and Claremont Meadows on the west and St. Marys in the east (Burke Moody 2007). The Werrington Enterprise Living and Learning (WELL) Precinct that is situated in the Claremont Meadows is assumed to provide sufficient drainage capacity for existing development but does not have sufficient capacity to support additional land-use development (Penrith City Council 2008b). This further adds pressure to the Creek System which is already the most degraded water system of the Hawkesbury-Nepean Valley (Burke & Moody 2007).

St Mary's New Release Area – an example of on-ground planning implementation and the development challenges it presents

In Penrith, a number of new release areas have been identified and targeted as staged development in the next 15- 20 years. The St Mary's New Release Area, East of South Creek, is one such region which covers about 1,545 hectares. It is divided into three development precinct; western, central and Dunheved land. These Precincts are zoned as urban development- and industrial/business lands. This area is planned to accommodate approximately 3,420 dwellings (Penrith City Council 2008a). The New Release area at St Mary's is also the former Australian Defense Industries Site (ADI). The ADI site is situated North-West of St Mary's along the South Creek and has been a greater focus of attention by the general public, local community and conservationists due to its significance as part of the Cumberland Plain Woodlands supporting endangered species and native vegetation. It has also been a site for nuclear waste storage. Several issues have been voiced by communities against development on this site. A website has been hosted by the Western Sydney Conservation Alliance Inc., to highlight the development issues in ADI, and lobby against the State's decision to continue to develop in this New Release Area.

The site is prone to flooding from South Creek, Rope Creeks and urban discharge. The Draft *Development Agreement ADI Land (*Penrith City Council 2000) St. Marys report submitted by the Penrith City Council to the Department of Urban Affairs and Planning indicate that the Probable Maximum Flood Levels in some areas in the South Creek Catchment is six metres higher than the 100-year flood which is the standard planning level. This means that all the development inclusive of new development in this region will be inundated during floods higher than 100-year probability. The situation will be further exacerbated if development in floodplains is carried out and in case filling of floodplains take place to accommodate urban pressures in the St Mary's New Release area. An estimate of about one million cubic metres of floodplain storage will be lost under the floodplain filling scheme in the South Creek for the development of the ADI site (Penrith City Council 2000).

Figure 5.18: St Mary's New Release Area

Kevin Crameri, former Mayor of Penrith, commented on the severity of flooding issue in this region. Having lived at the northern boundary of the ADI Site, he provided some insights to the potential problems being faced by current residents and the likely impacts of future development:

> I have lived there for 51 years and I have got a five acre block of land which I have built a house on. Water of recent times has been coming onto my land, which in the past it has never done. Twice last year in the middle of the drought when we had a storm I had water coming onto my land and into my house. It has never done that before and it is only since they have been doing work on the ADI Site. Any development on that site is going to increase flooding on South Creek. You have got all of Shanes Park below the 1 in 20 (year flood line) where they have built all their houses. If you take that huge area and put roads in there and houses with garages...South Creek is going to flood much quicker. For the state government you only have to have to be above the 1 in 100 year flood line. So everyone who is 1 in 120 or 1 in 150 then will go underwater. They have got a massive problem because a third of the site is 1 in 100 and two thirds is flood liable, so two thirds of it, in a big flood like the 1867 flood, are going to be under water. All of the homes they put in there will be under water. Once we get something which is more than a 1 in 100 year, which doesn't mean it is going to be every 100 years; we had one in '57, we had one in '60, and they were all 1 in 100 floods. That's when you are going to start having real problems, if you get a wet season.

Despite these real issues, the council has approved development in ADI.

5.4.4. Urban development and flood risks in the Hawkesbury City Council

The Sydney Metropolitan Strategy indicates an addition of 5,000 dwellings in the Hawkesbury LGA between 2010-2031 (Hawkesbury City Council 2012). The Development Plan in the Hawkesbury LGA is similar to that of Penrith's, where the region will be subjected to a number of development activities which will include infill development, redevelopment, and new rural and industrial development. Flood-prone areas will be developed with development controls that will presumably reduce flood risks. In terms of urban planning, the North West Sub-regional strategy indicates that additional dwellings will be established close to the urban centres or at the periphery for easy access to existing facilities and services. In context with development in urban centres, in the flood-prone region, there is a strong need to assess the existing drainage system capacity to compensate for the increase in overland flows. The Residential Land Strategy identifies Richmond, Windsor, North Richmond, Wilberforce, Glossodia Windsor/Bligh Pk regions to accommodate 2,000 more dwellings.

The Metropolitan Development Program has indicated Bligh Park Stage 2 and Pit Town for further development and growth.

Out of the four councils under review in this chapter, the Hawkesbury City Council is geographically the most flood-prone region in the valley (see Figure 5.19 below).

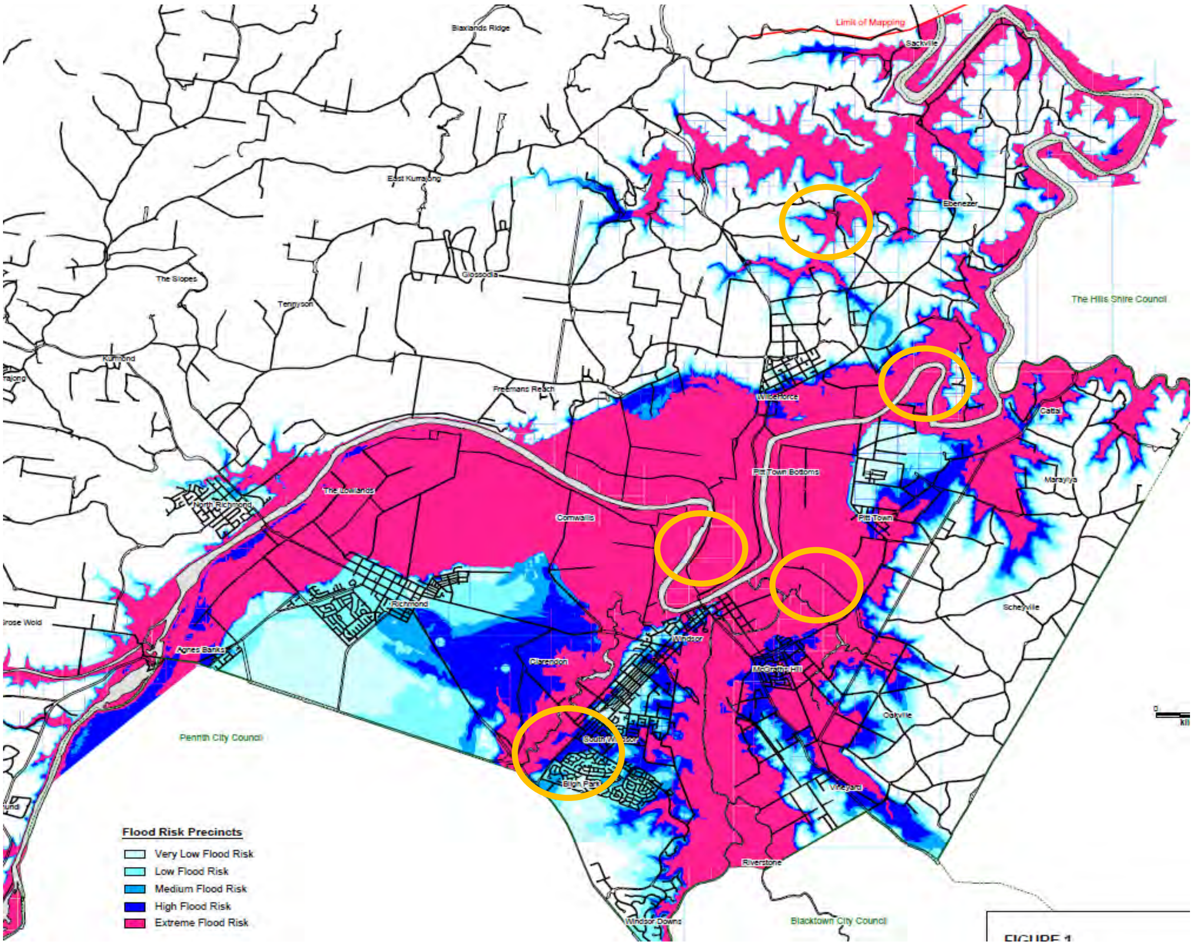


Figure 5.19. Flood extant in the Hawkesbury-Nepean region (Hawkesbury City Council 2012)

Hawkesbury-Nepean LGA's vulnerability to flooding is due to its unique geographical location. It's where the water entering the catchment leaves through a narrow gorge at Sackville. The narrow gorge acts as a 'choke point', therefore, the inflows of the Hawkesbury River and its tributaries are much larger than the outflows (Hawkesbury City Council 2012). As a result, a large amount of water flows back and inundates the floodplains of the Hawkesbury River, in the Hawkesbury City Council region in the Windsor and Richmond area. This adds to the complexity of flood management in the region (More details provided in Chapter 2).

Historically the 1867 flood had a massive impact on the Hawkesbury region. Bewsher, Grech and Yeo (2013) suggest that a reoccurrence of the 1867 flood today will result in loss of lives, considerable economic consequences, damage to facilities, infrastructure, and creation of islands which may be overwhelmed by a large flood. The risk is even higher due to the lack of consideration for planning for larger floods. For instance, the difference in a 100-year flood level and Probable Maximum Flood is much larger in the Hawkesbury River. According to Bewsher (et al. 2013), an extreme flood in the Hawkesbury region can be as high as a three story building above the 100-year flood level. Therefore, planning just for a 1-in-a-100-year scenario may still result in massive flooding and considerable socio-economic loss.

The 2010-2011 floods in Brisbane, Queensland, are a relatively recent example of the possible catastrophe large floods can cause. The flood event was a 1-in-a-100 year event.

> Rainfalls in excess of 1000 mm were recorded in the Brisbane River catchment during December and January with the vast amount of this rainfall falling in the 96 hours to 9 am on the 13th of January. The most significant rainfall intensities were well above the 1% Annual Exceedance Probability (100 year Annual Recurrence Interval)' (Bureau of Meteorology 2014).

As a result of these 2010-2011 flood events, approximately 12,000 people were evacuated, 15,000 properties in metropolitan Brisbane were inundated and 3,570 businesses were flooded with an estimated loss of $4 billion (Van den Honert & McAneney 2011).

More than 56,000 insurance claims were made (insurance cost of around $2.55 billion) with 28,000 homes requiring rebuilding and many others in need of extensive repairing (Van den Honert & McAneney 2011). A catchment such as the Hawkesbury-Nepean with 70,000 people requiring evacuation due to a large flood would presumably have a lot more economic damage even in a flood event that is equal to or under a 1-in-a-100 year event.

The flood map (Figure 5.19) shows the extent of flood risks in the region. The yellow circles highlight the region where development is planned. As it can be inferred from the flood risk map, these regions are categorised as areas of extreme, high and medium flood risks. Brewsher (et al. 2013) indicates that buildings in the Hawkesbury LGA are seriously exposed to floods and that a considerable number of dwellings are affected by flooding from 50-100 year events at Windsor, Pitt Town and Wilberforce. In addition the regions of Bligh Park and Richmond are significantly affected in large flood events (Brewsher et al. 2013, p.

2). The report highlighted concerns with regard to whether evacuation measures will be sufficient to provide a reasonable safety net when the numbers of evacuees are bound to increase with extensive development.

5.5. Flood management framework in the Hawkesbury-Nepean catchment

In principle, Flood Risk Management in the Hawkesbury Nepean valley harnesses an adaptive process through its merit-based approach where social, ecological, economic and flooding factors are considered for any development in the floodplains (NSW Government 2005). The Flood Prone Land Policy provides the legal framework for councils to manage their flood risks through an umbrella document, the Floodplain Development Manual (NSW Government 2005). The Manual outlines a five-step process for assessing and managing flood risks. The process involves data collection, a flood study, a floodplain risk management plan, and the implementation and review of the plan to identify and monitor emerging issues. As per the Manual, each council has to establish a Floodplain Management Committee to encourage an inclusive process for other state members and the community to be involved. In principle, this enables participation and knowledge exchange from a wide-range of stakeholders. The members generally include the Council, Councillor, representatives from the NSW Office of Environment and Heritage, State Emergency Services, community representatives and any other interested environmental or industry group. The Committee oversees the process which would also include defining acceptable flood risk levels, and reviewing evacuation plans incorporated in the flood study. While an existing adaptive process sets a framework for continuous learning, gaps in the existing system have a tendency towards maladaptation. Section 5.6 briefly discusses the components of this framework that have the potential to cause disruptions in implementing an adaptive management framework.

5.6. Gaps in flood management in the Hawkesbury-Nepean catchment

There is a degree of variation and lack of consistency in the way floods are managed within each council. The degree of variation depends on social pressures, the extent to which flooding is perceived as a serious risk to people and development, and belief systems around climate change. The following discussions summarise some of the common problems in flood management that emerged through data collection and the document review process.

5.6.1. Business-as-usual approach to flood planning and management

The current practices of flood planning and management emphasises the maintaining of pre-development flows for new development with little to no regard for addressing climate change.

An established culture of risk aversion

Discussions with various council representatives confirmed that planning controls of 1-in-a-100 year flood are implemented.

> It is a risk-based assessment but generally [the councils] have adopted the 100 year flood planning level as a general benchmark for residential, industrial, and commercial [development]. In some areas there could be 50 year in rural areas. In Hawkesbury-Nepean catchment they are all 100 year [flood planning levels] (Interview 3, July 2013).

To ameliorate impacts of overland flows resulting from additional development, there, exists a dam failure strategy (Interview 4, July 2013). However, these dams and detention basins are not designed to reduce risks in a probability higher than the 100-year floods nor has this been considered in future flood management studies. Development is approved as long as it is able to maintain pre-development flows. Since development of detention basins is a strategy being implemented in the new release area as a means to maintain pre-development flood conditions, there is a planning risk involved for development in the region, especially under the rapidly changing climate conditions. The Austral Floodplain Risk Management Study (Perrens Consultants 2003) indicates that even if all the mitigation options suggested in the study were to be implemented, there would still be a continuing flood risk as the mitigation measures are designed to address flooding scenarios of a 1-in-a 100-year or less.

Bewsher and Maddocks (2003) have conducted a number of floodplain studies in the NSW and they argue that floods larger than 1-in-a-100 year event have been found to have significant risks as indicated in some of the floodplain studies conducted in NSW. According to them, a historical review of major flooding in Australia highlights that, ‘rare floods are common’ (Bewsher & Maddocks 2003, p. 3). Flood planning, however, does not take into account future unpredictability and risk of climate change.

Issues of climate change

Through discussion with some of the council representatives, it was observed that there exists a lack of motivation to undertake climate change studies. While interviewing a council representative, it was highlighted that in most cases councils do not incorporate climate change impacts in flood-related assessment studies.

> Council's current flood studies did not consider climate change impacts. However, in future revisions of flood studies Council may consider incorporating impacts of climate change (Interview 3, July 2013).

One of the reasons indicated by another council staff was the denial of accepting climate changes in future planning.

> Climate change study was changed to 'natural hazards resilience study' otherwise it couldn't have gotten it through the council (Interview 5, September 2013).

The lack of inclusion of climate change impacts is also attributed to the limited data that fail to provide more definite outcomes of climate change impacts (Hawkesbury City Council 2012). The unpredictability of rainfall-forecasting discussed in the previous chapter indicates the difficulty in setting management goals by managers based on climate change, as the question would be how much change is expected and it could be from 10-20% or 50% which can result in transformation of existing systems into a completely novel entity.

> At the moment what we can say to the manager is that the evidence suggests that things will change in future…we can't necessary predict the overall direction of change. In 50-100 years but we can probably tell [them] what's around the corner. The manager has to set goals and is presumably using measures of performance or whatever in terms of what they are trying to manage. Change might be in the order of 10-20 % increase. What does that mean...does it mean that you could cope with that? If change is 50% then we are entering into a new world. The manager has to go back and evaluate what is the value of what they are managing for and the knowledge of their responsible system in terms of their goals (Interview 6, April 2013).

The Hawkesbury Floodplain Risk Management Study and Plan, (Hawkesbury City Council 2012), indicates that flood risks due to climate change are negligible in the Hawkesbury LGA. Under this assumption, the climate change influences have not been recommended to be included in the planning and development instruments such as the LEPs.

Out of the four councils, the Hawkesbury City Council is the only council that has managed to conduct a study that can be considered to be a climate change study. It shows how climate change issues are not high-up on the list for the governing body when planning for future development. Although through discussions, some references were made to undertaking climate change consideration and the use of modelling but on further inquiry, no particular studies were made available that provide information on what climate change assessments were conducted or are planned. Generally, council representatives acknowledge that climate change is an essential factor to be considered, especially the impacts on the region due to precipitation. There is, however, no evidence of climate change integration into the planning and future development aspects. The lack of accuracy on models to determine climate change impacts and the prevailing belief system whether climate change exists seems to be the driving force for the lack of prioritising climate change as an essential detriment to planning and development and exacerbating flood risks in the region.

Chapter 2 of this thesis highlights the social and institutional barriers to adaptive learning. These include a culture of denial, scepticism and risk aversion. Barriers to flood management discussed in this chapter are influenced by the way organisations involved perceive their role in the process and their understanding of risks. Chapter 6 discusses how complexities in flood management are rooted in perceptions and views about flood risks in the Hawkesbury-Nepean Region.

5.6.2. Knowledge gaps in managing flood risks

Adapting to change requires the need to develop understanding of how landscapes and natural systems behave. A major change that poses a risk to adaptation in this catchment is development and weather extremes that increase the risks of flooding. Knowledge gaps are observed in the latency of up-to-date information, lack of understanding on accumulative impacts of overland flows in an impervious landscape and political barriers that render openness-to-learning.

Inadequate information on flows and their impacts

According to a council representative, the issue of overland flows exists in areas that have a high proportion of impervious surfaces, which if observed within the Liverpool Council Area forms the east of the council that includes the Cabramatta Catchment and the Georges River Catchment (Interview 3, July 2013). The catchment can be characterised by a highly developed area including the Liverpool CBD, and its surrounding regions. Due to the limited physical space, the capacity to implement a Water Sensitive Urban Design (WSUD) is very limited in areas such as the Liverpool CBD. To mitigate this, trunk drainage systems are in place that takes the overland flows away from sites of impact into the Georges River with chances of potential increase in the velocity and quantity of water in the catchment. Since the west region of the Liverpool council, particularly the Growth Centres, constitute a rural suburb, problems of overland flow are presumed to be non-existent and insignificant (Interview 3, July 2013). Since the west region presents a less developed landscape, planning for this region would take into account the implementation of WSUD to curtail potential overland flow issues when 110,000 new dwellings will be introduced (Interview 3, July 2013).

In the case of Penrith LGA, the majority of development is planned to be in developed areas which is bound to impact the existing drainage systems that are designed for a 1-in 5 year flood event. Expansion of hard impervious surfaces, predicted climate change scenarios and limited drainage capacity could result in high flood risks in the region. In order to assess the 'real' impacts of such factors in the Penrith region, the council needs to have critical knowledge about potential flood risk. This would be critical to implementing appropriate adaptive strategies. The progress for such action apparently is rather 'slow' on-the-ground. So far, only three flood studies have been conducted for the Penrith LGA.

These include:

- Peach Tree Creek Flood Study Draft 1994, Penrith City Council
- Nepean River at Penrith Flood Study 1997, Penrith City Council
- Penrith Overland Flow Flood "Overview Study", 2006 implemented by Cardno Lawson Treloar.

The flood management process in NSW requires flood studies to be updated every five years whereas in practice, studies take twice as long to develop. Furthermore, once the studies have been conducted, political barriers often prolong their implementation. The Penrith overland flow flood study, a generalised study of flooding potential in the region, has not been adopted (Interview 7, September 2013). The study was conducted in 2006 and six years from its publication, it has yet to be put into practice. A study on the Penrith lakes Upper Catchment was conducted in 2012 and showed that 42.5% of the catchment is impervious which results in 413 ha out of the entire 973 ha being impervious (Interview 7, September 2013). This is the only study conducted to investigate the percentage of imperviousness in the region. The report however has not been shared at the time of the interview. In order for the council to approve development, the decision makers would require access to the best sources of knowledge about the region. Time lapse in revising flood studies and adopting management plans would more likely increase flood risks.

The shaded sections in Figure 5.20 indicate the extent of impervious surface which will increase as a result of future planned development. The massive transformation of landscape requires a critical examination of flow changes and information on runoff volumes within a particular area and their likely impact at a larger scale. This is also a critical issue in regions where a large number of new developments is in-fill, in already urbanised regions, such as Penrith and Hawkesbury.

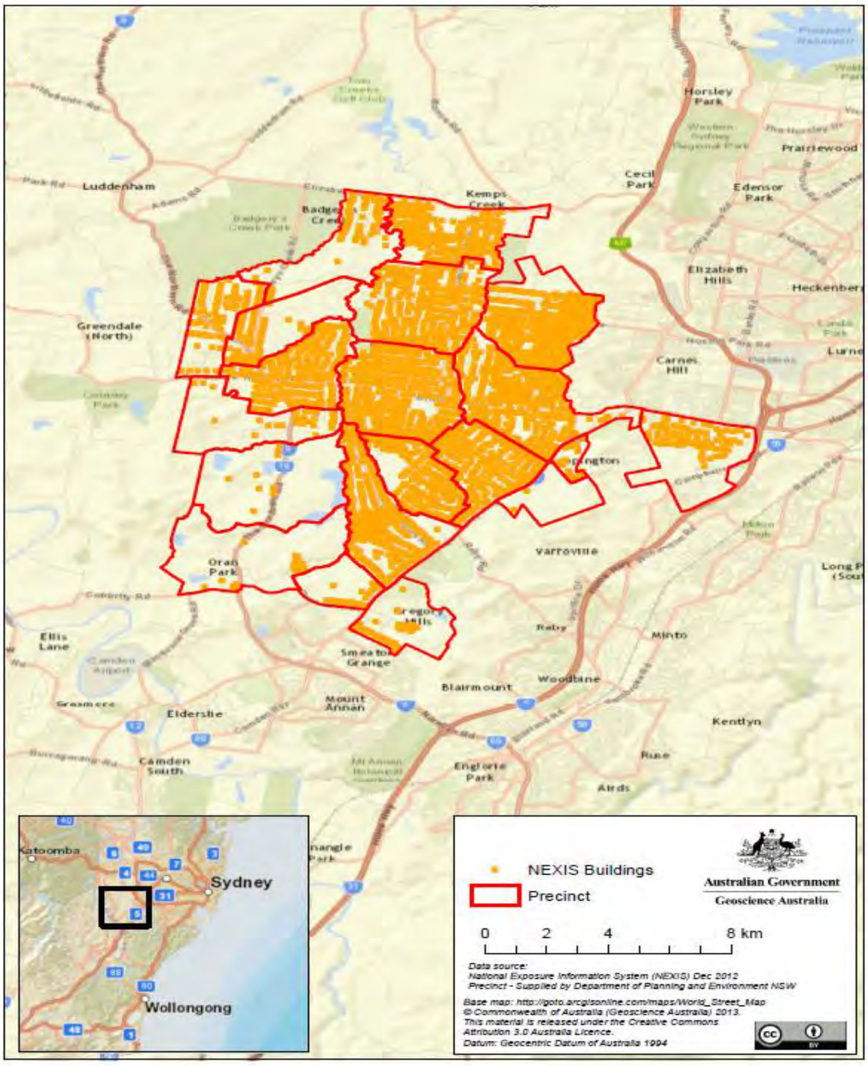


Figure 5.20: Impervious surface water area for Liverpool Growth Centre region

As part of this chapter, professionals working in state and local councils were contacted to obtain information on the overall runoff volumes generated currently in these regions of the catchment to determine how much this volume will increase with new development and increased impervious surfaces, particularly in the Growth Centres. Professionals contacted were asked if information on previous impervious ratios based on dwelling numbers and sizes, both new and proposed, existed. They were also asked to provide information on any overland flow study that provides information on runoff volumes for current and future development for the entire catchment or their respective LGA.

It was observed that the level of understanding and knowledge of critical components, such as determining total increase in volumes of storm water runoff, was limited. Assessment of how much the volume of water will be increased due to additional development and its accumulative impacts on water courses downstream or the entire catchment haven't been given much attention. During the course of these interviews it was either found to be something that recently gained attention and was at an early stage of development, or hasn't been undertaken at all. As discussed earlier, the current management of storm water takes place through reducing discharge, where new development will increase storm water runoff to a pre-development state through establishing on-site detention basins. There are, however, no broad-scale studies to assess the increase in volume due to development. Consequently, little knowledge is available in terms of increase in flows and how these will impact the landscape and environment collectively.

> There are no broad studies regarding the increase in volume due to development. The council has undertaken flood studies for known flood areas. Where new development occurs we are trying to not make flooding issues worst so we implement on-site detention basins (Interview 1, August 2013).

In most cases the respondents were more inclined to refer to another organisation for information:

> I have been advised that NSW Office of Water has no data for storm water runoff. Possibly Sydney Water and Sydney Catchment Authority may have some information (NSW Office of Water, per. Com., 3, 2013).

> Sydney Water has had a strategic model for the whole catchment for decades. I believe they are currently upgrading it. Sydney Catchment authority use them too (Water Research Centre, per. Com., 4, 2013).

However when the agency that was thought to be responsible for monitoring entire catchments was contacted, they indicated that the responsibility was not theirs to consider overall runoff volumes and that their responsibility was to manage drinking water catchments of the region.

> Our role is essentially to manage the catchments of the dams for raw water to our customers so we deal with the upstream part of the Hawkesbury catchment. This includes the upstream of Warragamba Dam and upstream of Nepean dam so it doesn't include the lower part of the lower Hawkesbury catchment… We don't manage our dams for flood mitigation. It is all for drinking water. So our objective is to keep them topped-up so to speak… catchment audit reports are developed every three years now. [These reports] focus on catchment quality. It doesn't focus on the quantity [volumes of runoff] (Interview 9, August 2013)

Other respondents indicated that the requested information was either not available, insufficient or was planned to be developed in the near future:

> Unfortunately the information you are requesting is not available. We did start a GIS project to pick up building footprints in the area; however, we had some data integrity issues with the information collated and it is programmed to be re-done in the near future. This information would have only indicated the building dwellings and not the paved area (Council, per. Com., 5, 2013).).
>
> The [information on Growth Centres] has not been planned for rezoning at this stage as far as I know. However, you might want to look at the south west growth centre website and see what the proposal is for the areas you have requested (Council, per. Com., 6, 2013).
>
> With regard to your requests I am afraid that Penrith has only one completed flood study which is “Updated South Creek Flood Study 2014”. For other areas, studies are yet to be completed. For areas that you are interested in we don’t have completed studies; council is using old studies prepared by Sydney Water, PWD etc. Nepean River Flood Study is on hold due to issues with the Penrith Lake (awaiting ruling from Dept. of Planning) (Council, per. Com., 7, 2013).

Lack of integration between development objectives and flood risk information

The Councils need to establish a greater level of synergies in its planning and development guidelines with issues of extreme weather conditions and flooding. Synergies in the planning document will espouse on-ground implementation. For instance, the Local Environmental Plans and the Development Control Plans are the planning instruments that enable councils to structure development within their Local Government Areas. These plans define land use and provide specific guidelines for detailed development requirements. In the case of the Hawkesbury City Council, Draft LEP 2011 was adopted from a previous draft LEP 2009; the draft LEP 2011 does not fully addresses issues pertaining to flood planning by the Hawkesbury Flood Risk Management Study. The HFRMS&P (The Hawkesbury City Council 2012) indicates that the inclusion of more specific flood planning clauses in the LEP will provide several benefits. More importantly, it will give significance to the flooding issues in the region while reviewing applications for development; identify key flood-related issues to be considered while considering applications and to ensure consistency and integration with the region’s flood studies and risk management plans (The Hawkesbury City Council 2012). Currently the draft LEP 2011 defines flood planning level as ‘1:100 ARI (average recurrent interval) flood event (LEP 2011, p. 48), whereas the HFRMS&P indicates flood planning for 1:100 does not reduce the risk of flooding in the region. The LEP doesn’t provide any guidelines for planning for floods higher than 1:100 or Probable Maximum Floods or provides flood maps for identification of flood hazards and risks in a particular area. In addition, there is no reference to floodplain risk management planning. Such clauses, however, have been included in some of the councils in the Hawkesbury-Nepean regions, such as the Penrith City Council LEP 2010 (NSW Government 2010b, p. 68) and by Camden City Council (Interview 8, January 2014).

The Hawkesbury City Council is the first council to have a Flood Risk Management Study and Plan in place. The process took several years to be completed. With the plan and study ready for adoption, the challenge is to work out the implementation of the plan which according to one of the staff is a highly politicised process and may take several years before it is implemented:

> Flood studies are contentious. It is a model people have difficulty in believing and what they have experienced so there is always debate about the level, extent, and velocity of floods based on people's experience...everyone has an opinion. When we set these development limits it all comes down to have we taken away developmental potential from that area and how much will it cost the developer and those can be highly controversial. People say that those floods are not going to happen so why can't I develop. The biggest one in living memory was in the 50s and 60s that was only a 1 in 40-year flood (Interview 5, September 2013).

While the implementation of a flood management plan becomes a matter of political debate and is slowed down by vested interests, the development in the region continues. The NSW Infrastructure and Planning Department has expedited the development process through Growth Centre Precinct Planning which by-passes local authorities, thus reducing their role in approving an authority to become a referral entity (State of NSW, Department of Planning 2010). The decision-making process, on one hand, favours an accelerated growth but on the other hand, does not provide similar provisions for implementation of flood studies and flood plans.

At the time of interviews, it was determined that the Penrith City Council lacked comprehensive flood maps to help identify areas for large floods of a 1-in-a-100 year or greater level. Flood maps were at the time being developed for a detailed assessment of the area; however, the overall flood study was not adopted due to political issues pertaining to the fate of the Penrith Lakes. These are massive artificially constructed detention basins that can influence flows in the Nepean-Hawkesbury Rivers. Decision on the Penrith Lakes regarding whether or not they will exist in the future will greatly change the hydrology of the area and therefore will also impact the flooding pattern in the region. On one hand it is reasonable to 'hold off' the implementation of flood studies or advance the development of flood risk management plans until the decision on the Penrith Lakes is finalised, but on the other hand it is unreasonable to not expedite the decision to implement mitigation plans when development in the region is already under progress. While flood mapping and flood risk management plans were slow to formulate, development continued in new release areas with the clearance of the Cumberland plains for new dwellings (Western Sydney Conservation Alliances Inc. 2015). The flood management studies and the subsequent plans should be in sync with the planning and development of the region to manage overland flows and reduce flood risks. In order to approve development, managers and decision-makers require the necessary technical knowledge to make informed decisions. The delay in implementation of flood studies in contrast to the accelerated development suggests the lack of concern by authorities for the seriousness of flood issues that may further be exacerbated with new development.

5.6.3. Prevailing jurisdictional culture – A system of 'patchy' management

Chapter 4, discusses the prevalent jurisdictional and sectoral culture to management with regard to the Blue Mountains. This section provides further elaboration on this in relation to flood management.

The responsibility of councils for managing waterways is closely associated with their jurisdictional boundaries. For instance, flood management of Kemp Creek is the responsibility of the Liverpool City Council, but changes in flows due to development in the South Creek are the responsibility of the Camden and other councils which fall within its catchment. Maintaining acceptable pre-development flows within each LGA is also the responsibility of respective councils. However, determining how the accumulative impact of development would bring changes in catchment flows that can potentially impact the major rivers such as the Nepean and Hawkesbury is not taken into consideration by councils or the Flood Management Committees established by each council. This 'jurisdictional culture' that bounds councils to act within their defined boundaries is reinforced by the state level policies and regulations that impart responsibilities to local government. For instance, Growth Centres development is planned to take place as a staged process. In order to facilitate this, the Growth Centres have been categorised into a series of precincts. Hence the South West Growth Centre is divided into 18 precincts (Ribbons et al. 2013). As discussed earlier in this chapter with regard to the precinct planning process, prior to development, each precinct is assessed and then the information is made part of a precinct plan that is reviewed by the NSW Department of Primary Industries for approval. Once approved, the councils ensure that land-use planning and development endorses the Precinct Plan.

The division of Growth Centres into 18 Precincts means the development of separate flood management and water strategies for each precinct in isolation, which tends to overlook the catchment as a whole, and its relation to larger water systems of which these smaller catchments are a part. A holistic approach to determine the accumulative impacts of development in all precincts on the main river system is not taken into account. Ribbons et al. (2013.) emphasise that the current requirement for flood studies for new Growth Regions is to maintain flood behaviour at a pre-development state but there is no requirement to undertake a holistic evaluation of the collective impact of all the development on the catchment. Ribbons et al. (2013) have highlighted this need for the Camden Growth Area (Ribbons et al. 2013) and have made attempts to rectify this (See Figure 5.21 below for details).

Case example: Camden City Council

Development in the Growth Centres is planned in stages. It comes under the State Environmental Planning Policy (SEPP) 2006 regulation that guides planning in the Growth Centres. For every Precinct there is a Development Control Plan and is part of the Growth Centre SEPP. The Camden Council has developed an overall *Camden Growth Centre Precincts Development Control Plan,* instead of individual DCPs for each Precinct, which will be applied to current and future development in the South West Growth Centres of Camden LGA (Ribbons et al. 2013.) This overall DCP also includes provision of flood related management and refers to the Camden Council's Flood Risk Management Policy, designed in 2006 (Camden Council 2006 cited in Ribbons et al 2013). According to Ribbons et al.: 'This provides a consistency of approach to planning and development procedures for flood risk management for all flood-prone land across the Camden LGA' (p. 7). Similar options can be adopted by other councils to increase the level of integration in development plans and flood risk management plans.

Figure 5.21 Case example: (Camden City Council)

The 'patchy' management approach where sub-catchments are managed in isolation or rather in disconnection from larger natural systems is in contradiction to the landscape scale, total catchment management or the biospheric scale of managing Social Ecological Systems. The councils do not have an overall flood management study and mitigation plan that provides a flood overview of the entire LGA (Interview 3, July 2013). Instead, within the local boundary area, the council acts on a need-based flood management process which focuses on the identification of hotspots and conduct studies and implements flood mitigations at a catchment/sub-catchment level on prioritised hotspots. Cross-boundary collaboration is limited to where a certain catchment shares a boundary with the subsequent Council LGA. The flood management committee provides the avenues for information sharing but there is no avenue to share information between different committees and among other stakeholders. For instance, in the *Liverpool Floodplain Management Committee*, there are representatives from surrounding councils such as Penrith and the same applies for the Penrith flood management committee; however, despite the presence of these members in respective committees, issues discussed are pertinent to the LGA that the committee represents. Opportunities to discuss or collaborate between different flood management committees and other risk analysts, to bring together much broader and cross-boundary issues of catchment management are absent or negligible. South Creek and Jamison Creek provide evidences (Figure 5.23 and Figure 5.24 below) of how flood management is carried out within a jurisdictional framework.

Case Example: Flood Studies in the South Creek Catchment

South Creek is a large catchment system with headwaters in Camden. The Creek flows from south to north where it joins the Hawkesbury River at Windsor (Ribbons et al). The Catchment is spread across eight LGAs out of which five of them have a significant portion of the Catchment; Blacktown, Camden, Hawkesbury, Liverpool and Penrith. With recent development planned in most of these LGAs, it would have been a rational decision to conduct a holistic floodplain study of South Creek and identify accumulative impact of development on flood behaviour. A review of a number of flood related studies on South Creek demonstrates the bounded jurisdictional culture that fails to recognise the need for local agencies to invest in understanding how catchment functions and behaviours are impacted by urbanisation at a large scale.

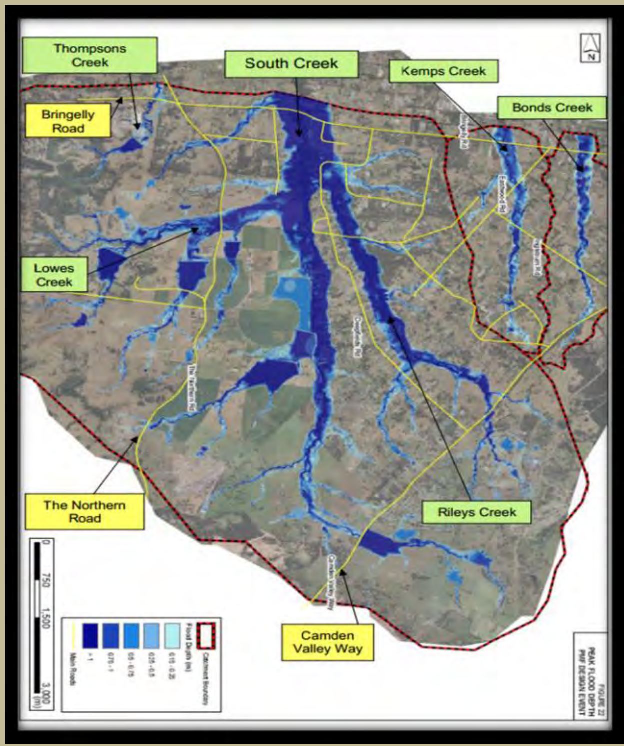


Figure 5.22: (opposite) Shows the connectivity of water courses for South Creek (Ribbons et al. 2013).

Notice that the following reports are about one catchment but divided into several studies and only a section of the catchment area that falls in a particular LGA is discussed as a study area for these flood studies:

- South Creek Floodplain Risk Management Study and Plan for the Liverpool Local Government Area, 2004 (Bewsher Consulting Pty Ltd 2004) - this report was conducted to investigate options to reduce flood risks in the study area which forms part of South Creek that falls within the Liverpool LGA. The study focus on specific study area but does not take into account the impact of future development on the flood issues in the tributaries of South Creek;
- South Creek Flood Study prepared for Lake Macquarie City Council, 2011 (Cardno LawsonTreloar Pty Ltd 2011)
- Austral & Leppington North Precincts, Riparian Corridor and Flooding Assessment Prepared for NSW Department of Planning & Infrastructure, 2011 (Cardno (NSW/ACT) Pty Ltd 2011) is an example of how studies focus on a particular precinct as a study area within Liverpool LGA.
- Similar examples can be observed even in more recent reports such as the study on Upper South Creek Flood Study, Final report 2011, Revision 1. May 2012. Report prepared for Camden Council which includes study area of the headwater region and the upper tributaries of the catchment (WmaWater 2012).
- The South Creek Flood Study in 1990 that includes the whole of the south Creek Catchment (Bewsher Consulting Pty Ltd 2004).

From the review of documents available online it appears that South Creek Catchment has been a significant focus of study by different councils. While there exists individual flood studies and flood risk management plans for the same catchment there hasn't been a comprehensive floodplain study that includes accumulative impacts of urbanisation or demonstrate the impacts of development activities on larger water systems and at the same time take into account climate change implications on critical catchment systems such as the South Creek.

Figure 5.23: Case Example: Flood Studies in the South Creek Catchment

The Floodplain Management Manual (NSW Government 2005) describes five steps for councils to adopt for flood management. These steps/processes include data collection, conduct of study, development of a floodplain management study and plan and finally the implementation of the plan. As with most councils, flood studies in the Blue Mountains City Council LGA, are conducted for known flood problem areas. For instance, the council has conducted flood studies for Jamison creek and South Leura, among a few others. These flood studies focus on specific areas. An overall flood study for the entire LGA to determine collective impacts and plan in a more holistic way has not been conducted. The example of the Jamison creek flood study demonstrates the localised scope of these flood studies on which flood mitigation plans for a region are based. (Figure 5.24.)

Case Example: Jamison Creek

Jamison creek situated in the Blue Mountains flows into the Warragamba Dam. The creek's sub-catchment constitutes natural areas and also large residential and commercial development (Cardno Willing 2005). The only flood study to be conducted for Jamison creek was in 2005 by Cardno. The study signifies that the potential for flooding in this catchment will result from short burst of intense rains and is likely to impact developed catchments adjacent to the water course. It can be inferred that with more development, increase impervious surfaces will more likely increase localised flooding issues. It is believed that the on-site detentions will compensate for changes resulting from more development.

As with other flood studies, the realisation of connectivity of water systems and land use has been undermined hence the study did not provide any form of analysis that links the increase in the possible number of dwellings and new infrastructure in the Blue Mountain Area to the potential impact downstream and flows into the Warragamba Dam. Nor is there an overall flood study that show the potential of flood impacts due to development upstream or in the surrounding area of the catchment and its accumulate impacts on flows downstream.

Figure 5.24: Case Example: Jamison Creek

Head in the sand approach – what is not our responsibility does not concern us!

Chapter 4 discusses the sectoral divisions within agencies whereby research and planning is dominated by discipline-specific interventions. The factors that create vulnerabilities in hanging swamps such as fire, urbanisation, impacts of intense rains and sedimentation are examined and managed in isolation. This culture is prevalent in councils across the catchment.

When it comes to development where councils fail to exercise regulatory controls, the council has adopted a more or less 'head-in-sand approach' – *what is not our responsibility should not concern us*. During discussions with council representatives, a number of times the interviewees demonstrated their lack of understanding about a development issue. For instance, with regard to an inquiry on how the drainage capacity for in-fill development will be supplemented to support additional development, the council's representatives indicated that this is a problem that should concern the NSW Infrastructure and Planning Department (Interview 7, September 2013). The attitude is different in different councils and therefore the response to development is also different. Where certain councils consent to State government decisions on development, others consider it an issue of by-passing council's authority and discarding local issues (See Chapter 4).

A large amount of development in the Penrith region, especially in the New Release Area is also planned to take place in rural landscapes dominated by native vegetation. In response to the likely impact on vegetation as part of the Cumberland plains, the council staff available for discussion, comprising the water quality and flood management unit, indicated that this question should be directed to the environmental unit of the Council and did not concern the water management or flood unit (Interview 7, September 2013) —this is another example indicating the discipline-specific approach to managing natural resources and the need for a greater level of integration within departments. At a much broader level, this thinking-paradigm exists while tackling development issues. In most cases the council has taken a 'back seat' due to the fact that development in the Penrith LGA has been approved by the State Government, hence issues of overland flows, lack of drainage or increased risk of flooding is not a priority agenda for the council. The following narration of Kevin Crameri, former Mayor of Penrith highlights this dilemma:

> The pollution of south creek is such that it is no better than an open sewer at the moment. There are three sewerage treatment plants going into it and it all ends up in the Hawkesbury River...There has got to be massive discussions and sorting out of sewerage treatment, not only to take out the pollution, but also the extra flow that is going to go in there...It is not a problem to the council because the state government has said that that land can be developed, therefore it is Sydney Water's problem, and what can we do, it's the State Government's problem. Sydney Water can't handle what it's got now, but they are going to get extra money. The only reason the state government is supporting this is that they are getting extra money (Western Sydney Conservation Alliances Inc. 2013).

Political barriers have created situations where indiscriminate development continues to fulfil state-level development targets without giving serious consideration to increasing flood risks in a changing landscape with a lack of drivers to assess accumulative impacts.

5.6.4. A complex governance system that lacks coordination

The governance of the flood management and development in the Hawkesbury-Nepean catchment is a challenging one as it involves a number of agencies. Each of these agencies has their specialised roles and in certain cases overlapping responsibilities. For purpose of discussion and analysis, coordination between five main agencies: the State

Emergency Service, Sydney Catchment Authority (SCA), Western Sydney Regional Organisation of Councils (WSROC), Sydney Water and the council are discussed below.

Councils have the main responsibility to plan and manage floods. At the state level, the State Emergency Services is the main authority for flood emergency response. The agency coordinates with the Bureau of Meteorology (BoM) for information and during large floods corresponds directly with the affected community in the targeted local government area. In disaster emergency situations, the councils coordinate with the State Emergency Service and provides the necessary coordination support. Although the State Emergency Service has its representation in the Flood Risk Management Advisory Committees of each council in the region, the coordination with the council is limited. Through discussions with the Hawkesbury City Council representative, it was expressed that there is a need for a closer coordination and sharing of information with the State Emergency Service (Interview 5, September 2013). According to the representative, the need for coordination is critical as councils approve development and would require up-to-date information to determine development options that do not constrict evacuation in case of a large flood. In practice, however, the interviewee indicated that councils are often sidelined and such information is not sufficiently provided (Interview 5, September 2013). Another council representative noted that there was also a need to share information regarding planning and management decisions between other agencies such as the State Emergency Service and Sydney Catchment Authorities and that councils should be kept in the loop (Interview 3, July 2013). The State Emergency Service's role is focused towards taking reactive measures to pacify a flood situation. The interviewees felt that they should be more involved during the development stage so that more relevant and timely information can be shared with the council for better flood planning. One of the council representatives summarises the problem of coordination gaps:

> It can be quite difficult in getting information out of them [the Emergency Service], particularly, on evacuation capacities. For years we relied on an internal flood map which the State Emergency Service gave us and then as a result of the recent flood study we came up with better flood maps ... we send all of our electronic stuff down to them but it is more the next step that required coordination. We have the role in approving development which will add more people and will affect them in their evacuation, and so it is getting that development to evacuation [link]. We can put this many houses in this area but we don`t get support in terms of information from them so that we can plan better. We have asked for this before but it might be the case that they don't know themselves, and it is one of those things that are very difficult to work out. (Interview 5, September 2013).

Councils are the main local agencies engaged in the development and management of resources within their LGA. At a regional scale it becomes more rational for state level agencies to closely coordinate with these agencies. For instance, the Sydney Catchment Authority manages the operation of Warragamba Dam; therefore, in order to release water downstream and manage its impact downstream under high flood conditions or during high rainfall events, it would require close coordination with councils. This becomes more critical when new development planned for the next several decades is in close proximity to the Hawkesbury-Nepean Rivers. A system of close coordination and opportunities of integration through research to advance understanding of the possible impacts is necessary. This becomes essential when a holistic framework of managing a complex catchment like the Hawkesbury-Nepean is to be implemented. There is a need for better information on climate change impacts, and the function of Warragamba Dam in mitigating floods and provide drinking supplies to an expanding population, while preventing socio-economic and environment damages as a result of disaster. This requires coordination between these organisations to develop and plan for different future scenarios. Currently, however, no such mechanism exists where the SCA coordinates with councils downstream of the Warragamba.

The role of SCA is to control the volume of water in the drinking water catchment that forms a sequence of dams, including the Warragamba dam and other dams upstream. Coordination of SCA with Sydney Water pertains to management and augmentation of water supplies for current and future population. However, when it comes to flood management, its coordination with flood management agencies such as the State Emergency Service is rudimentary, wherein they only serve as a medium for sharing meteorological information and are contacted only when there is a flood emergency (Interview 10, May 2013).

Councils' responsibilities for development are further complicated by the lack of consistency in sharing responsibilities across the catchment. For instance, the development in the Growth Centres is the responsibility of the NSW Department of Planning and Infrastructure. It is the Department's responsibility to identify new release areas, conduct socio-economic and environmental studies, and develop the planning documents which supersedes the existing LEPs and DCPs for these regions. In this connection, councils act as 'puppets' or 'instruments' to review development applications based on a prerequisite standard that may or may not take into account their local LEP requirements. On the other hand, where development is taking place outside the Growth Centres, the standard approval authority is the local council and applications are assessed based on the Council's LEP and DCPs. This again is not consistent as in certain cases like the Australian Defence Industries site (Penrith) and Vineyard (Hawkesbury), release areas that are under the Growth Centres, are predominantly managed by councils for development purposes rather than the NSW Planning and Infrastructure department. This leads to an ad-hoc framework of governance with overlapping responsibilities that lack coordination.

In terms of infrastructure development, the responsibilities are once again overlapping. The water infrastructure is developed by Sydney Water. The maintenance of such infrastructure is the responsibility of the council. Storm water systems and their management in some cases are carried by the council, whereas in others, it is the responsibility of Sydney Water.

With state and local government agencies engaged in complex and at times overlapping roles for development and flood management, their specific roles—that are inconsistent throughout the catchment—adds to the complex management of the Hawkesbury-Nepean River system. On the other hand, it provides little opportunity to establish a strong contact point for these agencies to streamline and improve governance in managing floods through improved coordination. A more practical solution would be to identify a regional level body that can enhance coordination of information and help to streamline responsibilities. Such an entity does not exist at the moment. There is a regional level agency called the *Western Sydney Regional Organisation of Councils* that is a collaboration of ten councils in Western Sydney; however it carries out small projects funded by internal and external sources but is primarily a lobby group. Although it is the only regional agency that looks into enhancing collaboration between councils, it is a small agency with limited resources and capacity to coordinate flood management and information across the Hawkesbury-Nepean catchment. It has, in its current state, little to no capacity to conduct regional scale flood studies and assess climate change impacts. The drive should come from a state-level entity to provide funds and support a regional scale study. In principle, it sounds a reasonable recommendation but the situation is not that simple. Contestant interests of stakeholders, different political agendas and lack of advocacy for the significance of a regional level understanding of this catchment are some of the obstacles that prevent such initiatives. The following is the summary of some issues highlighted by a Council officer that signifies the complex nature of this water catchment.

> There needs to be a regional flood risk management study and plan which is the obvious thing to do. So get all the council's on board potentially one sweep of rules for everyone but that did not progress and the State government said that each local council can do their own thing. It really comes down to who is going to drive it and who is going to pay for it. There hasn't been a commitment from state government to do that. It is going to be a big costly job and it requires state funding. From a technical point of view

> you might find a great deal of consistency where you might find all the council staff saying yes that the floor height standard should be this and the flood compatible material should be that but when it gets into the political sphere you will have rate payers calling and saying we don't want these rules as it is going to cost too much to develop or will reduce the development potential. As a consequence those rules are further scrutinised and potentially amended (Interview 5, September 2013).

There are other examples of cross-boundary coordination for flood management in critical catchments; one such is the Upper Parramatta River Catchment Trust. The Trust has been involved in reducing flood impacts in the Parramatta River, a main tributary of Sydney Harbour. Others include Catchment Management Authorities in Victoria and biosphere frameworks that rely on regional scale coordination and local governance respectively for managing resources and implementing effective adaptive strategies. Such examples could be examined further to determine important lessons learned and the feasibility of such a design for managing a much larger catchment, such as the Hawkesbury-Nepean River System.

5.7. Maladaptation in the existing flood management system of the Hawkesbury-Nepean region

In this chapter, a detailed account of four councils within the Hawkesbury-Nepean river system has been discussed with regard to flooding risks in each LGA and the gaps it presents for effective management. Based on the above premise, a number of things can be taken as a common understanding of prevailing trends in flood management and the existing gaps in the Hawkesbury-Nepean region that require better understanding, integration and improved coordination processes.

The flood management framework in the Hawkesbury Nepean catchment should support an adaptive process through data collection and development of detailed flood studies for every Local Government Area within the floodplains. Adaptation in this system, however, is disrupted when processes of information exchange and risk-reducing flood planning are hindered due to socio-political factors. Barnett & O'Neill (2010) define five types of maladaptation. Maladaptation can be defined as 'an adaptation that does not succeed in reducing vulnerability but increases it instead' (McCarthy, 2001, p. 990). Barriers identified in the previous section of this chapter present a challenge to implementing effective adaptation strategies. The following is a brief summary, derived from this chapter, of this action that can potentially create maladaptive practices.

The flood management framework professes a merit-based approach where, in principle, all risks of floods should be considered. Councils across this catchment, however, follow a consistent flood planning level despite changing circumstances. A 1% AEP is generally adopted as a minimum residential flood level. The councils lack policy to assess large and rare floods. In some cases, as for the Liverpool City Council, an additional freeboard of five meters is added on top of a 100-year floor level, for which development must comply, whereas the Hawkesbury Council does not support freeboard despite being a highly flood-prone region in the Valley. The tendency to follow a historically set planning level disrupts the need for adaptation planning and preparation for larger floods. Barnett & O'Neill (2010) argue that reduced incentives to adapt and path dependency are two types of maladaptation.

The current standard for approving development relies on the principle that new developments maintains the pre-development flow regimes and do not increase flood problems. Where development has the risk of increasing flows and flood hazards, ecologically sensitive design and controls are implemented (Hawkesbury City Council 2012). In this regard, in most cases detention basins are proposed as a strategy to ameliorate additional flows in new development regions. This, however, does not take into account possibilities of rare flood events that may be triggered in the near future due to climate change. From the lack of consideration of climate change, it can be inferred that the flood management and future development planning has a much greater focus on the current situation and maintaining the flows at the current state—path dependency can be a critical maladaptive response. The current system of management does not ensure how natural systems will adapt to rapid climate change fluctuations in the future.

Adaptive management requires an inclusive process of learning and integration of knowledge. The Floodplain Development Manual outlines that a community's acceptable flood level should be defined. In the existing flood management process, this requirement is fulfilled by a community representative on the floodplain management committee. Maladaptation in the existing system occurs in two ways. One, if there is no community representative on the committee. Second, communities' involvement is limited to their attendance at consultative workshops that prioritise mitigation options. However, no consultative process exists to involve the community to 'have their say' in defining their acceptable flood risks. Chapter 2, section 2.5 discusses the impediments to learning created as a result of socio-political barriers. Castree & Braun (2001) argue that environmental decisions often omit the concerned and affected parties in environmental management decisions. Knowledge gaps also exist when there is lack of consistency in information sharing with other 'players' involved in flood risk assessments. Adaptation becomes disruptive when consensus on decisions excludes other risk assessors such as insurance companies, communities and other stakeholders. Chapter 6 & 7 elaborate on these issues in further detail.

There is no consistent standard for flood management within councils. For instance, setting of freeboard above flood planning level is up to the discretion of individual councils and so is the value of using Urban Sensitive Designs for better flood management. Furthermore, flood management studies in most cases are seen as separate from planning and development controls. There is little or no reference to consulting flood mitigation plans in policies that review and approve developments such as the LEP. The need to link flood studies and flood risk mitigation plans to development plans is again an independent choice for the councils.

The existing flood management framework focuses on a jurisdictional approach to flood management which addresses issues of risk management within each LGA. As per the requirement of the Floodplain Development Manual (NSW Government 2005), the councils, have and are under the process of conducting flood management studies. These flood management studies focus on flood-prone regions within a relevant LGA. In most cases only a particular sub-catchment is focused on in a flood study. With development taking place at various stages in the identified precincts throughout the region, the collective impacts of new development on the entire Hawkesbury-Nepean catchment accentuate the need for an overall flood study. There is a lack of consistency in the conduct of overall flood studies among councils. Some feel the need to do it while others lay emphasis on conducting individual flood studies for flood-prone catchment. Subsequently, the cumulative impacts and influence of management decisions across the catchment are not appropriately assessed. This localised interaction highlights an important thinking paradigm where local agencies are not encouraged to 'look' beyond their jurisdictional boundaries, simply because they are not required to. As one of the Council representatives states:

> ...flood studies [of a particular catchment in a LGA] are not shared with other agencies because the purpose of these studies is local focus. It is not [designed to address issues] like if we have a large rain event in the Blue Mountains, how it is going to affect the flood levels in the Hawkesbury-Nepean Catchment or the Warragamba Dam (Interview 11, August 2013).

An interviewee, an expert in urban planning from the University of Western Sydney, elaborates that recently, councils have started to realise the need to assess impacts on the catchment or on a large scale, but confirms that there is no evidence of that happening on-the ground. ‘So far it is just lip service’ (Interview 12, September 2013). Absence of a catchment-scale flood management framework creates a knowledge gap and impedes adaptive planning and management at a regional scale.

Issues of maladaptation processes are not unique to this particular catchment. Branlat and Woods (2010, p. 260) explain that maladaptation can result due to decision-makers getting stuck in a culture that follows outdated behaviours (e.g., when a system over relies on past successes although conditions of operation change). Issues of lack of involvement of communities and other stakeholders in flood planning and management have also been identified in the development of urban Flood Risk Management (FRM) policy in the UK (White, Richards & Carter 2007). Wood and others (2012) discuss the communication barrier and difference in the understanding of FRM processes by different stakeholders as an impediment to implementing FRM. Knowledge gaps, absence of regional databases and communication issues in Central Asia and Greece have been highlighted in FRM processes across national boundaries (United Nations Economic Commission for Europe (UNECE) 2009). Reforms in FRM towards a catchment oriented model/ river basin scale have also been adapted in Germany and other countries (Dworak and Görlach 2005; Heintz et al. 2012) to enable a holistic flood risk governance approach.

5.8. Conclusions

There has been a recent drive to push councils to expedite their flood studies including flood mapping, development of flood plans and overland flow assessments among others. This urgency was triggered by the 2010-2011 floods in Queensland that demonstrated the potential for flooding in urbanised catchments and the need to improve preparedness to risks. For the Hawkesbury-Nepean catchment, the focus on floods has come at a critical point especially with the formulation of NSW’s new reform strategy that accelerates development in the region. Out of the four councils that were reviewed, the Hawkesbury City Council is the only council with a flood mitigation plan while others are in progress. The timing is also crucial as development approvals for certain areas within the four councils continue at a rapid pace. Hence it is all the more important that councils take into serious consideration addressing the issues of large floods, climate change and cross-boundary flood impacts during this critical phase of development and expansion. It is essential to revisit large floods and assess how the reoccurrence of the 1867 floods would now and in the future impact the region with its highly urbanised environment, and a critical review of whether sufficient measures are undertaken by state and local agencies to address this. The barriers to adaptive management in the Hawkesbury-Nepean catchment as discussed in this chapter, indicate the need for better integration of research and coordination among key agencies for holistic planning in the catchment. Adaptation to a changing landscape is only possible if the principles of panarchy that translate into the need to understand the embeddedness of systems are realised to assess accumulative impacts of floods due to development and climate change risks. This requires an in-depth understanding of the drivers that trigger motivations and interests to move in this direction. A governance system that is flexible and can adapt to change requires recognition of mal-adaptive processes. The next chapter examines an underlying problem that hinders such endeavours. In doing so it examines how complexities in flood risk management are created due to the way flood risks are perceived by decision-makers and experts.

Chapter 6: Addressing Barriers to Flood Risk Management in the Hawkesbury-Nepean – a Complex Problem of Perceptions

Note: A version of this chapter has been peer-reviewed and published in an international journal. Masud was the primary author and contributed by far the majority of the research and writing for the paper: Masud, S, Merson, J & Robinson, FD 2015, 'Adapting a holistic approach to flood management in the Hawkesbury–Nepean region: complexities and perceptions of the agencies involved', Journal of Environmental Planning and Management, DOI: 10.1080/09640568.2015.1056339

6.1. Introduction

The previous chapter identifies the problems in existing process of flood risk management in the Hawkesbury-Nepean region with particular emphasis on maladaptive processes. This chapter examines reasons as to why this is so. Through discussions with professionals involved directly or indirectly with flood risk assessment or its management this chapter highlights the constraint due to the way decision-makers perceive flood management issues of the catchment. This chapter builds on the issues identified in the previous chapter and looks into the complex nature of managing flood risks in the Hawkesbury-Nepean Catchment, Australia. In order to dissect this complex situation, several aspects are explored: (i) the complexities created by the way different agencies are involved in assessing flood risks and their different and interrelated roles in dealing with flood risk management; (ii) difference in perceptions of professionals involved in flood management on setting an acceptable level of flood risk; (iii) their perceptions on community engagement setting acceptable level of flood risks; (iv) views on the usefulness of having a holistic flood risk management plan at a regional scale; and, (v) challenges of consolidated and centralised information system. Conclusions from the study were drawn through the conduct of semi-structured interviews from relevant agencies. This chapter concludes that the complexity of managing a large catchment such as the Hawkesbury-Nepean is further exacerbated by the difference in the way these professionals at local, regional/state levels perceive the problem of managing flood risks. This has led to: (a) different set standards for acceptable risks; (b) inconsistent attempt to set-up a regional scale flood management plan that looks at the entire catchment – beyond the jurisdictional boundaries. (c) absence of a regional scale agency with license to share and update information in a centralised system with easy access to other agencies such as the insurance companies and the society at large (d) Lack of forums for dialogue with agencies such as insurance companies to ensure a coordinated and integrated approach to flood risk assessment and management.

6.2. Method of inquiry

This chapter covers a selective group of interviewees that represent key stakeholder agencies involved in flood management of the Hawkesbury-Nepean. For the purpose of this chapter, nineteen semi-structured interviews were conducted from December 2013 to March 2014 with representatives from three scales of governance. To ensure confidentiality, broad categories are used. These include, at the local level four interviews from representatives of three local government agencies (coded as Council Groups). The selection of these councils was based on their close proximity to the Hawkesbury-Nepean Region, their willingness to participate in the semi-structured interviews and more importantly there was a known contact, with which interviews for other elements of this research have been conducted and re-establishing contact for further information and additional interviews was more feasible. In addition, twelve interviews from representatives of government agencies responsible for development and environmental management across NSW (coded as State Agency (SA) 1 to 3)), and two interviews of representatives from agencies engaged in compiling and maintaining databases on floods and in providing national resources and information at the federal level (coded as Information Support Agencies (ISA)) were conducted. The two representatives from federal agencies were interviewed to understand the linkages of different databases and the need for centralisation of information to facilitate easy access. In addition, experts with extensive experience and insights into FRM governance in the region were also contacted to gather expert opinion on the complexity of large catchment management. Interviews from a real estate agency (coded as Real-Estate Group) and three insurance companies (coded as the Insurance Group) are also included. For the Insurance Group, initially five companies were contacted, two refused to participate due to the confidentiality of the information that was the focus of discussions for the interviews. Table 6.1 shows the interview categories and distribution of interviews between different scales.

Table 6.1. Summary of interviews conducted

Scale	views Conducted	**Category**
Local level	4	Council Group.
State Level	13	SA1, SA2, SA3, Real-estate Group, Insurance Group.
Federal Level	2	Information Support Agency (ISA)

Interviewees include those who were either engaged in flood, water, environmental or hazard management within their respective organisations, or were able to provide strategic and policy perspectives. The semi-structured interviews, on average, were conducted for 60 to 90 minutes and were based on the following broad questions around four themes:

1. Roles and responsibilities of the organisation in FRM in the region.
    a. To what extent is your organisation involved in FRM? What is your specific role in this regard?
    b. Which agencies within your organisation deals with flood management?
    c. In your opinion, who has the primary responsibility of managing flood risks?
2. Views on setting an acceptable level of risk and the role of communities.
    a. Who should define the flood risks?
    b. Should local communities be engaged in defining their own acceptable risks? Why or why not?
    c. How do you perceive 1% AEP as a flood planning level?
3. Perceptions on a catchment-scale FRM plan and the value of regional-scale coordination.
    a. Are you aware of any regional agency that provides a regional-scale FRM in the catchment?
    b. In your opinion, is there a need to have a regional FRM plan and an agency that should manage the plan and coordinate FRM activities across the catchment?
4. Issues on flood risk information and challenges of diverse information needs.
    a. What information with regard to floods do you require and where do you get this information?
    b. What difficulties have you experienced in terms of getting information on flood risks?

6.3. Flood risk management—challenges in a multiple-tier governance system

In Australia, the National Strategy for Disaster Resilience (COAG 2011) sets the broad terms for managing disasters. The strategy advocates for the cooperation of multiple responsible sectors to improve resilience against disasters, and on improved coordination across all sectors of the society. The Australian Emergency Floodplain Framework signifies the need for a cooperative approach to managing flood risks; different tiers of governance need to work together and provide technical, financial, legislative and regulatory inputs to manage flood risks (COAG 2011). In NSW, the Flood Prone Land Policy provides the legal framework for councils to manage their flood risks through an umbrella document, the Floodplain Development Manual (NSW Government 2005). Subsequently, FRM in Australia engages a multitude of stakeholders at local and state levels (Box, Thomalla, and Van den Honert 2013). The spectrum of agencies at state level involved in FRM range from environmental protection, natural resource management and planning agencies to emergency and response entities. At the local level, council bodies remain focal points for floodplain management and development controls. In addition, insurance companies play a significant role in identifying and communicating flood risks to government agencies and communities (Insurance Group, interview 1, January 2014).

For the purpose of discussions the agencies interviewed were divided into seven categories. Table 6.3 provides a brief overview of the key agencies involved in FRM and the role they perform as sourced from the semi-structured interviews. The interviews provided elaboration on their different responsibilities and levels of involvement in flood risk assessment and management.

Table 6.2. Role and responsibility of Agencies involved in FRM

Agency	**Perceived Role in Flood Risk Management**	**Scale and Approach Adopted**	**Primary Role**
SA1*	Not a core responsibility. Flood issues are dealt as a small component of development. Broadly look at social, economic and environmental aspects. Primary focus is on the rezoning of the region from rural to urban or residential and as part of that process flood management is considered. No detailed flood assessments are carried out Generally flood management is involved through legislation,	**Scope:** NSW State-wide **FRM:** Indirect involvement as and when it becomes a core issue for development. **Approach:** No 'in-house' capacity to conduct Flood Risk Assessments. Generally outsourced.	Planning/ Guidance

	policy, strategic planning and development assessment.		
SA2*	Provision of financial assistance through the NSW floodplain management program Provide technical assistance to the Flood risk management committees and other technical groups. Internal advice to other groups within the Agency such as the Minsters Office and to planning groups.	**Scope:** NSW State-wide **FRM:** Direct legislative and supervisory role. **Approach:** No 'in-house' capacity to conduct floo d risk assessment.	Policy/Guidance/ Financial
SA3*	Involved in flood mitigations since 1955. Primary role is the evacuation and welfare of affected communities and provide warnings. Leading agency in flood prevention, preparedness and response agency. Responsible for preparing for, responding to and also responsible for immediate recovery not long term recovery.	**Scope:** NSW State-wide **FRM:** Direct involvement. Significant role in-terms of establishing evacuation routes, emergency preparedness and response. **Approach:** Rely on flood studies conducted by councils.	Regulatory/ Administrative
Council Group	Maintains to be the central agency for floodplain development and management. Conducts flood assessments under the NSW Floodplain Development Manual (2005).	**Scope:** Local government **FRM:** Direct involvement. Primary agency to access flood risks and plan for mitigation. **Approach:** Development of Flood Risk Management Plan used for strategic planning for land use planning, establishing development controls and mitigation options.	Administrative/ Coordination
Insurance Group	Provides premiums and insurances that reflect the true risks. Identify risks in the catchment and try to assess individual	**Scope:** NSW State-wide **FRM:** Direct involvement. Risk assessment for accurate pricing.	Regulatory/ Informatory

	property and its natural peril flood risk, earthquake and then charge the right price for the right risk. Serves as a feedback mechanism to councils, consumers and government. If the risk become too high it is reflected in the price presumably instigation market and the government to take action.	**Approach:** ‘in house’ approach. Assessment process varies within agencies. Confidentiality maintained due to a competitive business market.	
Real-estate Group	Focus on urban renewal - really getting that development going. Conducts development specific flood assessment and drainage system development at a project level. Not a consent authority, prefers not to get involved in the decision making process pertaining to flood management.	**Scope:** NSW State-wide **FRM:** Indirect role. Does not do any ‘in-house’ risk assessment. **Approach:** Project level assessments. Mostly relies on information from the councils.	Administrative
ISA**	Focused on providing a national-scale decision-support system through aggregating flood information from regional and state-level agencies. Relies on the Council group and state agencies for provision of regional/local flood risk data. Potential to integrate information across scale – valuable source for decision makers involved in the FRM processes in the region.	**Scope:** Nation-wide **FRM:** Indirect role. Identifies data source on floods. **Approach:** National level.	Administrative/ Informatory
*SA1 – SA3: State agencies **ISA: Information Support Agencies at Federal level.			

6.3.1. Roles of the state

At the state level, flood risk assessment is spread across legislative, technical and advisory support with little direct intervention in flood risk assessment, as is the case for SA1 and SA2. SA3 is an exception as it deals with emergency preparedness and response to floods through identifying evacuation routes in developed floodplains. Other state agencies that are involved but not included for interview in this research are agencies involved with operation and safety of Warragamba Dam (the largest in the region), and the monitoring of river level gauges within the catchment. The information generated is shared with the Bureau of Meteorology (BOM) which is responsible for providing flood warning information to the Council Group and the SA3.

6.3.2. Roles of private entities

Other stakeholders, including the Real-Estate Group, perceived themselves to be remotely involved in flood risk assessment, and considers themselves as "not a consent authority" in flood risk management, and would prefer not to "get involved" in the decision-making process (Real-Estate Group, interview 2, January 2014). From their perspectives, flood risk assessment is only necessary when details of a development are streamlined. In their domain, flood risk assessment is project-based and is conducted as and when necessary.

Interviews with individuals in the Insurance Group category revealed that they perceive their role as an entity that helps to identify and reduce the risk of natural perils in potentially affected communities. Hence, the assessment of flood risk is vital and central to their organisational objectives. In addition, they provide a feedback loop to government agencies and other relevant sectors through pricing mechanisms that reflect "true risks" (Insurance Group, interview 1, January 2014). To them, Council and the Real-Estate Groups are the ones responsible for identifying real and acceptable level of risks with primary responsibility relying on individuals within a community.

6.3.3. Roles of local councils

The local councils are seen as the main authority for floodplain management and development control for planning in the floodplains. Hence, the different groups involved in FRM rely on information from them for planning, development and to an extent, insurance purposes. The reliance of up-to-date information predominantly rests with local councils who, in most cases, have limited resources. Consequently, the extent of data and information the councils have compiled depends on the financial support from state agencies. The interviews established that councils are facing issues of limited funding that tend to impede the implementation of their flood risk mitigation interventions. One interviewee states: “Sometimes structural improvements [are needed but] then it becomes a funding issue. We have to get the funds before we could do something about it” (Council Group, interview 3, January 2014).

6.3.4. Roles of federal agencies

The ISA at federal level serves to provide and integrate information across states. The databases are dependent on the flood risk information generated by the FRM process at the local level. It also provides support to the BOM for monitoring purposes.

There also appears to be limited funding support from the federal government. This lack of support could lessen incentives for better flood management to be undertaken by already under-resourced and over-burdened local councils. It may also result in delays for more frequent risk assessment, despite evidence of climatic changes influencing extreme weather events. This may create information gaps critical for agencies, both local and state, that are responsible for assessing and mitigating “real risks”. An example of the repercussions of reduced funding support is described by one of the council representatives: “Nepean flood study has gone up to ten years and it requires revision after five years - the reason is funding and resources. In council there are few people” (Council Group, interview 4, January 2014).

The problem of restricted funding is progressing with less fund allocation for future flood management in the region:

> Previously the funding assistance was more... council only paid 20%. Now it has been changed, the Federal Government has withdrawn its component state-wide, so now it is 2:1. Council pay 1/3 and State pays 2/3. More contribution from council [is expected] so our ability is limited now. We can’t do all the flood mitigation work as needed. Government [is] actually, putting less and less money every year and this year has been the lowest (Council Group, interview 3, January 2014).

The UK Environment Agency (2006) identifies that flood risk management decisions by default involve “multiple geographical and political scales” of governance from “local, regional and national” (p. 13). The multiple role different agencies play within their domain of responsibilities creates complexity in defining risks and the approaches adopted to assess flood risk. Berke, Beatley, and Wilhite (1989) identify barriers to coordination between different tiers of governance and across jurisdictions. Lustig and Maher (1997) also point out that the complex arrangement of agencies managing flood risks has led to poor coordination and management in Australia.

The UK Environment Agency (2006) identifies a number of problems with such a tiered approach:

> [It is] a pragmatic way to accommodate statutory responsibilities and multiple interests in decision making. A wide range of institutional stakeholders provides input, but, in the tiered system, this is done on an individualistic basis, shaped by the stakeholders' own narrow (and sometimes legally constrained) objectives. This current process does not easily allow for adaptive planning, or for new creative partnership opportunities to be discussed and accommodated. At its worst, it can be prone to locking in unsustainable behaviours because timely and relevant information flow (up and across the tiers) is so limited.

Information flows in such a tiered hierarchy has established downward flow, instead of flows in both upward and downward directions. Indeed, Morss *et al.* (2005) argues that in Flood Risk Management 'information needs to be channelled up and across the tiers.'

In the context of FRM, governance in the Hawkesbury-Nepean region demonstrates the prevalence of an "ultra-vies rule" (Environmental Agency 2006), where agencies can act only if given the authority to exercise their power. The interviews show how agencies exercise their prescribed authority in FRM that limits their organisation to narrow legally constrained objectives. Statements from discussions with some of the organisations in the region show the way individuals see their own and others' role in FRM, and how responsibilities are understood among these agencies:

> We don't have the resources to sit on [local level floodplain development committees] but [SA2], does [involve themselves] because they provide the funding and have the technical modelling capacities (SA1, interview 5, January 2014).

> [Flood risk assessment studies and its development] are council documents and council processes, [SA2] and the Minster for Environment doesn't sign off them. It is the council's responsibilities (SA1, interview 5, January 2014).

> We wouldn't do community engagement primarily on flood issues [as that is not our mandate]... but if we are doing a development project and flooding is an issue then it will be discussed among other issues (SA1, interview 6, January 2014).

> The responsibility is spread out. It is [SA1] responsibility for the technical information. It is [SA3] for evacuation. [SA1] is [responsible] in terms of Natural hazards and land use planning (SA1, interview 5, January 2014).

> We are not actually a consent authority so we don't have a role determining which areas are flood affected. We are driven by the decisions of the likes of councils. Not being a consent authority we tend not to get as involved in those decision making process (Real-estate, interview 2, January 2014).

The different prescribed roles also influence the viewpoint on what parameters of FRM should be considered and are important. Box, Thomalla, and Van den Honert (2013) explains that there are differences in the way organisations engaged in flood risk assessment, perceive their role and the role and expectations of others involved. This leads to poor communication and coordination between public and private organisations in Australia (Box, Thomalla, and Van den Honert 2013) and has been identified in other research studies (e.g. Hansson et al. 2011; USACE 2012).

Third column in Table 6.2 above, presents the scale at which different agencies, involved, operate and their degree of involvement in FRM in the Hawkesbury-Nepean region. It provides an overview of the different level of authority agencies hold for managing flood risks in the region. This is based on their priority areas and primary responsibilities. Among the seven categories of agencies interviewed, majority of the agencies lack 'in house' capacity or resources to conduct flood risk assessments. In most cases, they rely on the information provided by the councils or outsource risk assessors from a vast pool of individuals or consulting firms, each with their own criterion of risk assessment processes and models used to cater to the individual organisational needs. Cash et al. (2006), Moss & Newig (2010) and Haarstad (2014) discuss the complexity of water resource management highlighting the socio-political barriers that comes with management of this resource across different scales. FRM processes in the Hawkesbury-Nepean valley involve several tiers of management, each with different sets of responsibilities. It is the differences in these responsibilities that define a certain approach to viewing risk, therefore, creating complexity in establishing a consistent process for risk assessment and management in the region. Consequently, flood risk assessment is carried out to fulfil individual information needs in the Hawkesbury-Nepean. Limited resources can also threaten to reduce reassessment of flood risk in regions that are rapidly developing.

6.4. Defining an acceptable level of flood risk—whose responsibility?

To record perceptions on the acceptable level of risks, the interviewees were asked to comment on two accounts; their perception on engaging communities for defining the level of risks and their views on maintaining 1% AEP as an acceptable level of risk for the Hawkesbury-Nepean Region. The following tables (Table 6.3 and 6.4) provide a summary of responses.

From the responses recorded in Table 6.3, below, it can be summarised that community consultation for flood risk assessment is perceived to be the responsibility of local councils and State Emergency Service. At state level, community consultation processes are carried out in coordination with the councils and are based on a wide-range of issues, depending on the core responsibility of the respective state agency. Interviews with insurers and developers indicated that their direct involvement with the relevant community group is also limited to specific interactions with contractors or individuals for development or insurance purposes. These agencies do not have a community engagement component and as business entities prefer to maintain one-to-one interactions with the clients. For determining flood risks, their primary source of information is the council.

Representatives from the Insurance Group and the Real-Estate Group expressed their lack of purpose to engage with the communities' at large. In general, the Insurance Group and the developers that were involved in the discussions agreed that the responsibility relies on the individuals' to understand flood risks in their area. In terms of identifying their roles in information exchange and creating awareness about flood risks to broader society, mixed responses were received. The Real-Estate Group did not see any relevance to their line of work. On the other hand, a representative from a prominent national insurance company supported the notion of communicating risks to the larger community and expressed willingness to support discussions at federal government level to communicate information on the different cost of insurance in different flood areas (Insurance Group, interview 7, January 2014). However, this was not something that was supported by interviewees of another insurance group. They felt that risks should be communicated to clients or potential clients. Advertising flood risk information through consultation with communities, according to these interviewees, would not maintain client confidentiality and may devalue properties (Insurance Group, interview 1 and 7, January 2014).

Representatives from a national level agency for insurance were of the view that taking on the responsibility for community engagement is the role of the government. According to them insurance companies can supplement the information but cannot take on the responsibility. One interviewee argued that it is too risky for insurance companies to inform the communities about flood-prone areas as it may backfire, whereby communities may accuse insurance entities for providing flood information that would lead to charging high premiums (Insurance Group, interview 8, March 2014). However, being a national level authority to represent insurance companies, the interviewees felt that community engagement in the form of publishing information to be accessible to community on flood risk is not far down the track. The entity has the resources and data to do so (Insurance Group, interview 8, March 2014). However, letting communities decide on acceptable level of risks was seen as a way of creating more inconsistency and a barrier to establish more standardised mechanism for flood risk assessment and management (Insurance Group, interview 1, January 2014).

Table 6.3. Opinions on community engagement in FRM

Agency	**Level of community engagement and consultation for flood risk assessment**	**Perceptions on engaging community for determining acceptable level of risks**
SA1	The agency's strategic planning mostly involves rezoning of the land. Community engagement primarily on flood issues is not carried out.	Does not foresee as necessary. If there is a risk then the relevant government entity should inform communities of the risk. Councils are perceived as responsible authority to communicate risks.
SA2	No direct consultation. Advisory and technical support to council and participation in the Floodplain Risk Management Committee.	The issue is beyond the community. Communities lack sufficient knowledge to make appropriate decisions. Acceptable risks should be determined by technical working group such as the council, SES or OEH, strategic planners, consultants. Such agencies as a group tend to be best placed to put out the information to the Floodplain Risk Management Committee.
SA3	Conduct flood risk perception studies to gauge community understanding.	Important to understand the way people rationalise risks. Help to guide them so that they make appropriate and informed decisions to reduce risks.
Council Group	Community consultation is a pre-requisite of flood studies as outlined in the Floodplain development manual (2005).	The council already have a guideline to help define acceptable level of risk, hence community opinion in this case would complicate planning.
Insurance Group	Flood risk assessments for region or property are conducted on a one-to-one consultation with potential clients. Perceives government to play the primary role to inform the community about flood risks to	Doesn't see any role in assessing communities' acceptable level of risk as insurers have no part to play in deciding where the houses would be developed. It is more of an individual and council's decision. Does not support taking up the

	communities.	role of engaging community for mass level flood risk assessment for reasons of confidentiality to clients about their property. Issues of dealing with multiple acceptable levels contradicts standardisation of information.
Real-estate Group	Does not have a community engagement component as an organisational mandate.	No comment. Didn't have much relevance on this to comment.

The Floodplain Development Manual (2005) provides guidelines for community engagement through advising the floodplain managers to identify local community representatives as members of the *Floodplain Risk Management Committee*. The process of undertaking a flood study also takes into account community engagement mostly through sharing questionnaires that help to gauge information about floods. This information exchange does not extend to accessing the communities' perception on acceptable level of risk (Council Group, interview 9, January 2014).

During discussions with two of the council representatives, a general process was streamlined for engaging communities for assessing risks. There are a few avenues for community interaction. Community feedback is sought through, community representatives on the Floodplain development committee. Another level of engagement, which provides for a direct interaction with the community, is during the process of conducting and sharing information for flood studies. As part of the flood risk management study, questionnaires are sent to collect flood data and gauge the community's knowledge about floods in the region. Consequently, flood risk management options are shared with the communities and their opinions are collected as part of the socio-economic survey. According to the council representatives, the risk management options are based on the community's response and the feasibility of their implementation. A review of the questionnaire conducted for flood studies, available on one council's website, shows that information collected from the community deals with their knowledge on recent floods and the identification of the possible sources of flooding, focusing more on data collection relating to flood history (Liverpool City Council 2007). It does not take into account assessing people's acceptable level of risks. This observation reflects Molino & Karwaj's (2012) findings indicating the absence of exploring residents' perception in defining flood planning levels. As Godber et al. (2006, p. 36) have emphasised that community consultation processes tends to gain community feedback and comments on particular development, proposed land uses and planning schemes but not 'drive the setting of acceptable flood risk standards. This results in potential mismatch between imposed risk standards and community preferences'

Acceptable levels of flood risks are determined by extrapolating information from a range of quantitative measures and available scientific data. In this regard, local councils are expected to take on the responsibility of communicating risks to the communities. The perceived notion is that the communities' need to be informed of the flood risks rather than expected to define an acceptable level of flood risks. The process dictates a 'top-down' flow of information where an acceptable standard of flood risk is established through technical inputs and expected to be understood and accepted at different tiers of governance across different public and private agencies, including the local communities. This is evidenced by the following statement from a state level agency representative:

> Asking communities about their perceptions doesn't reduce the risks. Just because they say no, doesn't mean the problem [of flood risk] isn't there (SA1, interview 6, January 2014).

Similar 'top down' flows of information are expected to be acceptable for a broader community such as the insurers:

> They [the insurers] need to take into account the government identified parameters of 1-in-100-year, 1-in-200-year [acceptable flood risk level]. They need to respond to the government rules (Council Group, interview 10, January 2014).

A 2012 survey shows that 60% of councils in NSW are following the 1% AEP benchmark as an acceptable flood level (Molino & Karwaj 2012). Extensive literature exists that dispels setting 1% AEP or one-in-100-year flood as acceptable flood risk level (Godber 2002; Bewsher & Maddocks 2003; Collins & Simpson 2007; Bell & Tobin 2007; Molino et al 2012; Wenger et al. 2012; Molino et al. 2013). While risk assessment takes into account a more quantitative and scientific process, the implementation of flood management plans has a socio-political dimension to it. Review of previous research suggests that more often communities' point of views differ from expert evaluations on ways to manage flood risks (Young 1998; Steinführer & Kuhlicke 2009; & Kellens et al. 2011).

Young (1998, p. 16) suggests a combination of practical approaches to risk management which 'make-use' of the technical knowhow and incorporates knowledge of those at risk. Despite the literary criticism it still remains the dominant form of practice in the Hawkesbury-Nepean Region. Discussions with some council representatives emphasised the perceived lack of need to assess communities' acceptable level of risk defined by this benchmark. Direct community consultation for setting acceptable level of flood risk was seen as a challenge resulting in several different perspectives each with their own level of risk acceptability (Council Group, interview 3, January 2014). The Council Group representatives also felt that the requirement is already fulfilled by the community representation on the *Floodplain Risk Management Committee* which, according to some interviewees, is responsible for setting the acceptable level of flood risks in a particular council. Despite having the provision of a committee setting acceptable risk levels, a council representative confirmed that generally in the Hawkesbury Nepean Valley, flood risks for planning are established as a 1 AEP% as an acceptable risk level (Council Group, interview 10, January 2014) Community representation, however, as previously indicated in chapter 6 depends on expressed demand by the community, the lack of which results in no representation in the Floodplain Risk Management committee. This has been the case for one of the councils interviewed (SA2, interview 11, February 2014).

Aside from challenges regarding benchmarks, a number of related issues were identified in engaging communities for assessing flood risks (summarised in Table 6.4. below). One of these was about having communities agreeing on a set standard for acceptable risk. A number of factors can drive such decisions such as the recent occurrence of a flood in the region, their interest in purchasing a property or the status of their ownership of the land. Hence, diverse values will lead to different standards of acceptable levels of risk. More importantly, the communities, in most cases are unaware of what will be acceptable to them (SA2, interview 12, March 2014).

Scholars argue that the acceptable flood level set by government agencies, such as the 1% AEP, when technically communicated to non-government stakeholders is not clearly understood and, therefore, may lead to misinterpretation of exposure to flood risks and result in variation in acceptable levels of flood risks (Godber 2005; Bell & Tobin 2007). According to Godber (2005, p. 26) 'The extent to which the formal standards are misinterpreted suggests stakeholders may potentially be exposed to risks greater than they perceive acceptable.' A survey conducted to assess people's perception about acceptable risks in Australia, following the 2011 floods in Queensland, also indicated the difference in people's expectation about flood risks and existing planning regime (Molino & Karwaj 2012). Bell and Tobin (2007) suggest that flood risk communication can only be effective if it takes into account the concerns of the target audience. In their words: 'collectively agreed-upon flood levels might also be more useful in creating and enforcing flood policy' (Bell & Tobin 2007, p. 308).

The interviews had made it apparent that a degree of dichotomy between different tiers of governance, especially between local councils and the state, and even between agencies exists. This is more evident in their varied interpretations of what an acceptable level of flood risk is and whether it is crucial to engage communities. Table 6.4 and 6.5 show this variety when asked to comment on their views about having 1% AEP as an acceptable flood level for planning.

Table 6.4. View on 1% AEP as an acceptable flood risk

Agencies	Perspective on 1 %AEP as an acceptable level of flood risk	Origin of 1 % AEP (Who decides)
SA1	The 100 year flood and PMF provide guidelines.	No idea where it comes from. Historically used for development controls Now institutionalised through 2007 Development Guidelines issued by the NSW Department of Planning.
SA2	An appropriate level of risk for property.	Historically it has been there for a long time. It has been captured by experience across the world.
SA3	It is an artificial distinction	It is an arbitrary division line and overtime it became institutionalised. Adopted from the US practice.
Council Group	It is a risk-based assessment, not a fixed thing but generally adapted as a planning level. It is easily manageable, as it is possible to prevent the damage with proper use of material and precautions.	It is the requirement of the floodplain development manual. The Floodplain Risk Management Committee decides the acceptable level. This is discussed at the risk management planning level and the Council (Minster) make that decision.
Insurance Group	Conservative view set for planning purposes. Lack of clarity on what is the true 100 year frequency. Chances of misinterpretation of flood safe regions. Anything above 100 years for instance flood with 101- year return interval is not accounted for in planning. Potential for false communication of 'true risks' to communities	No comment.
Real Estate Group	All sort of modelling is based on 1% AEP. It is questionable as to what is within 1% AEP and what is out of it for risk mitigation. uestionable if it is adequate or not especially in the context of climate change.	Government decision.

As observed in Table 6.4, mixed responses were received about the usefulness of using 1% AEP as an acceptable benchmark. Council representatives believed that the decision is made 'higher up' and it is an acceptable level in terms of economic feasibility where damage could be prevented or significantly reduced through mitigation. Representatives at state levels agreed that it is an appropriate guideline for planning (SA1, interview 6, January 2014; SA2 interview 12, March 2014). Another representative from SA1, however, clarified that 1% AEP is not a 'by default' option that must be followed by everyone. Instead, the councils are allowed in exceptional circumstances to request a change in flood planning levels.

> [In] 2007 the NSW Planning Department issued a guideline for councils that said councils are not to place development controls beyond the 1% AEP plus freeboard unless they get exceptional circumstances approval from our department or [SA2]. Councils tend to take that as a blanket prohibition. It isn't a blanket prohibition and I often correct that it is by exception. Most councils don't apply for exceptional circumstances (SA1 interview 5, January 2014).

Molino & Karwaj (2012) argue that it is the institutionalisation of the 1% AEP set by the NSW Department of Planning (New South Wales Department of Planning 2007) that restricts councils from setting their own acceptable level of risks for planning; hence the adoption of 1% AEP as a general standard. With councils generally accepting this as their flood planning level with variations in freeboard ranges (Wenger et al. 2013), other agencies consider this as illogical (SA3, interview 13, December 2013) and misleading (Insurance Group, interview 1, January 2014). According to the Insurance Group interviewees, the 1% AEP benchmark as a determinant of acceptable risk is not based on an exact science. It is evolving such that changes in the use of different parameters as inputs in hydrological modelling may result in a different flood height for a flood of 1% AEP. This means that estimates of a 1% AEP can be different from different perspectives and is dependent upon a number of factors such as the changes in landscape, increase in hard surfaces, type of soil, velocity of flow and with different inputs the flood height for such a flood may differ, over the years, with changing landscapes (Insurance Group, interview 7, January 2014). The non-static flood line for a 1% AEP flood, scholars argue, can even place people at unacceptable levels of flood risk (Wenger et al 2012 & 2013).

The principal challenge, therefore, is to understand what a 1% AEP really means.

> [With development such as Wivenhoe dam, in Brisbane, for example] you can't really look at the historical floods and their return intervals because the

> fundamental flow dynamics have changed and so the models have changed (Insurance Group, interview 7, January 2014).

Another representative from a national organisation representing insurance companies suggested that there is a need to have some form of a benchmark and 1% AEP seems to be an appropriate one. What is needed, however, is the appropriateness of communicating what is meant by a 1% AEP so that effective action could be taken such as building properties at an appropriate height.

> We have problems with how the language of 1-in-100 [1% AEP] is interpreted by people and understood. There are flaws in the language. We need to change the language around that (Insurance Group, interview 9, March 2014)

Van den Honert and McAneney (2011), elaborate that flood maps, used as a primary source of information for risk analysis, mostly record the extent of flooding modelled for a 1% AEP. They argue that it doesn't provide information for larger floods. Van den Honert and McAneney (2011, p. 1169) explain that insurers and other land use planners require 'modelled flood surfaces that can be interpreted to see how flood depths vary as a function of annual return interval at given locations'. Furthermore, having a consistent threshold such as the 1% AEP for development does not reflect true risks; in a lot of situations, especially in the Hawkesbury-Nepean, there is height difference of several meters between a 1% AEP and the Probable Maximum Flood (PMF) (Van den Honert & McAneney 2011).

As a result, different groups assessing flood risks in the region have developed their own levels of acceptable risks for flood mitigation and planning, based on their organisational objectives and responsibilities, and have opted for planning for different range of floods including PMFs (SA3, interview 13, December 2013; Insurance Group, interview 1, January 2014).

Godber's (2005 & 2006) research on acceptable risks in flood prone regions of Gold Coast and Nerang River catchment highlights critical viewpoints of different stakeholder groups (community, local government and developers) that resonate with the views of interviewees in this study. The lack of emphasis on what is the acceptable level of risk by the community is highlighted by the existing mindset, which advocates that communities need to be informed about risks and that gauging multiple perspective on risk would complicate planning interventions. The historically set acceptable standard of 1% AEP, this study shows, has a varied degree of acceptability among the targeted community and broader stakeholders. The varying degree of expectations and assumptions about others engaged in flood risk management also add to the complexity in coordination and practising a ‘shared responsibility’ model indicated by the national framework as outlined in the *National Strategy for Disaster Resilience* (COAG 2011).

The element of ‘shared responsibility’ can be rightly achieved when a consistent understanding is established about acceptable risks. This needs to be addressed to allow for the identification of ‘true risks’ and acceptability of flood risk in a wider community for better flood risk planning, management and cooperation between public, private entities and the affected community.

6.5. ‘Catchmentisation’ – views on catchment-scale flood-risk management

As discussed in previous chapter, the majority of flood studies are carried out locally in small scales. Reviews on floodplain management in Australia, for example, in Brisbane in the state of Queensland and in localities in the state of Victoria, indicate that municipal boundaries among other reasons prevent the generation of catchment-scale flood studies (Wenger, Hussey & Pittock 2013). The Queensland Flood Commission of Inquiry highlighted the need for a regional-scale approach to flood management (QFCI 2012), a necessity that has also been voiced by those involved in FRM in the USA, UK, China and the Netherlands, as well as in Australia (Heintz et al. 2012; Druery et al. 2010). Wenger et al. (2013) stresses the need to have catchment-scale management for flood risk; Ribbons et al. (2013) talks about the value of assessing accumulative impacts of development in floodplains in Liverpool; Tinnion (2013) elaborates on the use of new models for catchment-based approach to flood management in Queensland; Molino (2013) discusses the development of a regional floodplain database for Moreton Bay, an attempt to derive a holistic flood risk framework for regional level flood planning; and UK Environmental Agency (2006), coins ‘catchmentisation’ as a necessity for establishing stakeholder partnerships for effective flood risk management in the UK context. In NSW, for instance, regional-scale management of natural resources is reflected in the implementation of catchment action plans (NRC 2006). In the USA, the Army Corps of Engineers’ Regional Sediment Management Program implements adaptive management strategies that allow a system-based approach to integrate multiple projects across the region that support sediment controls and provide environmental benefits in addition to flood and storm reduction (Lillycrop et al. 2011).

Nevertheless, limited “on-ground” evidence of this level of flood management is visible in NSW. The Hawkesbury-Nepean Flood Management Strategy (1997) was one concrete step towards “catchmentisation” for better flood planning and management. In this strategy document, six councils, impacted by potential floods downstream of the Warragamba Dam in the Hawkesbury-Nepean Rivers, were considered for a consolidated floodplain management plan (Hawkesbury-Nepean Flood Management Advisory Committee 1997). This, however, did not materialise. An interviewee from a local council reported: "The councils were supposed [to] set-up their floodplain management plan under the umbrella of this regional plan and that has not fully happened so the regional plan never developed and the local plans are a real patchwork approach" (SA3, interview 13, December 2013).

In the state of Victoria, Catchment Management Authorities (CMAs) are the designated authority for flood management and are considered as referral bodies for development approval (Wenger, Hussey and Pittock 2013). CMAs in NSW, however, did not focus on flood management and their recent merger with local land services for improved integration of land management does not account for flood planning either (NSW Government 2013).

Interviewees from SA1, SA2 and the Council Group argued that the role of CMAs in NSW was seen as irrelevant to flood risk management and planning. CMAs were perceived as environmental management groups that have the responsibility of looking after the entire catchment, and had little to no involvement in flood planning processes (SA1, interview 6, January 2014; Council Group, interview 4, January 2014; SA2, interview 12, March 2014). They were seen as agencies that are focused on rehabilitation and revegetation to improve environmental conservation outcomes. Response from a flood management representative from the Council Group indicated the absence of CMAs as contributing towards flood management '*In my four years here I had no interaction with CMA. Flood Management Authority and NSW Office of Environment and Heritage are the main agencies*' (Council Group, interview 10, January 2014). Despite the former CMAs lack of involvement, some of the interviewees felt that, if given the resources they can play a role in addressing flood issues and provide a more regional-scale perspective. A council group representative expressed the need to have flood management as part of CMAs *Catchment Action Plan* (Council Group, interview 4, January 2014). There was a general agreement among the interviewees, that within the existing mandate, CMAs had little incentive to engage in flood risk management. Table 6.5 below summarise the viewpoints of interviewees with regard to the role of CMAs in FRM in the NSW.

Table 6.5. Perceived Role of CMAs NSW

Agencies	Views on CMAs in Flood Risk Management
SA1	Don't have a specific role as CMAs do not drive any of the flood management processes. Primarily, responsibility is land revegetation issues. CMAs role doesn't seem to be changing in terms of flood hazard management in future.

	Their role is focused on, on-the-ground environmental management rather than flood management. More focused about making sure degraded creek is revegetated. Floods generate from development and the community, whereas CMAs have nothing to do with promotion, direction or control of development or even communities. The role is taken up by the councils instead.
SA2	The CMAs in Victoria State work on a catchment-based model, whereas in NSW the responsibility for floodplain management and planning rests with the local government.
Council Group	It is not in their role. If they have the resources and their role is modified then they could do it. At the moment, CMAs can only be involved in the integrated flood study. Preparing guidelines and documentation at a catchment-scale.

Representatives from the national level insurance entity provided examples from Victoria where the CMA model is in use. Although they indicated that it adds another administrative layer, the Victorian CMA model was described as a good example of a total catchment model for managing floods. Such a model has enabled consistent flood mapping and publishing of information which is shared throughout the state through a standardised process. '*By giving someone responsibility above the local government boundaries...a far more synergised response from the whole [can be achieved]. I think that model would work quite well here [NSW]* (Insurance Group, interview 9, March 2014). With the absence of a regional-scale entity to coordinate floodplain management, catchment-scale information and the provision of a comprehensive understanding of flood risks in the region are likewise conspicuously absent. Through discussion with interviewees from local and state level agencies, there was generally an expressed need to have catchment- scale flood planning. However, some supported the idea more than others. Summary points of these views have been listed in Table 6.6, below.

Table 6.6. Views on the Need for a Catchment Scale Flood Planning

Agencies	Views
SA1	Good idea to have catchment-scale flood planning to instigate consistency. Useful to have a standard set of controls and parameters that apply across multiple precincts and multiple councils or government areas. A good example is bushfire controls and management by the Rural Fire Services. Councils do not have the resources to foster such initiatives, for Hawkesbury-Nepean the state government should convene such interventions.
SA2	There is the issue of governance, who is going to do it, no one is taking responsibility. It seems that government is placing a lot of responsibility to councils.
SA3	Useful, the Hawkesbury-Nepean Flood Management Strategy, 1997 was implemented for the purpose but it never eventuated.

Council Group	Difficult to have one plan. Different methods may be required to observe flood behaviour and not all the region is impacted in the same way against floods so it would be hard to manage one plan. Funding would be an important issues and consistent revision of the plan would require continuous source of funds.
Insurance Group	Catchment-wide plan definitely, especially in place if there are multiple councils in one river system. Allow easier access to information. Feasibility of updating information on one plan and the same database.
Real-Estate Group	Interesting idea but not useful as suburb scale information is more useful for targeted projects.

The interviews indicate that different perspectives exist with regard to having a catchment-scale floodplain management plan. State level agencies' representatives supported the usefulness of having a catchment-wide plan to ensure consistency. Reference to the integrated model for fire management used by the Australian Rural Fire Services was discussed as an example where a regional-scale agency provide input in planning and development phases. A similar model at a regional scale that can provide standard sets of controls and parameters across LGAs within the Hawkesbury Nepean catchment was deemed imperative. Others also supported the concept due to its value in providing consistency in information and access to a centralised data compilation and collection portal for easy public access, identification of gaps and benefits in focusing resources in priority areas (SA1, interview 5, January 2014; Council Group, interviews, 3 and 15, January & March 2014 respectively).

While SAs and the Insurance Group support the development of a consolidated catchment-scale plan, the Council group and the Real-estate group expressed concern about its limited application. Representatives from the Council Group highlighted the complexities of establishing such a plan in terms of determining a suitable model for assessment. Currently, a number of models are used with each serving a particular purpose and drawing findings on different parameters based on user selection. Another complexity was observed in terms of the difficulty due to the scale of catchment which encompasses a number of councils hence creating difficulty in coordinating the work councils would be expected to undertake for setting-up such a plan (SA1, interview 5, January 2014). The Council Group representative indicated that catchment-scale consolidated flood risk plans are 'in practice' for smaller catchments, with a recent example being the development of the South Creek catchment study and plan, being implemented by the Penrith City Council (Council Group, interview 10, January 2014). However, the council group representative also pointed out that they lack the capacity and resources to conduct smaller catchment-scale flood studies and plan, therefore, a plan for the entire Hawkesbury-Nepean catchment is beyond the capacity of any council. Meanwhile, the Real-Estate group had a different perspective for not having a catchment-scale plan, citing the scale of their activities which are largely focused on a suburban level. For them, any catchment-scale plan was seen as 'interesting' but not particularly useful (Real-Estate, interview 16, January 2014).

During the conduct of interviews, it was realised that little reference, with the exception of SA3 which have been directly involved in implementing some of the recommendations of the Strategy, was given about Hawkesbury-Nepean Flood Management Strategy, 1997. The Strategy served as an attempt to move towards a more catchment-scale management approach (Hawkesbury-Nepean Flood Management Advisory Committee 1997). This might be due to the fact that little knowledge or understanding possibly exists in terms of the utility of a catchment-scale risk management plan. It can also be due to the fact that the people involved in discussions for this research did not have the institutional memory of such a Strategy hence little reference to the study was mentioned. An interviewee from the SA2 category, responsible for policy implementation and strategic planning, indicated that rather than a single plan, a catchment-scale flood plan management strategy should be in place. The strategy can be useful to highlight catchment-wide issues. In addition to the catchment-wide scale, the interviewee argued that councils should continue to have their floodplain management plans in order to deal with their local issues. A single strategy provides a logical approach, but there should be a process whereby local floodplain management plans are also linked, and there should be an understanding that local plans will cater to local council issues (SA2, interview 12, March 2014). There were, however, some opportunities seen for developing a regional scale floodplain management plan. Opportunities were observed in the light of having large-scale mitigation projects, evacuation plans; and flood recovery response and flood recording. The presence of a regional body responsible for regional plan may also aid in standardisation of flood damage assessment and recording information (Council Group, interview 15, March 2014).

Thus 'Catchmentisation' in FRM for the Hawkesbury-Nepean can be seen as a possible solution to a number of issues including (i) provision of a better understanding of flood behaviour and impact on a large scale; (ii) highlighting areas that require particular focus on flood risk mitigation and (iii) provision of a more direct focus on utilising limited resources on priority areas. The challenge, however, to such modes of management exists due to the absence of a regional scale organisation that would coordinate, maintain and support a dynamic catchment-scale flood risk plan. Another challenge is the difference in viewpoints that exist among members of different agencies dealing with flood risk management. The disparity in perceptions on what is vital for managing flood risks for such a large catchment limits incentive to foster coordinated efforts for catchment-scale management.

6.6. Challenges in communicating flood-risk information—councils versus insurers

A dominant theme that arose from the interviews was the absence of information sharing processes and the type of date-sets that would support FRM's multiple needs. Although, councils were recognised as information hubs for generating information on floodplain management, insufficient information was identified as a barrier to understanding the 'true risks' of floods in the Hawkesbury-Nepean Region. Interviewees from the Insurance Group strongly highlighted this concern.

A representative from one of the prominent insurance companies provided a detailed account of the difficulties they had during the compilation of a comprehensive national database for flood risk assessment. The interviewee stated that data for flood risk assessment were collected from eleven different sources, each with issues in varied quality and reliability from individual consultants to councils. During the course of this data collection, their company contacted 80-100 councils. The greatest challenge in NSW, is the absence of a single source of information (Insurance Group, interview 9, March 2014). Although within NSW the *NSW Office of Environment and Heritage* has the overarching responsibility to coordinate floodplain management in the region, it has failed to play an active role in facilitating the compilation of the insurance company's database (Insurance Group, interview 9, March 2014). Data collected from the states of Victoria and Queensland were considered to be a lot easier than that gathered from NSW, primarily due to the existence of an overarching agency to facilitate the process. In the NSW, the company encountered a number of issues: the absence of information, refusal to provide access to information; and insufficient information presented as basic polygonal maps based on historical events with no metadata or information on how it was created and by whom. In addition, information was provided in different file formats with different return period assessments. 'It would be unfortunate if every insurance company is going through the same issues [of data collection and access] as [us]' (Insurance Group, interview 9, March 2014).

The interviewee further elaborated that more often the information shared is based on a conservative view where a 1% AEP and freeboard [9] is considered. Insurance companies, on the other hand, need information that provides frequency of a particular

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9 Freeboard is a factor of safety usually expressed in feet above a flood level for purposes of floodplain management (FEMA 2013).

hazard in a particular area. Pertinent information relates to surface levels of a particular flood event and elevation group to get depth for different scenarios (from 10-years to PMF). Hazard maps, developed by councils, meanwhile are primarily designed for planning purposes and not for insurance use. Premiums based on this data may, therefore, not accurately reflect the true risks.

Other interviewees from the Insurance Group also felt that councils are providing insufficient information, especially in terms of properties above a 1% AEP. While elaborating on this issue an interviewee explained that:

> Typically councils have said that there is a 1-in-a-100-year threshold and if you are already in that threshold then you are considered to be at flood risk but if you fall anywhere above the 1-in-a-100 year threshold, let's say 1-in-a-101-year flood you are not in a flood risk. So often there is a small amount of conflict where a customer may go to the council and say am I at flood risk, and they will say well according to our flood map you are out of the 1% AEP flood risk, and yet they come to an insurance industry and they may say that you are in a low flood risk. They would say no my council says I am at zero flood risk. [But] they didn't say that. They say it is not a 1% AEP risk (Insurance Group, interview 1, January 2014).

There is also an understanding that if development is approved in certain floodplain regions, appropriate measures have already been taken to mitigate flood risks? Since the Development Control Plans do not apply to regions of low flood risk which gives the signal that the region is flood risk free zone. According to the interviewees of the Insurance Group, such deductive information provides mixed signals to society and hence creates discrepancy in the information that council provides to society and the information that insurance companies share with individuals.

Discussions with a leading national organisation, responsible for consolidating information on risks for member insurance companies, have provided additional insights to some of the challenges presented in acquiring flood risk information. The interviews revealed that the barriers to consistent data and information exchange exist due to the absence of state-level coordination. On this note, one of the participants indicated that:

> …there is no consistent set of rules! There is not even a consistent set of - 'this is how you do a flood study'. They [the NSW Councils] don't even have to report back to the state agency. For every other state in Australia there is a single agency that coordinates it all...There is no requirement that the study should be published in a consistent way or given back to the state or revealed to the community or given to insurers, it is all very ado (Insurance Group, interview 8, March 2014).

While speaking on the experience of data collection with other state agencies, the interviewees argued that the situation in the NSW varies with each council. Due to the absence of a state agency, the sharing of information relies on the discretion of individual councils. The representatives found that some councils are very willing to share information while others simply choose not to share or would share on conditions of selling the data. They further elaborated that unlike other states, the Office of Environment and Heritage and the State Emergency Services do not have a legislative role to collect, distribute and publish flood risk data. In contrast, Queensland and Victoria states have a ministerial responsibility to ensure that appropriate actions are taken. In Queensland, Victoria and even Western Australia, there are designated state agencies that all councils are required to provide flood maps to. There are also specific requirements for submitting such flood maps supported by information on size, shape density and methodology. This has facilitated insurance companies' in data collection from these states where new information is updated and automatically centralised (Insurance Group, interviews 1 and 9, January & March 2014, respectively).

The need for using updated flood risk information cannot be undermined. For insurance purposes, it has a very strong economic dimension to it – with little to no information on flood risks, worst case scenarios are used to set premium costs. According to an interviewee *When you bring in a detailed flood surface it instantly and generally lowers the flood risk for everybody....[with reference to Growth Centres] we have got nothing for Western Sydney, for a start we would like to get precinct by precinct information. Liverpool is the only one that has provided flood maps. Everyone is paying top dollar for their premium and they shouldn't be* (Insurance Group, interview 9, March 2014). Information generally provided to the insurers by the councils is publicly available i.e., documents that can be downloaded from the website. Such documents usually have a map but what the insurers need is the GIS data behind it.

These insights demonstrate an important challenge, i.e., inconsistency of the available data and the barriers of accessing data. There are, however, other types of barriers to data sharing based on the varying degree of expectations that organisations involved in risk assessments have of others. For instance, information sharing among insurance companies was also seen as a challenge. There are mixed views about sharing information to gain a common understanding. Where one interviewee from the Insurance Group emphasised the critical need of data sharing, another saw it as a devaluation of properties of potential customers and preferred to maintain such information as confidential. Of the five insurance companies contacted for interviews, two refused to discuss their FRM and data gathering, on grounds of confidentiality.

A brief telephone conversation with another interviewee, who refused to participate in a detailed interview, argued that the councils are unwilling to provide updated information because it will result in exposing those flood risk areas which have not been marked as such in the past. Such information if shared with the insurance companies will result in implementing appropriate premiums reflecting ‘true risks’ which may be higher than the current rates (Insurance Group, pers. communication, 3 January 2014).

An interviewee from SA2, who works closely with councils in floodplain management, indicated that not all councils favour sharing information with the insurance companies. The reasons for their apprehensions in sharing information may vary, some are comfortable in sharing data whereas others which are targeted for a large number of future development, and are highly flood prone regions, are not willing to share their flood risk information (SA2, interview 11, February 2014).

The difficulties faced by insurers in acquiring flood risk data from councils in the NSW, was discussed with some council members. A member involved in strategic planning in one of the councils in the region identified a number of issues in sharing of flood risk information. Primarily, at an internal staff level, the accuracy of the data and extant of assessment could be a reason. At a council level it’s a political issue of acceptance of the data provided and at community level, acceptability in the light of local knowledge, past experience, perceptions about flood in their region and scepticism about the source of information such as the use of models (Council Group, interview 15, March 2014). Such barriers prevent some councils from having a conservative approach in terms of widely sharing flood risk information. The council group representatives felt little need to develop information beyond the 1% AEP criteria set by government for development interventions. As one of the Council Group representative stated:

> Insurance companies should be realistic. They need to assess what is the risk of that particular event so when we say this particular property is 100-year-flood free, in our opinion, any flood above 100 year...it’s chances is extremely, extremely low and they should not charge for that (Council Group, interview 3, January 2014).

The council representative also believed that the insurance companies’ database is not updated as regularly as possible. One of the reasons for this, which the interviewee highlighted, was the issues of rapid development. With development, new information is generated which changes the level of flood risks. Such information, according to Council Group representatives, is not readily updated by the insurance companies as it might lead to low premiums as risks are reduced, hence more often than not insurers avoid such information and revise their pricing accordingly (Council Group, interview 10, January 2014).

The above discrepancies in views as expressed by representative of the insurance and council groups are the crux of the problem of implementing a coordinated information sharing program. With conflicting views, it is difficult to harness a level of confidence and trust among organisations responsible for flood risk assessment. Ross et al. (2009) voiced similar views, stating that trust and collaboration are essential and the lack of it is 'detrimental to the delivery of an effective flood risk management service' (pp. 853).

Related to this challenge is the lack of understanding about the roles and responsibilities of FRM stakeholders. A discussion with a former, Committee Member of the Hawkesbury-Nepean Floodplain Management Strategy, 1997, highlighted the issue of complexity in the way organisations perceive flood risks as per their organisational objectives. According to this interviewee, flood risk assessment may mean different things to different agencies (SA3, interview 17, February 2014). For instance, representatives from the Insurance Group hold the society, government and developers responsible for identifying and mitigating risks. As expressed in the following statements:

> ... If there are houses on the floodplains...they are going to flood, there should be a project or program of work to address the issue so if you build on floodplains, council release the land, [and] developers build houses on it' (Insurance Group, interview 1, January 2014).
>
> ...we have no part to play in putting their house there; it is the council and the individual. The insurer is basically asked to cover the risk when it is actually been put there we don't have any role in deciding where the property should be located or and what it is built from. The builders are actually involved in lobbying with the council to build properties in these areas (Insurance Group, interview 8, January 2014).

In contrast, Real-Estate representatives perceive themselves as temporary custodians of land until development is ensued and handed to the owners. They expressed that agencies with long-term interactions with communities like insurance groups, councils and others have far greater FRM responsibilities. Interviewees were also asked about their views on who they think has the core FRM responsibility. The majority were in agreement that the responsibility of risk management lies with the individual property owner since they are the ones responsible for purchasing a property. They should get sufficient information from agencies prior to purchasing. This view point sits in contrast with the community survey conducted with the residents of the Hawkesbury-Nepean in the subsequent chapter (Chapter 7) and also with the studies conducted to gauge community perspectives particularly on floods or climate change adaptation. Various community groups in different regions of Australia, including the Hawkesbury-Nepean region considered government entities as being responsible for providing protection against floods and reducing flood risks or natural hazards, (Godber 2002; Becker et al 2008; Reser et al 2010; Molino & Karwaj 2012. & Box et al. 2013). The assumption has always been that if the land is approved for development it should be flood safe.

Such misconceptions about responsibilities highlight the need for close coordination between different groups involved in FRM. There is a need for close dialogue and clear communication of roles and expectations of each other. Ross (et al 2009) suggest that collaboration with stakeholders and community groups should be at the heart of any flood risk management strategy as flood risk management depends on the performance of multiple agencies and communities.

The issues related to coordinated scientific information and data sharing is not a unique problem in FRM in NSW where a large number of agencies are involved. Scholars have highlighted this challenge in Australia and elsewhere (Fanning 2012). Morss et al. (2005) discusses the interaction of scientific information with societal decision-making in FRM. Morss highlighted a number of issues that run counter to some of the discussions in this chapter, such as the challenges of the diverse and intertwined nature of decision makers; and the challenges presented in decision-making due to the difference in perspectives and responses between managers, practitioners and scientists. Issues of uncoordinated data collection programs in the US in water resource management have been highlighted by Braden et al (2014). Sufficient means to model risk have been identified as an issue of inadequate flood maps in Australia (Carter 2012). Restriction of data sharing by administrative boundary in FRM in the UK has been discussed by Flood Risk Management (ICE 2011). Issues of withholding information on flood risk have been highlighted by Insurance Australia Group (Wilkins 2011). Issues of data sharing between councils and insurances have been presented in public forums (Fanning 2012).

Nonetheless, extensive discussions on the issue of coordinating information to cater to multiple needs require that steps have to be taken to achieve a more consistent process. Examples of national-scale databases were discussed during the interviews. A state-level database is being compiled by one of the federal agencies in an attempt to centralised information on floods. The database is part of a 4-year project that commenced in 2012. The need for a national-scale database was recommended from the National Disaster Insurance

Review. One of the objectives was to provide an avenue that can serve to connect information on floods available within different jurisdictions across Australia (ISA, interview 18, May 2014). However, the utility of such a database depends on active participation of jurisdictions. One of the greatest challenges in getting such support is the licensing of data and its open access to all (ISA, interview 18, May 2014). Where the ISA aims to provide transparent data to enable easy access of information to public and insurance companies, some jurisdictions, especially in the Hawkesbury-Nepean region, are wary of transferring information into the public domain. Thus, the utility of data available at this level can only be valuable to others if full there is full cooperation from all jurisdictions, especially in terms of data provision. The current utility of these data for flood risk assessment purposes appears to be limited. It hasn't been extensively explored in this study, but references during interviews indicated its lack of utility.

> '[the program] is up and running but there is no data. None of the state government has provided any data. The councils are saying that if my data needs to go they have to pay me for it. So the whole thing is based on good will' (Insurance Group, interview 9, March 2014).

With the exception of one representative from the Insurance Group, no other interviewee identified this national-level data source as a primary or secondary source of acquiring information for flood risks. In most cases the expectations were to get useful information from the councils rather than any other source.

One of the reasons for its lack of use was stated by a representative of a national level insurance group:

> We don't use any information from GeoSciences and for Geofabric, we use it for other hazards. For flood [information] we only use the council data and the reason is that it is such an emotive issue tied into development controls and mitigation controls that [there is a need to provide] consistent information to the individual. We are using the same data that is provided by the local council so there is no gap created by misinformation (Insurance Group, interview 9, March 2014).

One of the other reasons could be that the information available with regard to Geographical Information System (GIS) data mostly shows flood extent whereas agencies such as insurance companies require information on flood depth (ISA, interview 18, May 2014).

Interviews indicated that there existed a general understanding about the value of consolidated and centralised information and datasets accessible to everyone involved. A brief review resulted in identifying a number of databases that exist to provide certain degree of geospatial information that can be used to assess conditions of natural assets at broad-scale. More particularly, at state-level, projects such as the National Flood Information Project, the NSW Flood Database focuses on providing information pertaining to floods. These databases are being developed in the context of providing a broad-scale vision of flooding issues and their management to make informed decisions on a larger scale as opposed to local level flood planning.

> The database is the key to trying to make information available to the government to make informed decisions so state government gets information from local government and then gets considered in state government decision making (SA2, interview 12, March 2014).

The interviews revealed that there is little clarity on how the national database would link with state-level databases. This lack of certainty was not only expressed by interviewees involved in its development but also among interviewees from the other agencies (ISA, interview 19, January 2014). The Council Group did not see a direct benefit of such database (Council Group, interview 15, March 2014); and participants from SA1 and SA2 were not sure about how the state-level flood database will be linked with the national database (SA1, interview 5, January 2014; SA2, interview 11 and 12, January & March 2014). The Insurance Group has also expressed concern about the duplication of information at state and national levels (Insurance Group, interview 7, January 2014). In terms of access and utility, issues of licensing, maintenance of data and funding requirements were some other challenges discussed.

An initiative to develop state-level database is a step forward for FRM, especially in its promise to provide a readily available and more centralised source of information for all. At the same time, however, there is a need to develop a common understanding among stakeholders about how they can contribute towards this database.

6.7. Conclusions

This chapter presents some of the management issues that serve as potential barriers for a more comprehensive, cross boundary, catchment-scale coordinated effort for FRM in the Hawkesbury-Nepean region. It highlights gaps in the application of an existing adaptive process of FRM in the catchment.

In summary, implementation of an adaptive FRM needs to recognise the complexity presented in a multi-tiered mechanism of management. Agencies are primarily driven by their own respective objectives, and their different responsibilities have created a mesh of uncoordinated attempts to manage and assess flood risks.

The extension of FRM beyond the realms of governments signifies the need for more strategic coordination. The absence of a forum or dialogue between different groups is one of the many causes for the lack of understanding about data requirements, type of data available and the objectives of information exchange with different agencies, both within and outside the government institution. The absence of a single, comprehensive, open-source database creates a missing, yet vital, link between updated information and ready utilisation of data.

A catchment-scale approach may present an opportunity to consolidate individual efforts more effectively. As an interviewee states that *it is fair to say that there is a grim realisation that we need a much more integrated approach* (SA3, interview, 4 December 2014). There is, therefore, a need to look at integrated models and approaches in other Australian states to derive lessons to bridge the gap that the current governance of FRM presents in the Hawkesbury-Nepean region. There is also a need for alignment of scales at which flood risks are assessed and managed from local project levels to a catchment-scale. Issues of scale mismatch have been discussed in the literature earlier to highlight the problems of resource management (Cash et al. 2006; Moss & Newig 2010; Wentworth 2014). In addition, lack of understanding of risks and perception on risk management can hinder the development of adaptive capacities among different risk assessors, policy implementers and decision-makers. Birkholz et al. 2014 highlights the critical need to understanding risks and perceptions associated with risks as a critical driver for implementing adaptive processes to harness SES resilience.

Chapter 7: Community Perceptions on FRM—Outcomes of a Survey in the Hawkesbury-Nepean region

Masud, S, Merson, J & Robinson, FD 2016, 'Factors influencing communities' flood risk perceptions—Outcome of a community survey in the Hawkesbury-Nepean Catchment, Australia,' *Australasian Journal of Environmental Management*, (Under review for publication)

7.1. Introduction

In the previous chapter, perceptions of experts involved in flood management were taken into account. A few aspects identified a common view of the expectations reflected by these professionals with regard to flood risk management. More particularly, flood information was considered to be a top-down process, insofar that communities were identified as responsible parties to acquire flood risk information about their property. In addition, issues of access to technical and other information were highlighted and the need for catchmentisation was discussed to assess the regional or total catchment management opportunities for the Hawkesbury-Nepean.

An integral part of flood management is the wide range of communities that reside in these floodplains. These communities are positively or negatively affected by the decisions implemented by policy makers at federal, state and local levels. Consequently, it is imperative to explore the current level of understanding of communities about flood risks and their management. The Department of Primary Industries (NSW Office of Water (2014) conducted a preliminary review to examine the problem of floods risks in the Hawkesbury-Nepean catchment. The review indicated that there is a need to enhance community education on flood risk and response. This chapter focuses primarily on residents' perception of flood risks and their expectations of flood management authorities. Chapter 6 concluded that there is a need for inter-agency coordination to improve risk communication in the Hawkesbury-Nepean catchment. Chapter 7 assesses the social dimensions of flood risks through a community survey. One of the objectives of this chapter was to analyse the perceptions of communities on flood risks as more often precautionary behaviour is based on how an individual perceives risks. Another purpose of this is to highlight the difference in perceptions between policy/decision makers and communities. This would have strong implications for the effectiveness of flood risk management and adaptation of precautionary actions to reduce risks and improve planning and development discourses in the region.

7.2. Social dimensions of risks

According to Beck (1992), modernisation and advancement in technology has created a society shaped by individualism. While there are arguably many benefits to be gained from this form of social theory, it can be said that individualisation has delivered an increased level of risk to society; "The support networks of family for example are replaced by reliance on one's own ingenuity to develop a personal support network, while economic security provided by the nuclear family is replaced by individual responsibility" (Jarvis 2007, p. 25). Where modernity has created opportunities, at the same time, increasingly it is faced with social, political, ecological and individual risk (Jarvis 2007, p.28). In order to curtail natural and man-made risks it is important to understand how risks are perceived by modern society. Section 2.5.4 of Chapter 2 establishes why it is important to assess risk perceptions for managing risk in an ever changing and dynamic society. Furthermore, Wood et al. 2012, explain that it is important to have an integrated approach to risk management where decision makers address stakeholder perspectives. It is a critical factor for an effective risk management policy (Wood et al. 2012). In most cases, the human dimensions to disaster management are identified but the process of 'how to' integrate interests, knowledge and values of stakeholders remains underdeveloped (Wood et al. 2012, p.1350).

Extensive research evidence exists, worldwide, that describes a number of factors that can influence communities' perceptions of risk and their subsequent response to disaster mitigation. Ho et al. 2008, explain that characteristics of flood victims can influence their perception to risks as found in a study in Taiwan where gender and experience of living through a previous disaster influences the way locals in a disaster-prone region rate risks to floods and other natural disasters. A comparison of people's perception about flood risk and expert's assessment in Switzerland also highlights that risk perception and its correlation to the expert's assessment varies across regions. According to Siegrist and Gutscher (2006, p. 977) this difference in risk perception can account for the inconsistency in communicating flood risk information to the public. Such inconsistency can also be because people's perception strongly depends on their own experiences with flooding. Zaalber et al. (2009) argue that people who have experienced flooding previously are more likely to perceive the consequences of future flooding to be more severe and consider themselves to be more vulnerable to future floods. Denial and communication of risks (Grothmann & Resusswig 2006), severity of past flood events, time-lapse between the last flood event (Pollard 2013, Cradduck 2014), communication of public risk (Lindell and Prater 2003) and dependency on public institutions (Manock et al. 2013) are some other factors that can influence the way communities perceive risks. A particular risk can be seen differently by different people.

Harding, Hendriks and Faruqi (2009) argue that more often, evaluating risk perceptions are ignored in environmental decision-making. They further elaborate that disparity in perceptions is often due to public ignorance of the science regarding an issue (Harding, Hendriks & Faruqi 2009, p.243). Thus public definitions of risk may involve different parameters than those expounded by technical risk assessors.

The floodplains of the Hawkesbury-Nepean have been cleared for development. Estimates show that currently 73,000 people are residing in the catchment in floodprone areas with an increase in population projected for the coming decades (NSW Office of Water 2014). New development plans indicate that there will be more housing developed in the two regions identified as the North-West and the South-West Growth centres, West of Sydney (NSW Planning and Infrastructure 2012). A detailed account of the proposed development has been discussed in Chapter 5. The North West Growth Centres are part of the Richmond and Windsor floodplains. Approximately 180,000 dwellings are planned in these growth centres with an investment of $7.5 billion in infrastructure (Smart Consulting 2013). Hence a flood event similar to the 2010-2011 flood in Queensland could impact the entire NSW economy by disrupting transport routes, facilities and increasing risk to life and property (NSW Planning and Infrastructure 2012).

The largest flood in the region's history, the 1867 flood (Sydney Catchment Authority 2010) reached a level that was three metres higher than the current development and even two metres higher than the flood planning levels which were designated as 1% AEP (1-in-a-100-year flood) (NSW Office of Water 2014). The expected flood height level of maximum floods is expected to be several metres higher than the flood planning level in the suburb of Windsor. Bewsher et al. (2002), elaborate that statistics by Sydney Water indicate that a maximum flood incident would completely inundate the cities of Richmond and Windsor and would cover an area of 300 km^2. The estimated economic loss under the 1% AEP flood is estimated to be $1.5-2.5 billion dollars (Ribbons 1997). Regions of Richmond, Windsor, Penrith and other surrounds are increasingly growing urban centres and are at risk to Hawkesbury-Nepean flooding. Hence episodes of heavy rainfall over a period of just a few days can cause severe flooding in the Hawkesbury-Nepean region (Gillespie 2002). According to the Hawkesbury Floodplain Risk Management Study and Plan (HFRMS&P) report (Hawkesbury City Council 2012) Richmond, North Richmond and Windsor regions have been characterised as class C and D, indicating that evacuation risk during a flood considering current development, is rated as serious to extreme in these regions.

The following are some pictures of flooding in the various regions of the Hawkesbury-Nepean during the 2012 heavy rainfall events.

Figure 7.1: Hawkesbury River rising during rains in 2012 in Windsor (Source: Farah News Online 2012)

Figure 7.2: The submerged Yarramundi Bridge on Springwood Rd, Richmond (Source: The Staff Writers, NEWS, 2012)

The community survey conducted as part of this thesis is in the 1% AEP level. A 1% AEP flood can have high to moderate flood risks depending on flood depths in a particular area. For the purpose of this research, selected regions within Windsor, North Richmond and Richmond were identified as extreme (North Richmond), or high to medium (Windsor, Richmond) flood risks (NSW Planning and Infrastructure 2012). Also, areas within Penrith and the Emu Plains region that were in a 1% AEP were considered.

7.3. Method of inquiry

In order to explore the perceptions of communities, a community survey was conducted in the Hawkesbury-Nepean catchment. The survey questionnaire comprised 19 questions divided into six categories which dealt with specific aspects of flood management. The first section was based on general information to determine the community profile. Other sections were designed to identify the respondent's perception about flood risk to their property; their knowledge about Catchment Management Authorities and Local Land Services; their perception on who should determine acceptable flood risks for their region; and their thoughts about who they think are responsible for providing flood-related information to the public. The last section of the survey was designed to gauge community understanding about the scale of the Hawkesbury-Nepean catchment and their views on having a regional body for management of the entire catchment.

The survey package comprised an introductory letter describing the purpose of the survey and ethical and confidential aspects of participation. Several modes of survey distribution were employed to ensure maximum participation and receive responses from different floodplain regions of the catchment. Survey distribution was carried out via door-to-door delivery, an online launch of the survey and face-to-face conduct of the survey. A total of 540 surveys were distributed via door-to-door to the residents of Windsor, North Richmond, Emu Plains and Penrith regions. For each door-to-door survey, a return pre-paid envelope was also provided and the residents were requested to return the completed questionnaire via the pre-paid envelope. The survey forms were distributed to residents residing within a distance of one kilometre or less from the Nepean or Hawkesbury Rivers. In the Penrith suburb, 50 surveys were distributed. The distribution of surveys was as follows: Emu Plains (150) Windsor (158) and North Richmond (182).

In addition to the door-to-door surveys, approximately 81 face-to-face surveys were conducted. In Penrith, 22 such surveys were conducted with the locals from the Hawkesbury Organic Farm market and also with commuters at the Penrith train station. In Windsor, locals visiting the Windsor Art Gallery and pedestrians at Howe Park were approached and another 22 surveys were conducted. In Richmond 37 face-to-face surveys were completed by locals visiting the Sunday Market and the children's playground at Richmond Park. It should be noted that proper care was given not to influence respondents' opinions and to avoid any bias during the face-to-face interviews. In most cases the respondents filled out the survey by themselves while in certain cases the responses were recorded by the interviewer after the multiple choice questions and the provided options were read aloud.

An online version of the survey was also launched to increase participation further. The online version was sent to Landcare groups in the Penrith and Hawkesbury LGAs and also to the Hawkesbury Environmental Network (HEN). The survey was also published on Facebook pages of HEN, *Greater Sydney Hawkesbury-Nepean Landcare*, *Redbank Recovery* and *Living in the Hawkesbury*. Also, the survey link was published in the monthly Landcare newsletter, reaching another 700 Landcare members in the region.

A total of 178 responses were received from all the survey distribution sources and 81 surveys were completed via face-to-face. From the 540 surveys distributed via post, only 14% of the surveys were returned (i.e., 75 completed surveys). Online survey statistics show that about 103 people clicked through the surveys, 21 completed the survey and 9 were partially completed. From the total of 178 surveys, 172 survey responses have been analysed in this chapter as additional responses were received at a much later time when half of the analysis for this chapter had already been completed. The additional responses received were similar to the 172 that were analysed; hence, excluding them in the analysis did not have any impact on the findings. The sample size represents a small portion of the entire population in the research area; therefore, the response drawn from the survey should be considered as indicative and not conclusive.

Data were analysed through SPSS. Information was extracted via descriptive statistics by using frequencies, cross-tabulation and chi-square analysis.

The questionnaire was designed for the resident communities of Hawkesbury-Nepean catchment. Similar surveys conducted in the region were reviewed to identify relevant questions (see Reser et al. 2010; Becker et al. 2008). The questionnaire design was developed in context with Bird's (2009) analysis of the current practices of developing questionnaires for recording perceptions of the public regarding natural disasters. The section of the questionnaire which has been analysed for this paper comprised mostly closed questions measuring nominal and ordinal characteristics (Sarantakos 2006).

To produce reliable results, the questions were non-technical and simple in wording (see Payne 2014). In line with Patton's (1990) categorisation of possible question designs, two categories of question types were used for this research study; namely, classification and perception type questions.

A pilot study was conducted in the Penrith region. A total of 25 surveys were received. The questionnaire was revised accordingly.

7.4. Limitations of the survey

This research attempts to understand factors that could potentially influence perceptions that drive residents of flood-prone regions to take action or inaction towards risk. It acknowledges the limitation that respondent's perception can be assessed through a standardised predefined set of questions. The use of alternative methods to define this correlation can also provide additional in-depth understanding of perceptions. For instance, presenting different scenarios to draw attention to flood risks has been used for community risk perception analysis (Molino & Karwaj 2012) Use of photographs of historical floods to determine residents' acceptable level of risk have provided useful insights about risk perceptions and degree of acceptance of risks (Keller et al. 2006; Becker et al. 2008; Molino & Karwaj 2012). There is, however, a need to pursue further studies to determine the influence of a combination of factors that can create individual perceptions towards a particular risk.

7.4. Respondents' profile

A total of 172 responses were analysed from the selected communities. Gender distribution indicated that more than 50 percent of the respondents were female. Hence the male/female ratio was 71:100, respectively. Age group variable was divided into five categories. The majority of the respondents were in the age bracket of 56 years and above, representing 77 respondents (45%) from this category. The lowest responses were received from the youngest age group which had 14 respondents (8%) (see Table 7.1).

Table 7.1 Frequency per age category

	Age Groups	Frequency	Percent
Valid	18-25	14	8.1
	25-35	18	10.5
	36-45	28	16.3
	46-55	31	18.0
	56 or older	77	44.8
Total		168	97.7
Missing value		4	2.3
Grand total		172	100.0

The respondents were divided into six occupational groups (see Figure 7.3 below). The 'Others' category had respondents that did not fit into any of the predefined categories.

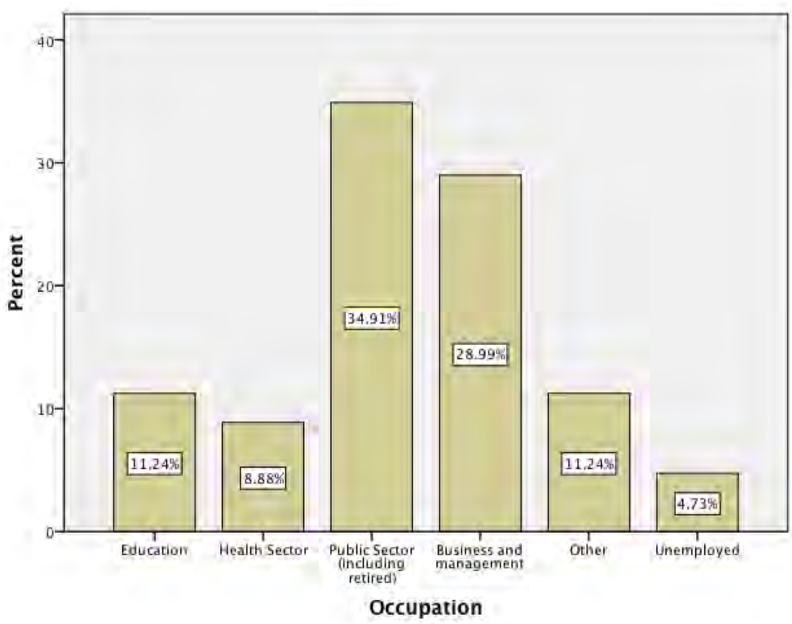


Figure 7.3: Respondents' categories by profession

On average, the duration of residency in the area for these respondents was 19 years with a minimum and maximum range of 1 to 76 years, respectively. The majority of responses were, therefore, received from older retired community groups with relatively more exposure and experience of living in the Hawkesbury-Nepean for nearly two decades.

The maximum number of responses was received from the Windsor region (32%) whereas Richmond provided 15% of the feedback closely followed by the suburbs of Penrith and Emu Plains (13%). Twelve percent of the respondents were from North Richmond and 5% were from suburbs surrounding Richmond. The remaining 25% were from a number of suburbs, each having 1% or less of the respondents from these regions. Some of these suburbs include Cranebrook, Castlereagh, Mulgoa, Riverstone, Doonside, Yellow Rock near Emu Plains and fewer than 2% from suburbs near Blacktown. This also included respondents who participated in the face-to-face surveys or via the online survey, Facebook Pages, Landcare groups and HEN members.

7.5. Survey results and discussions

The survey results and discussions are divided into two main categories. The first section of the analyses explores factors that could influence perceptions of flood risk to property. The second section examines the difference in perceptions and expectations of communities in managing flood risks.

7.5.1. Perception on flood risks to property

Perceptions of risk to property were analysed and cross-tabulated with duration of living, proximity of the property to a major river/water body, and gender, to determine any correlations.

The respondents were asked to rate their property in terms of flood risks. The question had four options: High Flood Risk (HFR); Moderate to Low Flood Risk (M-LFR); No Flood Risk (NFR) and No Flood Risk Awareness (NFRA). The responses received were divided into two categories: **Category A** represented participants living within one kilometre from the Hawkesbury-Nepean Rivers and **Category B** comprised participants who resided further away from the rivers or a major water body source in the floodplain (see Figure 7.4, below).

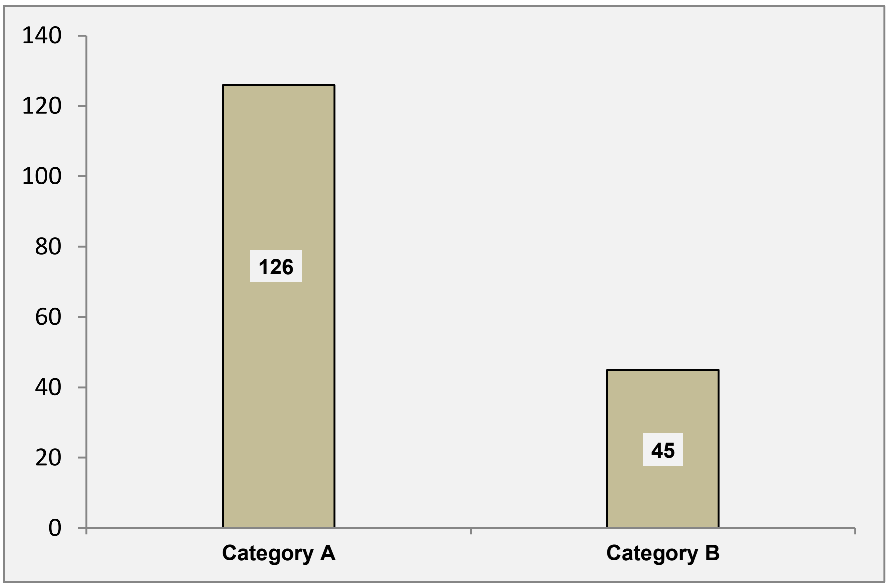


Figure 7.4. Proximity to the Rivers

Out of the 172 respondents, a total of 171 responded to this question. Of these, 126 reside within a one kilometre distance while 45 respondents lived further away. The largest portion of the respondents, (39%) identified their property under NFR, 35% rated their property as M-LFR and only 15% as HFR. The remaining 11% expressed no awareness of flood risks to their property. The bulk of these responses came from people who had been residing in the area for less than 20 years. All the respondents in the survey were residing in the 100-year flood zone or in a Probable Maximum Flood range (Hawkesbury City Council 2012; Morrison & Molino 2012).

Previous research indicates a number of reasons that can result in false perceptions or reduced risks towards floods. Cradduck (2014, p. 2) states that the “Australian population is generally aware of ‘natural hazards’, their understanding of water-related risks, however, may not be as good”. Lindell and Prater (2003, p.182) suggest that people tend to have ‘optimistic bias’ and ignore low probability events or think of them occurring far in the future.

Correlation between flood risk to property and duration of living

An analysis was carried out to observe if there is any correlation to an individual’s perception about flood risk to their property and to the number of years they had been living in the area. The ‘Living in the Area’ category was divided into four categorical timelines (see Table 7.2).

The data received had a wide range of experiences of residents living in the study area. For analysis two main groups were identified. The first analysis was applied to only those individuals residing within one kilometre of the Rivers (Category I) and then an additional analysis was carried out to include all the respondents (Category II).

From the 126 respondents living within a one kilometre distance (Category I) to the Hawkesbury Nepean Rivers, 118 of them had been living in the area between 1 to 40 years. Out of these 118, 31% of them were living in the catchment for 10 years or less, whereas 27% of the respondents had lived between 11-20 years and 21-40 years. The fourth category, representing individuals living in the area between 41-80 years, constituted 8% of the respondents. Hence the highest population of residents living within a one kilometre radius of the Rivers has moved recently within a decade in this study.

A significant portion of the residents, living within 1-km rated their property as M-LFR (40%) followed by NFR (25%) as a second highest rating of risk to property with only 20% identifying their property as high risks (Table 7.2). There were, however, differences in-between categories. It was observed that the flood risk to property rating changed as the duration of living increased. Respondents relatively new to the area indicated a lower percentage of their properties as HFR (15%), in comparison, individuals living for more than 40 years in the region indicated the highest percentage of their properties under HFR (40%).

This may also explain why the majority of the respondents have rated their property under moderate to low or no flood risk to property as a major chunk of the respondents have not lived in the area long enough to experience large floods or frequent recurrence of floods in recent years. According to Engineers Australia (2015), communities residing in areas where floods have not occurred in recent times will generally have a low perception of flood risks. This may also explain why a significant portion (40%, see Table 7.2) of the respondents have rated their property under moderate to low, or no flood risk to property.

Table 7.2. Category I - Flood risk to property and duration of living (Proximity 1 km)

Duration of living in the suburb		**Flood risk to property**				**Total**
		HFR	**M-LFR**	**NFR**	**NFRA**	
10 years or less	Count	6	17	8	8	39
	%	15.4%	43.6%	20.5%	20.5%	100.0%
11-20 years	Count	8	15	10	2	35
	%	22.9%	42.9%	28.6%	5.7%	100.0%
21-40 years	Count	6	13	10	5	34
	%	17.6%	38.2%	29.4%	14.7%	100.0%
41-80 years	Count	4	2	2	2	10
	%	40.0%	20.0%	20.0%	20.0%	100.0%
Total	Count	24	47	30	17	118
	%	20.3%	39.8%	25.4%	14.4%	100.0%
HFR: High Flood Risk, **M-LFR:** Moderate to Low Flood Risks, **NFR:** No Flood Risks, **NFRA:** No Flood Risk Awareness.						

The following are some of the respondents' comments associating low risk perceptions with duration of living.

> 'It has been a long time since 1990s—since there was a major flood' (Windsor Resident 9, 22 July 2014).
>
> 'After 23 years with no flood do you really expect any action [from the people]' (Windsor Resident 4, 18 July 2014).

Overall flood risk perception to property and duration of living—including distance of 1 km and beyond

Under the overall category, which includes all respondents residing within and outside a one kilometre radius (Category II, Table 7.3), similar results to those related to Category 1 were observed. Consequently, the lowest percentage of property under HFR was represented by people relatively new to the area and accounted for 12%; whereas, the highest percentage was represented by people living in the area for more than 40 years which accounted for 31% which was slightly less than the 40% represented by the people living in close proximity to the river under Category I (see Table 7.3 for details).

Table 7.3. Category II - Flood risk to property and duration of living (overall)

Duration of living in the suburb		**Flood risk to property**				**Total**
		HFR	**M-LFR**	**NFR**	**NFRA**	
10 years or less	Count	6	20	18	8	52
	%	11.5%	38.5%	34.6%	15.4%	100.0%
11-20 years	Count	8	19	18	4	49
	%	16.3%	38.8%	36.7%	8.2%	100.0%
21-40 years	Count	6	15	20	5	46
	%	13.0%	32.6%	43.5%	10.9%	100.0%
41-80 years	Count	4	2	5	2	13
	%	30.8%	15.4%	38.5%	15.4%	100.0%
Total	Count	24	56	61	19	160
	%	15.0%	35.0%	38.1%	11.9%	100.0%
HFR: High Flood Risk, **M-LFR:** Moderate to Low Flood Risks, **NFR:** No Flood Risks, **NFRA:** No Flood Risk Awareness.						

A Chi-square test indicates a significant relationship between duration of living and perception of risk to properties showing P value of .05. This suggests that those living in the area the shortest time had lower perceptions of risk in general. Those that lived in the area the longest were polarized on flood risk – presumably dependent upon their lived experience of floods and their exact location in relation to those past floods.

A critical difference observed in Category II was that the percentage of rating properties under NFR also increased in respondents who had been living in the area for the longest duration. It increased from 20% in Category I to 39% in Category II within the same 'duration of living in the area' group. It is likely that the longer a resident has lived without experiencing a major flood and the further away (i.e., not within an immediate proximity of a major water body), the chance of perceiving their property as having NFR increases. It also may be due to the fact that the majority of the older generations were included in the 'overall duration of living in the area' category. The correlation between duration and risk perception coincides with previous studies conducted by Lindell and Hwang 2008, Burningham et al. 2008; Nyakundi et al. 2010.

Correlation between proximity and risk to property

From the total of 170 respondents who provided feedback to this question, 20% of the property owners residing close to the river indicated their properties as HFR; however, a slightly higher percentage (26%) within the same category rated their property as NFR (Table 7.4, below). Tellingly, the majority of those living beyond one kilometre from the river but still in the 100-year flood zone perceived their property as having NFR (76%).

Table 7.4: Correlation of Proximity to water body and Flood risk to property

Proximity (1 km distance)			**Flood risk to property**				**Total**
			HFR	**M-LFR**	**NFR**	**NFRA**	
Category I	**Yes**	Count	25	51	32	17	125
		%	20.0%	40.8%	25.6%	13.6%	100.0%
Category II	**No**	Count	0	9	34	2	45
		%	0.0%	20.0%	75.6%	4.4%	100.0%
Total		Count	25	60	66	19	170
		%	14.7%	35.3%	38.8%	11.2%	100.0%
HFR: High Flood Risk, **M-LFR:** Moderate to Low Flood Risks, **NFR:** No Flood Risks, **NFRA:** No Flood Risk Awareness.							

A likely explanation for a higher level of NFR perception is that the participants from the Richmond region who chose to respond to this survey had moderate levels of flood risk to their property (NSW Planning and Infrastructure 2012). The majority, however, including Richmond residents indicating their property as NFR represents a false perception of flood risks in the region. Moderate flood risks may likely be perceived as NFR. Morrison and Molino (2012) argue that maintaining a flood planning level to 1% AEP can falsely communicate that the region is flood-safe. Grothmann and Reusswig (2006) explain that flood-proofing measures are likely to de-motivate precautionary behaviour creating a lower risk perception.

In addition, the group living away from the rivers in Category II had a lower flood risk rating (from 0% for HFR to 20% for M-LFR) than Category I. Nearly 41% of Category I respondents and 20% of the Category II respondents had selected M-LFR for their property. This shows that in comparison, almost double the percentage of people living in close proximity considered their property to be at risk to floods compared to residents living beyond one kilometre. Since the survey did not ask whether the respondents assessment of flood risk to their property was based on personal knowledge or was derived from a hazard map or other more technical source of information, it is difficult to determine the reason for the majority of residents living in close proximity to the river to rate their property as M-LFR. One of the explanations for this difference in property risk assessment could be based on the uneven ground surface level. A general observation while delivering the surveys to designated areas was the uneven surface of the residential areas, where a slight ground elevation would place some properties at a higher point than others and might result in the assessment of the property as having moderate to low flood risk instead of a high flood risk compared to an adjacent property, that was built at a lower elevation.

The risk perception to property showed mixed results when compared to previous studies. In summary, the relationship between proximity to risk perceptions coincides with previous research; however, further analysis of these variables indicates that statistically the dependence is marginally significant with the P value greater than 0.01. Some of the literature conflicts with the causal relationship between proximity and risk perception (Palm et al. 1990; Mileti & Darlington 1997). Lendell and Hwang (2008) argue that there might be other factors at play that justify these conflicting results. A discussion ensues on what other factors could have possibly influenced this correlation in the current study area.

Establishing a direct relationship between the proximity and perception of flood risk to property requires an additional examination of other factors. This also requires eliminating actual cases that have officially been rated as moderate to low risks to property which in this case is a small number, but potentially is able to influence the outcome of the overall perceptions. Pollard (2013, p. 5) identified six types of residents' perception and behaviours in relation to floods. One type of perception is the 'flood-proof by design' whereby a home with design immunity against a severe flood will be considered immune to flooding or 'flood-proof'. In the Hawkesbury-Nepean region, houses that fall under the 1% AEP require development controls such as freeboards above the 1% AEP flood. Hence, residents with flood-proof design are more likely to perceive their home as having no flood risks. Egan and Mcguirk (2000) also identify common misconceptions among the interviewees of the Hawkesbury-Nepean region pertaining to flood risks. These misconceptions were related to the reduced risks associated with the raising of the dam wall, reliance on public institutions for flood mitigation works and expectations that development is approved by the local government which may be interpreted as being flood-safe.

Further consideration is also required to the need to streamline the source on which residents based their risk perceptions. It was difficult to assess, through the current study, whether the assumption of the respondents about their property was based on the owners' self-assessment and personal experience or whether the source of information was based on information acquired from council, insurance companies or real-estate personnel.

From the 172 responses, 17 of the respondents were associated with a certain environmental group or society such as Landcare or HEN. Presumably, this association would potentially have increased the awareness of issues pertaining to the natural environment in the respondent's surrounds. However, in terms of flood risk perception about their own properties, the majority of the respondents (14) living within the one kilometre range of the river identified their property as under the moderate to low or no flood risk category. Five out of the total of 18 respondents in this category expressed not being aware of flood risk to their property. Not a single respondent in this particular category had identified their property under high risk. Harding and others (2009) explain that people tend to show more concern about issues that have an unknown but low risk compared to events that have a lower certainty of occurring but have a potentially higher risk. In this particular case, residents associated with a particular environmental group, more likely support a particular issue of environmental concern and perceive it as a greater risk, such as fire threats to natural forests or conservation of woodlands etc. than the uncertainty of a large flood impacting their region or property. As indicated by some respondents:

> [Community] inputs for fire makes more sense; not for flood risk (Penrith Resident 16, August 2014).
>
> I don't believe many people concern themselves with flood or flood risk. We are all highly conscious of bushfire risk and have evacuation plans as fire presents a more sudden and unpredictable risk. Whereas a flood (to me) seems to be more of a benign risk (Environmental Group 2, September 2014).

A low perception about flood risk from this particular group may also indicate their scepticism for the agency that communicates risks. Bickerstaff (2004) elaborates that, among other reasons, people's risk perception is influenced by the agencies that manage risk activities (e.g., government entities). Table 7.11, in a later section of this chapter provides details on the lack of trust respondent's expressed in government entities to manage floods.

Previous research indicates a number of reasons that can result in false perception of reduced risks towards floods. Meltsner (1979, cited in Lindell & Prater 2003) have noted that even long-term residents of a risk area may have little to no information about the hazard (p.128). Eleven percent of the 170 respondents indicated that they have no awareness or knowledge about the flood risks to their property. This percentage excluded those that were of the opinion that they don't require any flood information as they have sufficient knowledge based on their past experience of living in the area.

Pollard (2013) identified six types of residents' perception and behaviours in relation to floods. One type of perception is the 'flood-proof by design' (p. 5) whereby a home with a design immunity to a severe flood will be considered immune to flooding or 'flood-proof'. In the Hawkesbury-Nepean region, flood planning levels are based on 1% AEP. Houses that are outside the 1% AEP are considered to have low or no risks and do not require mitigation measures for flood-proofing. Houses that are in the 1% AEP zone require a freeboard, in most councils. Hence, the flood-proof design is more likely to indicate that homes are flood-safe with no risks to floods larger than 1% AEP. Grothmann and Reusswig (2006) also talk about the dependence of the people on public institutions. If the public authorities have protection barriers in place, such as dams or levees, the local perception will more likely de-motivate precautionary behaviour (p. 118). A 1% AEP may also send out the message that everything above this level is flood-safe (Morrison & Molino 2012).

Egan and Mcguirk (2000) also identify common misconceptions among the interviewees of the Hawkesbury-Nepean region pertaining to flood risks. These misconceptions related to reduced risks associated with the raising of the dam wall, reliance on public institutions for flood mitigation works and expectations that development is approved by the local government because it is flood-safe (p 40). Hence a number of factors could have influenced the relatively low risk perception of residents in the Hawkesbury-Nepean floodplains.

Correlation between age group and risk to property

In the current study, correlations between age and flood risk to property were examined. Perception about risk to property was found to increase with age, with the older generation representing a higher percentage of responses under HFR to property (about 20%). In comparison, HFR in the two youngest categories accounted for 0-11% and the middle age groups indicated 13-14% (Table 7.5). Fifty percent of the youngest age category

(18-25 age groups) believed they had NFR to their property, the highest percentage in the group. This is also the category that had the highest percentage of NFRA to their property (21%) which is in contrast with Botzen and Berg's (2012) argument of reduced risk aversion in the older generation. In general, there is found to be a progressive increase in percentages of respondents rating a property as high flood risk, with age.

Table 7.5. Correlation of Age to Flood risk to property

Age Range		**Flood risk to property**				**Total**
		HFR	**M-LFR**	**NFR**	**NFRA**	
18-25	Count	0	4	7	3	14
	%	0.0%	28.6%	50.0%	21.4%	100.0%
25-35	Count	2	7	8	1	18
	%	11.1%	38.9%	44.4%	5.6%	100.0%
36-45	Count	4	12	11	1	28
	%	14.3%	42.9%	39.3%	3.6%	100.0%
46-55	Count	4	14	9	3	30
	%	13.3%	46.7%	30.0%	10.0%	100.0%
56 or older	Count	15	22	29	11	77
	%	19.5%	28.6%	37.7%	14.3%	100.0%
Total	Count	25	59	64	19	167
	%	15.0%	35.3%	38.3%	11.4%	100.0%
HFR: High Flood Risk, **M-LFR:** Moderate to Low Flood Risks, **NFR:** No Flood Risks, **NFRA:** No Flood Risk Awareness.						

When looking at the overall ratings for all the respondents across different age groups, 11% of the participants have no awareness about the flood risks. Overall however, when risk perception is assessed across the different age categories, the majority, about 38 %, have indicated no flood risk to their property which is closely followed by moderate to low flood risk represented as 35.3%. Hence the majority perceive their property to be under no flood risk regardless of age groups.

The mixed results in this category also indicated a marginally statistical significance between the age and flood risk to property variables with a P value of 0.25. It should also be noted that more than half of the respondents in the older generation category (83%) of this research study resided away from the rivers or a major water body. Since, in this study, the correlation to proximity to the rivers presented a marginal relationship which constituted younger generations residing closer to the rivers, it is likely that these two variables are interdependent. Although research evidence, from other studies, indicates a statistically significant relationship between proximity to potential hazard and risk perception (Peacock 2003; Lindell et al. 2005; Lindell & Hwang 2008; Severtson & Burt 2012), when other social characteristics are combined such as age demographics, the risk perceptions to property present a marginally significant relationship.

Correlation between gender and risk to property

Research indicates that perception to risks tends to be a gendered phenomenon (Fothergill 1996; Terry 2009; Kellens et al. 2011). Harrison et al.'s (2007) study in Denmark, however, indicates that gender has no influence on risk attitudes. An earlier study by Schubert et al. (1999) also indicates that there is no difference with respect to gender and risk aversion when it comes to investment and insurance. In contrast, many argue that women are more likely to be risk-aversive than men especially when it comes to financial risks (Eckel & Grossman 2002; Borghans et al. 2009; Charness & Gneezy 2012). In the current study, gender responses to risk to property were analysed to determine any correlations to risk perception and gender.

The survey analysis results have shown that women respondents were slightly higher in number (58%) than men (42%). This may indicate that women's interests in flood risk and flood management may be slightly higher than men. It may also be due to other social factors, probably that there are more stay-at-home women than men, hence they had more time to respond to the survey.

Under the HFR category, the responses from both genders were not particularly close, with women (20%) respondents indicating a higher flood risk status to property than men (7%) (Table 7.6). The gender difference is also prominent in the second (M-LFR) category. Nearly 31% of male respondents agree that their dwellings are considered to be either moderate to low flood risks, whereas a slightly higher level of women (40%) perceive their property to fall in this category.

Women also rated themselves to have a higher level of flood risk information than men. Consequently, the lack of awareness about flood risks to property was observed to be higher in men (18%) than in women (2%). For purposes of better planning and increasing awareness among the flood-risk population, it would be useful to identify the likely sources that men and women use to access and gain information about flood risk in their area.

Table 7.6. Correlation of gender to flood risk to property

Gender	Flood risk to property				Total
	HFR	M-LFR	NFR	NFRA	
Male	18.3%	31.0%	32.4%	18.3%	100.0%
Female	20.2%	40.4%	37.4%	2.0%	100.0%
Total	19.4%	36.5%	35.3%	8.8%	100.0%
HFR: High Flood Risk, **M-LFR:** Moderate to Low Flood Risks, **NFR:** No Flood Risks, **NFRA:** No Flood Risk Awareness.					

In the current study more women responded to the survey than men. Women also claim to have better flood awareness then men and a higher number of women than men have identified their property under risk which coincides with Kellen et al. (2001), Ho et al. (2008) and other studies illustrating a direct relationship between gender and risks. Chi-square test also indicated a statistically significant relationship with gender and risk to property in this study with the P value less than .05.

7.5.2. Flood-risk information – whose responsibility?

In Chapter 6, professionals from different national, state and local level agencies were asked to comment on a number of issues pertaining to flood management. While discussing various elements of flood management, a number of professionals argued that the responsibility of obtaining the information about the risk-potential of an area or property should rest with the individual residing or buying property in the area. Representatives from different risk assessor agencies such as real estate, insurance companies and the local councils hold different opinions about who's responsible for managing flood risks. As discussed in the previous chapter, this responsibility was perceived to lie with the community and or the real estate agencies building or marketing these floodplain regions. Whereas some interviewees were of the view that insurance companies, (responsible for setting premiums), or the councils, (approving development,) should be held responsible. Hence other than the councils considered as primary flood managers for their LGAs, communities were considered as the central entity for being responsible for their property by the majority of the interviewees. This section of the survey explores a number of aspects to demonstrate the difference in needs, expectations and understanding about information dissemination and agency responsible for providing information on flood risks.

The survey respondents identified 14 different sources of information on floods. The frequency of use of these information sources is represented in Figure 7.5, below. The most popular source identified for acquiring information was the council (41%). The second most popular source of information identified was the internet (22.7%) and 10% of the survey respondents indicated that they consulted the Newspaper or TV as a primary source of getting flood information. In comparison, only 5% of the respondents identified the SES, which is the leading agency dealing with flood emergency and response, as an important source from which to acquire flood information. A relatively lower number of respondents identified the Bureau of Meteorology, BoM (1.7%), Police (1.7%) and Catchment Management Authorities, and CMAs (1.2 %). About 3.5% of the respondents indicated that they did not need flood information as they tended to rely on their own knowledge and experience of living in the region. Another group considered the information to be irrelevant as they perceived to have 'no flood risk' to their property, accounting for 1.7 % of the responses.

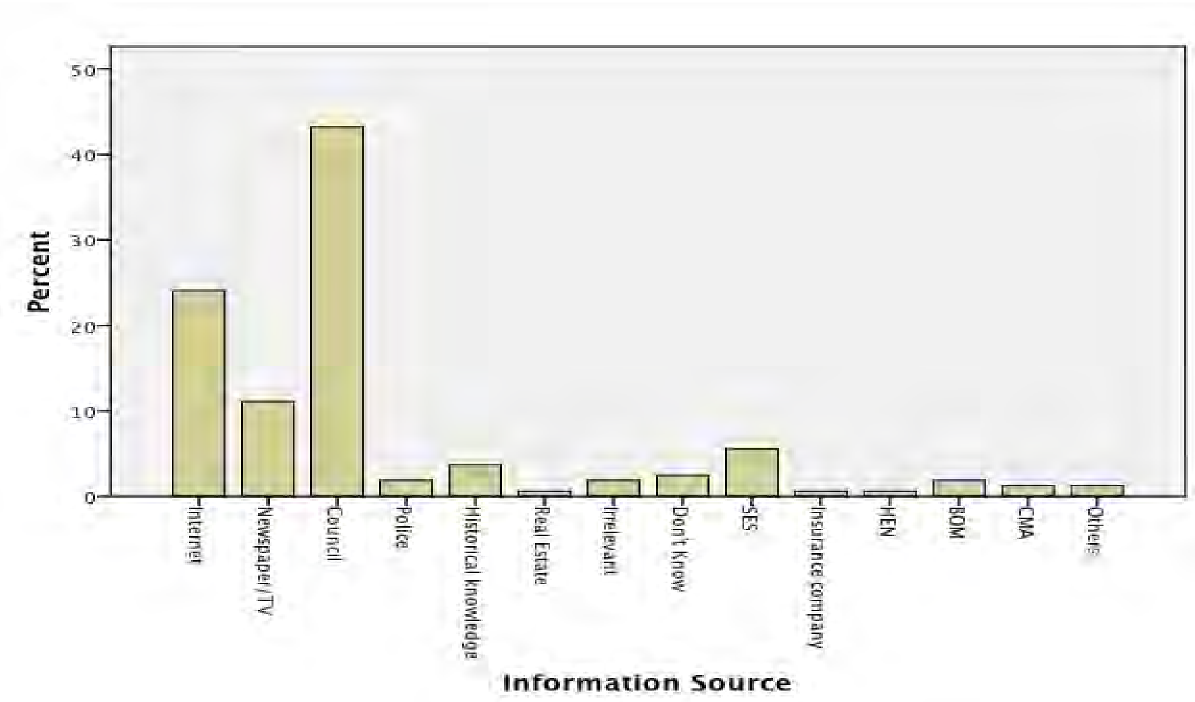


Figure 7.5. Use of different sources to acquire flood information

This response demonstrates communities have a good understanding that their primary source of information is the council. At the same time, however, the role of SES for information dissemination is not accounted for. In addition, the large number of possible sources identified by the respondents indicates the absence of a single reliable source and lack of understanding on who to contact for immediate flood information. This is due to the fact that flood management in NSW is divided into different isolated groups of organisations where professionals deal with various aspects of flood risks, their management and mitigation (Handmer 2008, p. 531). As a result there is dissatisfaction and confusion about the lack of information provided by government agencies.

> 'If we were to experience a 1:100-year flood next week that would inundate my stock paddocks…I have no idea where is the best place to remove my five horses to and at what point do we commence evacuation to ensure safety of both stock and family. Community needs to be informed of what street in what suburbs are likely to be inundated and where their closest evacuation point is. This information must be readily available to government agencies but simply had not been disseminated adequately. I don't believe a whole new agency needs to be invented to manage flood issues – there is far too much bureaucracy already- this simple information could be provided or updated once each year and mailed out with people's rates notices' (Penrith Resident 02, July 2014).

While professional flood managers argue that communities are responsible for acquiring information, the majority of the respondents were of the opinion that flood risk information ought to be provided to them. On a 6-level Likert scale ranging from 'strongly agree', at one extreme, to 'don't know', at the other, respondents were asked to indicate how they 'feel' about being informed about flood risks to their area. The majority (about 87%) which accounts for 44.8% of the respondents 'agreed', and 42.4% 'strongly agreed' to being informed about the flood risks by competent authorities. Only 8.7% of the respondents were in disagreement and 4% held a neutral opinion. Kjellgren (2013) argue that although there is increased effort to share the 'burden' of flood risk management between the government and communities, often communities are not aware of their share of responsibilities in flood-risk management. In addition communities may not be willing to share responsibilities or want to become accountable for their own protection (Steinfuhrer 2009 cited in Kjellgren 2013).

Respondents were also asked to identify which agency they think should take the responsibility of providing flood-related information. About 61% of respondents suggested that it should be the responsibility of the local council, while others indicated the SES (7.6%), federal/state government (6.4%) and CMA (6.4%) agencies ought to be responsible for the provision of flood information. A small portion of respondents (4.7%) had no idea about which agency could perform such a role.

This demonstrates the difference in expectations of agencies that define flood risks and expect communities to be aware of flood issues. Communities, on the other hand, have a strong tendency to rely on public institutions to provide the necessary information and support. Reliance on government entities to provide support for disaster management has been recorded in other research studies conducted in the US and Hungary (Lave & Lave 1991; Vari, Linnerooth-Bayer, and Ferencz 2003; and Gheytanchi et al. 2007). Birkholz et al. (2014) argue that community perception by which they assess potential risks and consequences of a hazard influences their behaviour and involvement in risk management.

A wide range of information was identified as useful to the respondents. A significant portion of respondents indicated that flood warnings should include rain depths and flood heights (26.6%). Others nominated evacuation routes (15%) to be of significance while 14% indicated that identification of problem areas, especially for people moving into this region with no prior knowledge of flood risks to property, was critical information which is often not available. About 10% of the respondents were interested in getting information that would tell them what to do during a flood while a small portion (2.3%) were interested in knowing about past flood records.

> When we moved we didn't know if the property we were buying was at risk to flooding. The real estate agent didn't tell us. Real estate agency should take this responsibility and provide both positive and negative information of the property that is for sale. …When we went to the next door neighbour they told us that this property is flood-prone (Penrith Resident 6, August 2014).

Chapter 6 identifies some of the critical barriers that prevent risk assessors from seeking information in the Hawkesbury-Nepean area. Issues of lack of trust, inconsistency in data collection and council's confidence in the data, were some barriers identified in accessing technical data on flood risks. Cadag and Gaillard (2012, p.100) argue that prevalence of disaster indicates a lack of political will to mainstream knowledge about good practice. This creates gaps in communities' understanding of scientific knowledge. In the current study, communities' views on the need for technical data to be publicly available were assessed. Although the type of information that the respondents indicated does not highlight their need for accessing technical data, when asked about their views on having such information in the public domain, the majority of them agreed. Around 91% of the respondents were of the opinion that technical/scientific information should be available to all. Technical information was seen as valuable information in assessing property market value.

> Community needs some source of information. Community pays money to do it... it shouldn't be like that. Information should be available rather than people hiring and paying to get this information (Windsor Resident 11, September 2014).

> 'People are informed and aware of the area. Also they have information about the property and know what they want to buy' (Windsor Resident 20, September 2014).

> '[Such information] helps to cross check information provided by local authorities to be correct or not…' (Windsor Resident 21, September 2014).

Handmer (2008) states that planning authorities may bear some legal liabilities but developers themselves do not bear any liability when dealing with residual risks; hence, their role as information provider is often overlooked. Burningham et al. (2008) explain that lack of awareness of flood risk usually pertains to flood risk-related information. According to them a survey study in the UK revealed that people are often unaware of risk to their properties because of they have no prior knowledge about the risks, or the available information was unclear or difficult to understand (Burningham et al. 2008, p. 225). Kjellgren (2013, p.1865) argue that lack of active efforts to disseminate flood-risk information tools is another reason for their low impact on communities' attitude and behaviours. During the conduct of face-to-face surveys in the Hawkesbury-Nepean catchment, a number of participants expressed their concerns about not being aware of the flood risk to the property they intended to buy. In most cases they blamed the real estate agents who failed to provide sufficient information about flood risks to the area. Technical information was seen as useful for purchasing and selling property. It was also seen as an additional source of information and was welcomed, as opposed to having no information at all. A few respondents also suggested that as property owners or potential buyers, technical information may not be very useful to them but nevertheless it should be in the public domain for use by others who might be interested.

> I think all environmental data should be available publicly. There is no reason in my mind to withhold this kind of information (Environmental Network 4, August 2014).

> Sharing of technical data was also seen as a way to make informed decisions

> The data should be made available in a form/language that can be accessed and understood by the public and allow people to make informed decisions about home purchase, evacuation routes; and so council's flood prone land is not developed for housing' (Environmental Network 10, August 2014).

Whereas the majority expressed their strong desire to have such information available, a small number, however disagreed. This accounted for about 3% of respondents, who disapproved of any access to technical data publicly, indicating that such information will increase false alarms.

'Most people would fill their heads with too many notions about an imagined catastrophe' (Richmond Resident 9, September 2014).

Or that:

'Most people would not understand' (Post Mail 42, September 2014).

The communities' expectation of information being publicly available can serve as a strong instigator for councils to ensure that such information is available and regularly updated. If the public feels strongly about open access to all types of information, then social pressures could influence responsible authorities to make technical data publicly available.

Cadag and Gaillard (2012) argue that gaps in actions and knowledge are one of the major obstacles to reducing risk for sustainability across scales. Communities and local authorities both require access to information and should be empowered to make decisions to reduce risks (UNISDR 2005). Social pressures may help to make concerned authorities accountable for withholding information or at least expedite the process of sharing information publicly as soon as it is made available, therefore increasing access to this information for other risk accessors such as insurance companies. This would also require a close interaction with communities to match expectations. One of the questions in the survey asked the respondents about their likelihood of attending any consultation meetings held in their area regarding flood management (Figure 7.6, below). Out of the 172 respondents, 64% expressed that they had never attended any meeting. Around 21% of the respondents had no knowledge of any type of community consultations taking place. A relatively small portion of respondents (11%), however, had attended occasional meetings. Only 3.5% indicated that they regularly attended these consultation meetings. The low rate of participation can be accounted for by the lack of awareness about consultation meetings, and the poor engagement of government agencies to involve residents. With little consultation, it would be difficult to incorporate social dimensions of flood risk management in policy frameworks to enable adaptive capacity and resilience of social networks.

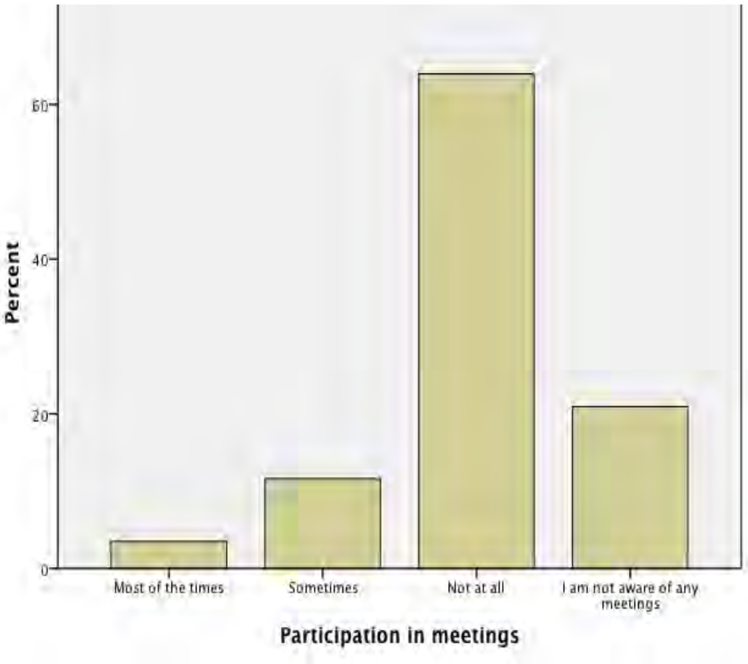


Figure 7.6. Communities' inclination towards engaging in consultative processes

The expectations of respondents to be informed of flood information by their local council especially in the context of buying properties; the absence of considering SES as a key source of information in the case of floods and the value communities see in having access to all types of information are in contrast with what is being implemented on-the-ground. The difference in expectation may also be accounted for by the lack of participation of community members in consultation processes. Manock et al. (2013) identify that the communities' lack of trust in authorities 'taking up' their views is one of the reasons for lack of public participation in the consultative processes for flood management. The perception of 'powerlessness', where the public is assumed to have low power to influence decisions can also discourage communities from sharing responsibility for flood management (Taylor et al. 2014). According to Bell et al. (2005, p. 472) 'the only credible form of information provision is grounded in trust that is built through two-way communication embedded in an inclusive participatory process.' Brown and Damery (2002) elaborate that unrealistic expectations of public institutions by risk communities generate disappointment and lack of trust that can reduce incentives to engage with authorities for flood planning. Difference in the perceptions and needs of communities in terms of flood risk is a major gap in achieving collaborative and co-adaptive action to deal with flood risks in the Hawkesbury-Nepean SES.

Birkholz et al. (2014, p. 13) argue that there is a need to develop a "better understanding of the links between emotions, risk perceptions and behaviours, as a precursor to developing more effective risk communication and disaster management policies." Currently the focus of research is largely on the physical aspects of flood mitigation and social dimensions are often ignored (Birkholz et al. 2014).

7.5.3. Perceived role of regional agencies in Flood Risk Management

This community survey also assessed the floodplain residents' existing knowledge about Catchment Management Authorities and also of the Local Land Services (LLS). As the latter now has CMAs merged into its structure, it was pertinent to assess if the target community groups are aware of these changes and how they understand them in terms of flood risk management. The respondents were also asked about their views on the possible role LLS can play in flood management to improve cross-disciplinary integration for better management.

Knowledge about Catchment Management Authorities

The respondents were prompted to describe their degree of interaction with their CMA and awareness of CMA. The degree of interactions was divided into five statements: they have worked with a CMA; they are aware of the role of CMA; they have attended a meeting of a CMA; they knew a contact person; or they were aware of CMA but never had been in contact with them.

Out of the 172 respondents, 99 (57.6%) said that they were aware of CMAs and a slightly lower proportion 73 (42.4 %) indicated they were not aware of CMAs (Figure 7.7, below). More than half of the respondents were aware of CMAs and just fewer than 50% expressed otherwise. In terms of the degree of interaction, as shown in the graph below, the majority of the respondents have indicated that they were aware of the CMA but never worked or participated in any meetings held by the catchment authorities. Thus the majority of the respondents have never been involved with their CMA. Furthermore, among those who were aware of the CMAs, only 12% participated in the meetings, whereas a much lesser number either knew someone at their CMA (9%) or have had the experience of working in their CMA (10%). Considering that 42.4% were not aware of CMAs, and of the 57.6% who were aware, only 42% that formed the majority under this category were familiar with the name of the agency although they had little idea about their role. A relatively smaller percentage within this category managed to participate in meetings held by the CMAs.

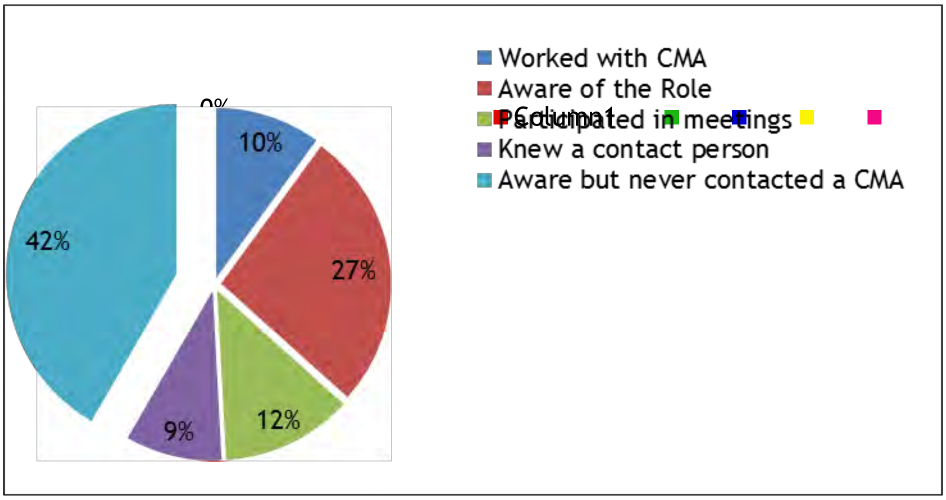


Figure 7.7: Interaction with CMAs

This doesn't depict a very strong outcome in terms of the communities' understanding about CMAs. Subsequently if their knowledge about CMAs is limited, it is highly unlikely to expect the respondents to comment on their potential for being a catchment-scale flood management agency. The subsequent chapter (chapter 8) of this research describes a catchment-scale framework for flood risk management. If such a framework is to be implemented, it is critical to understand that current knowledge about catchment-scale agencies and their current or possible role is very poor. This is likely to present a challenge in gaining support and implementing a participatory process for managing flood risks at regional/catchment-scale.

Knowledge about Local Land Services

At the beginning of 2014, the NRM reforms led to the establishment of the Local Land Services (LLS). The agency is responsible for supporting farming and the general community in rural and regional NSW to provide support for livestock, bio-security and advice on NRM. LLS also have taken on the responsibility of providing flood emergency advice. To assess participants' understanding about, and involvement with LLS, they were asked to indicate if they were aware of LLS and its role.

Out of 171 respondents who responded to the queries on LLS, a very small proportion of them indicated that they were familiar with LLS; whereas, around 81% of the respondents had no idea about LLS. Out of the 19% who said they are aware, only 3.5% were confident about having a very clear understanding about the role of this regional organisation. Subsequently, 12.8 % indicated that they had some idea about LLS. A very small number of respondents (4.7%), however, indicated that they had attended consultation meetings of the LLS. In response to whether the respondents thougt LLS could provide a more integrated approach to flood management, 72.7% did not provide an answer. This was expected as the general awareness level about LLS among the resident community is very low. Of those who did provide a response, only about 6% were in agreement. Different reasons were provided by respondents who were of the opinion that LLS can be a viable regional agency equipped to provide a more integrated flood management. They felt that (i) having a single authority would reduce the unnecessary bureaucracy; (ii) combined services would ensure good risk management; (iii) councils are already burdened with too many responsibilities; and (iv) since LLS monitors rainfall in the catchment, it would be more suitable to address flood risks.

> With their knowledge of catchment issues and 'regional approach' to NRM the LLS should be best placed to educate the local community about flood risk and management – more so than Penrith Council (Penrith Resident 02, August 2014).

About 16.4% of the respondents, however, had a neutral opinion on this. The response was either expressed as 'wait and see' or that the respondent wasn't sure if the agency had the resources to perform this function. About 3% were in disagreement. They expressed that the added responsibility would mean more work for limited staff; inclusion of larger areas would not benefit local communities as the focus would move away from local issues; and that it would add another layer of bureaucracy that "meddles" and "frustrates" the need to address the real threats associated with flooding.

Perceptions on merger

Respondent awareness and views on the merger of CMAs with LLS were explored. Considering the lack of familiarity of local residents with regard to these agencies, it was not surprising to find that only 7.6% indicated that they were aware of the change. In terms of expressing their opinions about this change, fewer than 2% agreed to the change. The group that ranked 'supported the merger', expressed that it would provide equal opportunity to have both the agencies be aware of these issues when involved in Local Government Area (LGA) planning. They also expressed that 'One Authority to manage the land' was an agreeable option. Despite the agreement of a few, twice the number of the respondents in this category strongly disagreed with this change. Of this 4%, a majority of the respondents had an association with one or more environmental or land conservation agencies. They, therefore, strongly opposed the merger indicating it to be a political move to "cut down" resources. They emphasised that as a result of this change it was unlikely that conservation issues and interests will be fully addressed. Table 7.7 summarises some of the concerns highlighted by this particular group of respondents.

Table 7.7. Views on the CMA and LLS merger

Two different organisations – government just cutting back in most things.
LLS is involved with farming land – not residential land.
They have lumped all the departments together they don’t represent well.
algamation of CMA to LLS is a political one and occurred due to a change of NSW government, Political decisions are not always made with the best interests of employees, the public or the environment.
epartments have to take on extra roles usually with less staff there is usually neglect in some areas.
Appears a cost cutting measure that weakens environmental protection and support of community groups and Landcare.

In terms of knowledge about regional agencies such as CMAs and LLS, very few respondents were truly aware of the two agencies. For communities to make informed decisions they need to first have information and knowledge about critical agencies. The small percentage of individuals who claimed to be well aware of these agencies held strong opinions about this change pertaining to ‘financial cut backs’ and compromising the potential of an entity to manage natural resources competently. This is an example of political barriers that devalue conservation goals. The low awareness levels of respondents about these agencies also indicate the absence of processes that ensure participatory community-driven consultative processes to incorporate community values and address concerns that directly affect them.

Where awareness about these agencies was not an issue when discussing the potential of CMAs as a flood management authority with experts, the communities on the other hand, would require a clearer understanding about these agencies to extract any meaningful feedback. Although this has been an exploratory research which draws upon information received from a small section of the residents of the Hawkesbury-Nepean floodplains, it does highlight a few useful shortcomings in the existing consultation processes. The strong opinions held by the community groups who had an understanding about these agencies reflect a wariness of the government's decisions. There is a need to build trust and address local concerns to have more 'involved' consultations on issues of resource management in general and on flood management and planning, in particular.

7.5.4. Perceptions on defining an acceptable level of flood risk – who should be involved?

According to Birkholz et al. (2014) there is a tendency for communities to rely on publicly funded protective measures for flood management. Policymakers are now seeking to transfer this responsibility to communities (Kjellgren 2013). This, however, will not be achieved through a one-way communication (i.e., 'transmission of a message from a source to a recipient group without any feedback') as people's behaviour is influenced by experiences and personal values (Kjellgren 2013, p.1860). Instead, two-way communication, long-term engagement and dialogue with the effective communities are necessary (Burn & Slovic 2012). This also provides an opportunity to the communities to define their information needs, a problem currently faced by the communities of the Hawkesbury-Nepean catchment (Kjellgren 2013). Lebel et al. (2006) indicate that participatory decision-making enhances society's ability to innovate and respond to crisis. Hence involvement of non-government entities helps to deal with complexities (Schultz & Lundholm 2010).

The previous chapter outlines the views of professionals with regard to defining an acceptable level of flood risk. In general, a top-down approach dominates the thinking paradigm. A mix of responses was received from interviewees working in different organisations. The general understanding was that communities need to be informed of flood risks and the responsibility of setting-up flood levels should be addressed by experts involved. In most cases, it was acknowledged that the standard 1% AEP is a suitable benchmark for planning for flood risks and that there was no need to change the existing level of flood risk.

In this chapter, the residents and other community members were invited to provide their views on who should be involved in defining an acceptable level of flood risk. The survey questions, in this regard, asked the respondent to express their views on Local Land Services (LLS) involvement in defining flood risk levels for planning and the local communities' engagement in defining risk levels. The respondents were also asked to elaborate on their choice.

Since the general awareness level of the respondents about the LLS, as discussed in the previous section, was low, very few commented on the feasibility of LLS as an agency that could help define an acceptable level of flood risk. From the total of 178 responses, 160 provided responses to this question. Out of the total responses received, 127, which represents 74%, indicated that they did not know whether or not LLS should be involved; however, about 7.6% agreed that LLS has potential. However, respondents from the environment network were sceptical about LLS indicating that it was not their role to do flood assessment or management. On the other hand, some argued that if CMAs have merged into LLS then CMAs can provide the knowledge, skills and resources to help define an acceptable level of flood risk. Others considered it to be a way to reduce bureaucracy by having one authority as a more feasible option. Some comments are presented in Table 7.8 below.

Table 7.8. Perceptions on the potential role Local Land Service can play in defining an acceptable flood risk level

'It seems an acceptable role but duplication of some other agency's role is unwarranted'.
'Better than politicians doing it!'
'Since the CMAs are being removed somebody has to do this and soon'
'This is imperative for creating safe exit/escape routes during floods'.
'The flood risk has never been properly defined or addressed on the ground. There are flood management reviews carried out by state agencies but the state will not commit to anything that identifies the true risk as they will then have to do something about it which will cost mega dollars. At both state and local government level they are risk averse and are very, very protective and secretive about flood information. Both authorities are not prepared to make a call on the acceptable level of flood risk. It would though be important to land owners as they could then obtain appropriate insurance and finance.

A few issues are highlighted from the participant's responses above: the expectation that CMAs had this role prior to their merger within LLS; the communities' speculation about the government to provide the much needed knowledge in earnest with regard to real flood risks; and the expectation that LLS is engaged in determining evacuation routes as flood mitigation measures. The respondents in this category are likely those respondents who claim to understand and know the role of LLS and are familiar with CMAs as well. From their responses, however, there seemed to be a disparity in their understanding about these organisations and their expected roles. Having sound knowledge about who is doing what in terms of flood management remains unclear. For communities to fully endorse initiatives led by the state and local agency to reduce flood risks, there is a need to improve the communication of risks between the decision-makers and those potentially affected.

A very small portion of individuals disagreed with having LLS (1.2%) set up acceptable level of flood risks. The reasons provided did not pertain to the current responsibilities of LLS but rather scepticism about 'setting up flood levels'. In response, one of the participants suggested that he/she doesn't believe in flood heights. Another indicated that establishing acceptable flood levels was not a solution to the problem and a more effective solution would be to increase the Warragamba Dam wall. This was supported by one other respondent who suggested that a more drastic measure such as dredging of the channels along with increasing the height of the dam wall were more viable options. Another reason for disagreement was to avoid bureaucrats making these decisions rather local inputs from people who live near the rivers; this approach was considered to be more acceptable.

In comparison to the above feedback, when community members were asked to indicate whether or not communities should be involved in defining an acceptable level of flood risks, 65% of the 150 respondents agreed, 13% disagreed and 7% had a 'neutral' response. A small percentage, about 2% of the respondents, were not sure about the usefulness of engaging communities to set up their acceptable flood risk levels (see Figure 7.8 for details).

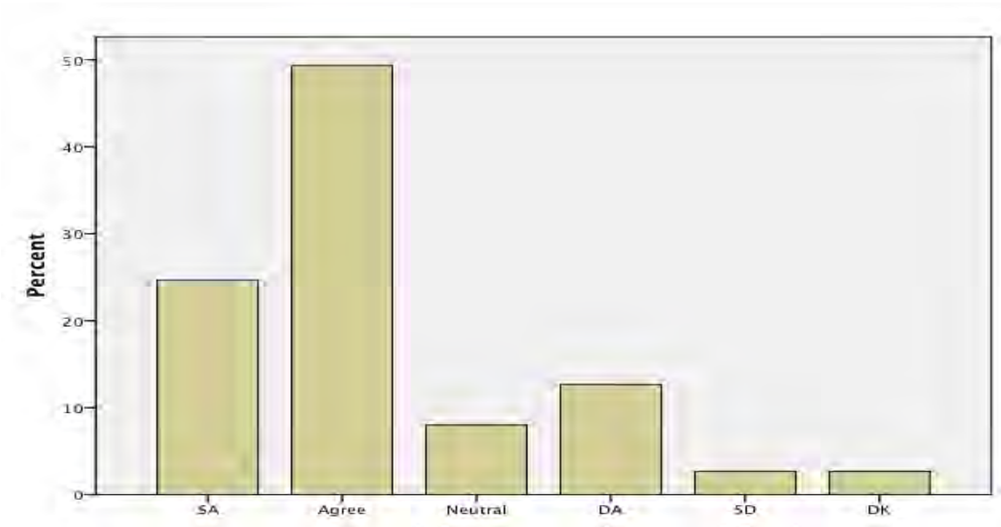


Figure 7.8. Community to define their flood risks

A large percentage of the respondents, as seen in Figure 7.8 wanted to be involved in defining their own acceptable flood risk levels. They were of the view that engagement would enable them and others to learn about flood issues. According to these respondents, people moving into this area to buy property have little knowledge and would benefit if involved in such decisions. They also expressed concern about the lack of community involvement that would lead to setting up flood heights that may be too high for them. This reflection indicates the concern highlighted in a similar survey by Molino and Karwaj (2012). Respondents were of the view that it is they who have to face the floods; therefore, they should be the ones involved in defining an acceptable level: 'it is not the council dealing with it every day, it is the people' (Penrith Resident 1, August 2014). Scott et al. (2013, p. 116) state that most policy plans and measures related to flood risk management are communicated to 'the public' through distributing information in a one-way manner with few opportunities to receive feedback. Community participation in flood risk management should be inclusive where diverse needs, values are considered and incorporated at the decision-making stage of planning (Fordham et al. 1991; Guinea Barrientos & Swain 2014). Furthermore, it aids in enhancing their social capacities. Scott et al. (2013) define six categories of social capacities that can fortify communities' ability to cope with and adapt to flood risks. These include knowledge, motivational, network, financial and governance capacities. The Australian's National Strategy for Disaster Resilience also states that 'greater disaster resilience can be achieved through learning, innovating and developing skills and resources at the individual, community and operational level to respond to […] a wide range of disasters' (COAG 2011, p. 13)

The respondents perceived a number of benefits to engage in defining the acceptable level for flood risk. These are summarised in Table 7.9, below.

Table 7.9. Views on community involvement in defining flood risk levels

To be better prepared. People would know what to do. Everyone becomes part of the decision. Greater ownership of the plan.
Local people know the history of the area, have local knowledge.
Helps define what is acceptable to us.
Avoid incorrect premiums. One company charging more than the other. If community involved in the decision they would know if they are at risk or not.
Helps to create extensive awareness of risks.
Community consultation on all decisions is important.

Other reasons provided related to the lack of trust in the government. Some of the comments that reflected this underlying trust was observed from statements such as: 'More aware of what is going on than the government'; 'Government have different views than what communities have to say'; 'Don't trust the government in making such decisions'. Respondents felt that local knowledge and experience is a valuable asset of their community and by engaging communities in determining flood levels, the local knowledge could be put to use. 'A lot of wisdom exists within communities especially where there are several generations' (Windsor Resident 11, July 2014).

The majority of participants wanted to 'have a say' in defining an acceptable level of flood risks; however, a small percentage (13%) did not. According to them, defining flood levels requires technical information and is best left for the government or other experts. They also expressed that allowing communities to define acceptable levels would jeopardise safety whereby certain stakeholders interested in building property would agree to an acceptable level that would cater to their development interests but could risk developing land in areas where there is flood risk. Furthermore, they elaborated that people, in general, lack the information and knowledge to define a suitable level of flood risk; therefore, the decision should be left to appropriate experts.

Figure 7.9 below presents a summary of comparison between perceptions of experts/flood managers (chapter 6) and the communities on defining flood risk levels. A small portion (13%) of the community respondents highlighted issues that the council representatives discussed in the previous chapter. However, the majority of the respondents as represented in the first two columns of the embedded bar graph in Figure 7.9 preferred to be involved in setting up acceptable levels of flood risk in their region. This contrasts with the views of interviewees from agencies involved in flood management, as they believe that community members need to be informed of their flood risks rather than be engaged in defining what an acceptable level of flood risk is to them.

Figure 7.9. Comparison of expert's perceptions on community involvement in defining risk levels (right) and communities' views with regards to defining their flood risks (left graph)

The lack of opportunities for communities to provide their input in flood management exists in other regions such as the UK and the Netherlands. Wiering et al. (2015, p. 51) explain that this is because of the centralised, state level management of flood risk where risks are treated as technical problems that need to be addressed via technocratic bureaucracy. It is also because of the lack of skills and understanding of local authorities on effective community engagement processes (Scott et al. 2013; Crawford et al. 2013).

7.5.5. Opinions on 'Catchmentisation' and a holistic flood management approach

Management of floods at a scale whether it is at catchment, regional or watershed level has been extensively applied in empirical research (Schumann & Pfutzner 2000; Hall et al. 2003; Redaelli et al. 2009; Padi et al. 2011; Rizzoli et al. 2011; Rifai et al. 2014; Yu et al. 2014). It advocates the need for integration, cross-scale coordination and holistic management of floods (Jonsson 2005; Schanze 2007; Wilby & Keenan 2012; Heintz et al. 2012; Pahl-Wostl et al. 2013).

Management at scale is one of the main themes of this thesis. See Chapter 6, Section 6.5, on 'catchmentisation'—its application and significance in Australia. In chapter 6 the value of 'catchmentisation' was solicited from experts. They were asked to give their opinions on the need for a catchment-scale flood management plan and the need for a regional agency to improve coordination. Representatives from state-level agencies supported the idea and thought it was useful to have a standard set of parameters across multiple councils or LGAs. They also expressed ease in access to information while council level representative expressed concerns pertaining to the risk of overlooking local issues and the challenge of governing such a large catchment by a regional-level entity. The current review of the Hawkesbury-Nepean Catchment titled, *'Hawkesbury-Nepean Valley Flood Management Review Stage One'* by the NSW Office of Water (2014) demonstrates the concerns the agencies involved have with trying to reduce flood risks. While the current options are explored, this survey explored perceptions about regional flood planning and management from the perspective of communities residing in the area.

In order to assess perceptions on having a holistic approach to managing catchment for effective flood mitigation, the residents participating in the current research survey were asked to express their understanding on the scale of the catchment. For this purpose, a map of the Hawkesbury-Nepean catchment was provided with major sub-catchments depicted. The respondents were asked to mark the boundaries of the Hawkesbury-Nepean catchment and also the boundaries of their LGA. This was carried out to determine their knowledge and understanding about the extent and the scale of the catchment. Once they were able to determine the size of the catchment, the respondents were asked to express their views on having a regional body to manage this catchment and if they were aware of any agency that was currently responsible for the entire catchment. They were also asked to suggest any agency that they thought could take on such a responsibility. The following sections elaborate on the results derived from the survey.

Understanding the scale of Hawkesbury-Nepean catchment

Out of 172 respondents, 144 provided feedback on this particular query. About 42% of the respondents were not aware of the scale of the catchment and they did not attempt to provide any estimates. About 34% of the residents encircled the boundary incorrectly. Only 17% of the participants were able to correctly mark the boundaries of the Hawkesbury-Nepean catchment with 7% providing a close estimate of the possible boundaries of the catchment. Hence the majority of the participants (70%) were not aware of the extent of the catchment. Details of the results represented in Figure 7.10 below.

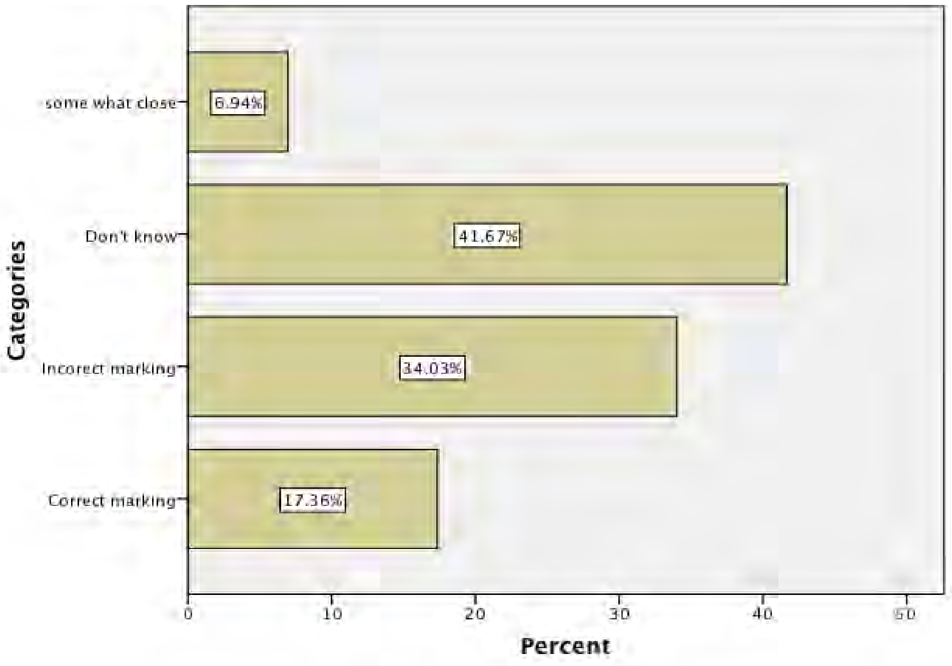


Figure 7.10. Knowledge of the Hawkesbury-Nepean catchment boundaries

In comparison, slightly fewer responses were received with regard to identifying boundaries of the respondent's LGA. Out of 139 people who provided this information, 30% incorrectly marked their LGA boundaries. Only 11% accurately labelled their LGAs and 20% were close. Whereas 18% didn't have any idea about what areas their LGA borders. Out of the total, only 11% of the respondents correctly marked the boundaries for their LGA and for the catchment and 24% respondents incorrectly marked both boundaries. This underlines that only 11% of the total respondents were aware of the two different geographical scales. Most of the respondents marked the boundaries of the Hawkesbury-Nepean catchment outside their LGAs indicating that they considered their region not part of the Hawkesbury-Nepean catchment. This survey represents a small sample size of the total population residing in the Hawkesbury-Nepean catchment, and although the findings are not representative of the entire population living in the region, it does provide some perspective on the current level of understanding of the perceived scale of the area that is being considered for effective flood management. If the population has a limited understanding about the scale of the catchment, it is highly likely that their opinions about the need to manage this catchment from a total catchment perspective or at regional level will require a greater level of understanding. Overall, however, the general understanding of the respondents suggests that they were aware that the catchment encompasses a number of local government boundaries. This can be observed by the fact that boundary representations, by all the respondents, whether correct or incorrect, encircled a number of sub-catchments and crossed multiple suburbs and in most cases encompassed two or more LGAs.

Perceptions on the need for a regional agency

In response to the need for a regional agency to coordinate flood management for the entire Hawkesbury-Nepean catchment, 73% of the respondents agreed that there is a need for a regional body to improve coordination. One of the major concerns highlighted by the respondents was that a regional body would ensure improved coordination and sharing of information. The respondents were of the opinion that currently 'each little area is doing its work and that they need to talk to each other' (Windsor Resident 7, July 2014). They expressed that the councils are looking at their own region and it was perceived that there is an absence of consistent planning. Other concerns highlighted were based on the need to avoide disruption of the natural flow of the river system and developing a 'big picture' understanding. The respondents emphasised that the need for a regional agency is essential due to the following main reasons:

> Floods can be wide spread and it can go across communities hence it can affect more than one boundary (Windsor Resident 18, July 2014)
>
> One river system, so it should have an overall management plan with local sub-agencies (Environment Network 5, August 2014)
>
> Regional agency can provide a more specific focus on the catchment. Opportunity to provide better coordination and integration about flood information (Windsor Resident 22, July 2014)
>
> Currently, managed] in little sections and no bigger picture (Penrith Resident 9, August 2014)
>
> When the Warragamba Dam open gates the whole area and property gets affected. So there is a need for a catchment-scale management (Interview Penrith 15, August 2014).

A number of respondents consented to the need for a regional agency to improve coordination upstream and downstream. One of the concerns highlighted repetitively dealt with the functioning of the Warragamba Dam and the potential problem it is more likely to cause when gates are opened and the properties are affected. The respondents expressed that a greater level of understanding is needed about rainfall in the headwaters of the dam so that release can take place days before the water hits the dam. Upstream dams including the Nepean dams were seen as crucial to the Hawkesbury flow and concerns about their management to regulate flows were highlighted. Hence a catchment-scale management authority was seen to ensure monitoring of different regions within the catchment, resultantly providing better information and understanding. The respondents perceived that poor flood management has occurred due to the presence of different local government bodies with overlapping responsibilities. According to them, having a single entity was a more feasible option as it would help to identify the impacts of floods occurring from one area to another.

A number of respondents were also critical of the way floods were being managed by the local council. Councils were seen as lacking in expertise, as agencies that lack cooperation with other LGAs, and as self-promoting entities that are ignorant on the issue. The flood advisory committee established by the councils was seen as ineffective with issues with gaining consensus in flood management decisions (Interview PM 56, August 2014). The respondents felt that there was a need for an expert set of skills that could guide the councils ,who in turn could communicate critical information to rate payers. Critical perceptions about the councils' ability to manage floods may be a reason for the lack of community representations in the Floodplain Management Committee, as discussed in the previous chapter.

The following quotes represent the respondents' views on the need for a regional agency. These respondents were associated with one or more environmental or conservation entities such as the Landcare group or the Hawkesbury Environmental Network.

> There is a need to have a body that can provide a fully coordinated approach to flood management within the catchment to ensure that the identified priorities are carried out on a regional basis rather than a local-based approach (Environment Network 19, August 2014).

> The Hawkesbury River is an important resource and should be managed cohesively. I say start again. Water is Australia's most important resource and we are only starting to figure that out. Abolish all councils and state governments and instead have a regional government based on catchments. State and Federal government portfolios overlap, costing heaps and creating a blame game. We need two tiers of government not three. Best to look at all

> Australian's catchment and create a plan. (Environment Network 13, August 2014).

> For countless years there has been a hodgepodge of agencies with responsibilities for the river and catchment – from CMAs, National parks, Sydney Water, Local councils, County councils etc. One regional agency would be useful. (Environment Network 4, August 2014).

Although the majority of the respondents strongly approved of having a regional body to improve flood management in the region, about 11% of them did not agree to have such a regional agency. One of the most common reasons given by the oppositional respondents was that the system was already too bureaucratic and having another tier of governance would complicate management. Others who disagreed were more concerned about addressing local issues. According to them, 'Council should manage their areas. It is more equipped to do it and less wasteful of time and resources'. A few respondents didn't see any value in having a regional body as they indicated that there hasn't been any flood in their area; thus, the issue of flooding was not considered to be significant. It was considered as a waste of tax payers' money. According to them, the councils should utilise taxpayers' money for better planning at the local level. Earlier sections of this chapter emphasise the factors that can lead to low risk perceptions. Lindell and Hwang (2008) also highlight the lack of past experiences to influence individual's perception of risks. About 10% of the respondents indicated that they lacked knowledge and 'didn't know' enough about the issue to comment.

Despite the fact that the majority of the respondents were not able to accurately indicate the boundaries of the catchment nor identify the scale of management under consideration, nearly 70% perceived value in having a regional body for improved coordination and to avoid flood management on a piece-meal basis. This view is in line with most of the interviewees representing the expert group in chapter 6 (Figure 7.11, below).

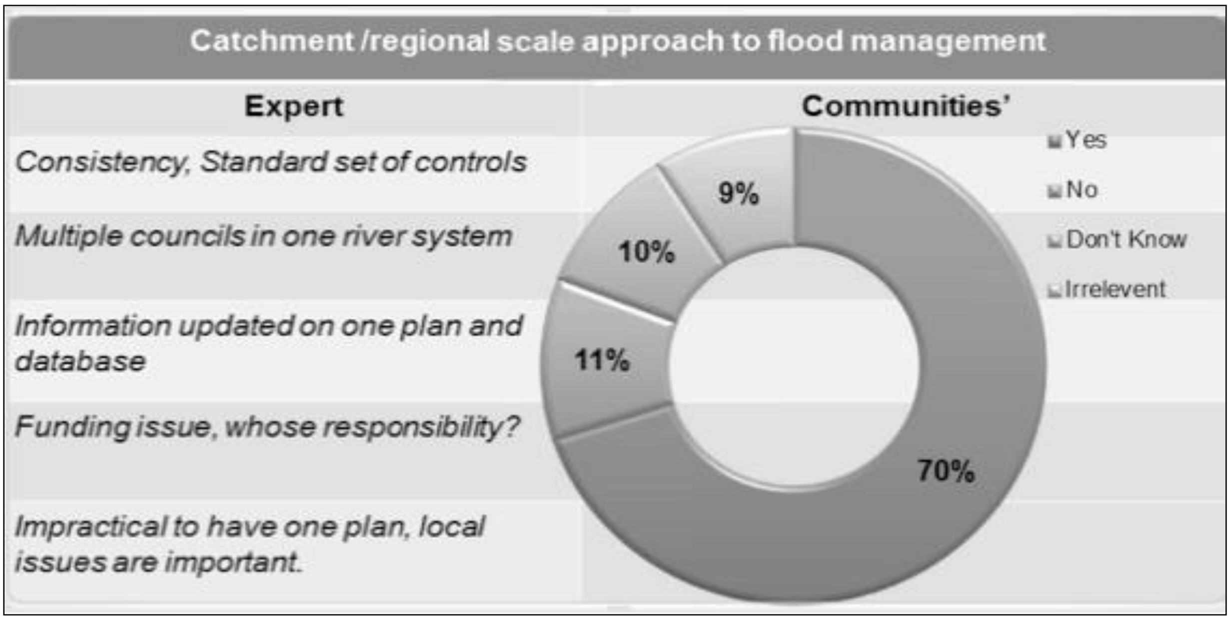


Figure 7.11. Comparison between expert and communities' opinion

The respondents were also assessed on their awareness of any agency that was currently engaged in regional level flood planning in the Hawkesbury-Nepean catchment. Nearly 80% of the respondents indicated that they were not aware of any agency or system of governance that oversaw the entire catchment for flood management. A small portion 17%, however, indicated that they have some idea that an agency exists for the purpose. The reason they provided was that to have a regional agency was inevitable and that although they weren't aware of the agency, they expressed that there has to be one that exists. Some of the responses provided in this regard are given below in the Table 7.10, below.

Table 7.10. Views on an existing regional agency for flood management

That's logical isn't it? NSW Public Department Works used to do it —not sure if they
There is already a catchment authority in place.
Sydney Water is doing it.
Department of Primary Industries deals with it.
Isn't this the LLS [responsibility]?

There is currently no regional scale agency to manage floods at a catchment-scale; however, a portion of the community members participating in the survey thought otherwise.

A regional agency for flood risk management

The respondents were asked to indicate an agency that could potentially take on the role of a regional agency for the Hawkesbury-Nepean catchment. A wide range of responses were received. Some respondents suggested that an overall management plan with local sub-agencies associated in its implementation should be encouraged. A few indicated that a federal level agency should coordinate this through policy implementation.

The most common governance framework that was suggested was to have an authority made up of individual council representatives who would be adequately qualified technical individuals. The councils involved should be the ones which are at the 'real risk' of floods and only these councils should 'have a say' in how flood management should take place in the region. In most cases respondents felt that local councils could play the role of a regional agency provided they were funded by the state government and were properly resourced. A small percentage also indicated that the role should be performed by CMAs and that the dissolution of CMAs was not a favourable decision. About 14% of the respondents supported a framework that involved councils as part of a regional coordination body. In addition, 11% suggested that the former Hawkesbury-Nepean Catchment Management Authority should act as the regional body for flood management; whereas, 45% of the respondents had no idea which agency could play this role. About 9% indicated that the SES should have this role.

Through the survey and face-to-face discussions with some of the residents in the region, a general sense of dissatisfaction was observed in the way flood management decisions were made. The following quotes (Table 7.11) express the residents' opinions in this regard.

Table 7.11. Issues with flood risk management

We have councils but they don't know anything [about floods]
Developers should be excluded from all participation in anything of public interest because they have their own development concerns.
New people to the area do not know about the flood problems.
People should be consulted. Opinions should be sought and listened too.
[Councils] don't have enough knowledge to be able to say anything.

The quotes above highlight some of the common concerns of the residents. They felt that there is a need for more information on floods, and that the councils do not meet the residents' expectations for information and flood facilitation. Residents felt that flood management is best if river banks are conserved and bridges are strengthened. Community consultation was considered lacking and some of the residents felt that there was a need to have a more 'hands-on' approach to determine how best flood risks for the affected areas are addressed.

> Floodplain management is extremely poor and considering the ramification of flooding in the Hawkesbury-Nepean this should be taken over by the State government and not left to petty feudals under reoccurred councils. The possibility of a Brisbane flood though unlikely would be catastrophic in the Hawkesbury-Nepean catchment and many businesses and residents are underinsured and would likely not recover. Focus is on saving lives which is great! But a major flood would seriously damage the state economy. (Environment Network 2, August 2014)

7.7. Why Community Perception Matters in Managing Complex SES?

Community perceptions can play an important role in enhancing communities' responses to reducing flood risks. Theories around vulnerability, adaptive capacity and resilience enforce a change in the thinking paradigm for flood risk management with greater responsibility shared with local communities (Birkholz et al. 2014). Vulnerability is defined by socio-cultural and political factors. In theory it is also linked with adaptive capacity (Lopez-Marrero 2010). Perception is an important social construct that influences vulnerability and the ability of a society to cope with risks (Few 2003). According to Lindell and Perry (2004) communication through the right channels can increase adoption of options by those who have unrealistically low perceptions. It is also important to assess what factors can influence perceptions in a government-led, top-down approach, as practised in the Hawkesbury-Nepean region, where councils who define acceptable flood risk planning levels need to understand what triggers communities' acceptability to ensure application of a more integrated approach to flood risks.

Birkholz et al. 2014 suggest that disaster management strategies are beginning to relay a greater degree of emphasis on perception strategies to enhance communities' adaptive capacity and social resilience against flood risks. The survey findings described in this chapter indicate that communities are dynamic with different viewpoints on flood risk management. They are not a single group or entity with a consistent level of understanding and opinions. For integrated flood risk management this complexity will need to be acknowledged and appropriately accounted for.

Scott et al. (2013) emphasise that there is a need to build social capacities of communities and local organisations to manage flood risks. They elaborate that the increased emphasis on non-structural measures requires greater involvement of the public for integrated flood risk management (Merz et al. 2010). Understanding flood risk perceptions of communities, therefore, provides a better understanding of building resilience and social capacities to cope with floods.

7.8. Conclusions

Information from the survey presented in this research demonstrates that there is a difference in the way people perceive risks and anticipate flood risk management. The results of this community survey also show differences in expectations between two groups—the experts (chapter 7 explains expert perceptions in detail)—and the residents of the Hawkesbury-Nepean floodplains. Having different expectations is more likely to create false hope and a lack of clarity about the role and responsibility of agencies engaged in flood management which leads to a lack of trust and low participation in government-led consultative processes.

Risk perception studies have been conducted in isolation in the Hawkesbury-Nepean catchment and little evidence exists for their integration in consultation processes for flood management. There is a need to ensure that the social dimensions in the current technical-led risk assessment paradigm are understood and integrated in risk management strategies. There is also a need to focus on research that explores the factors that trigger communities to make decisions towards flood mitigation options. This would provide a greater level of understanding about what locals' value and how engagement processes can be improved to address their values and concerns.

While the residents generally lacked knowledge about the scale of the catchment, they strongly endorsed the idea of a regional agency to coordinate flood management in the Hawkesbury-Nepean region. A regional agency was seen as an opportunity to reduce multiple tiers of governance, to enhance councils' ability to manage floods locally through expert inputs and to create a more holistic understanding of the entire catchment—knowledge of one region being impacted and its influences on other areas in the catchment was considered to be valuable information. The subsequent chapters examine other regional scale models implemented in Australia, for their strengths and opportunities in establishing a regional and a more participatory flood management framework.

Chapter 8: Analysis of a Catchment Scale Management Framework and its Implication for Flood Management in NSW

8.1. Introduction

Issues of uncertainty are a characteristic of a dynamic Social-Ecological System (SES) as described in Chapter 2 of this thesis. Extreme weather conditions enhance this uncertainty and thus the need to increase the adaptiveness of social and environmental systems. Discussions in the preceding chapters have attempted to highlight the barriers in the current system of flood governance in NSW. They can be broadly listed as follows:

1. Challenges of information exchange and coordination—Risk assessors require more standardised information on flood risks. Effective communication of risks for communities is needed to increase awareness to make informed decisions.
2. Barriers to learning exist due to prevailing socio-political interests that drive natural resource management agendas.
3. Barriers to effective management due to difference in perceptions on flood risks, acceptable level of risks and expectations of various stakeholder groups such as the community groups, real estate groups, insurance companies and policy decision-makers at state and local levels in terms of flood management responsibility.
4. Issues of scale in flood management of the Hawkesbury-Nepean catchment.
5. Extreme weather events continue to disrupt Socio-Ecological-Systemss resulting in socio-economic losses with environmental damages. (The 2015 storm event in Sydney, at the time of this research, was a recent example reinforcing the need to improve governance in flood management, as argued in this thesis.)

The following is a brief account of the impacts of the 2015 storm event, that were below a 1% AEP event, and the potential of similar events that could incapacitate existing mechanisms for flood management in NSW. It also demonstrates the critical value of perceiving and understanding risks to ensure implementation of a well-coordinated plan.

On 20th April, 2015, the Sydney region was hit by massive storms and heavy rains that lasted for about three days. More particularly, the impact was observed in the Central Coasts, Sydney Metropolitan, Hunter and Illawara districts (Visentin 2015). Three consecutive days of high winds of 90 km/h to 130 km/h with 220 mm of rain had fallen on the

Sydney CBD, 'making it the wettest two-day spell in 18 years' (Bagshaw, Aubusson & Fallon 2015).

A NSW police member explains the intensity of these events: "To give you a sense of the size and scope—in Dungog there's more rain that has come down in the last 24 hrs than they have seen in a 24 hr period for the past century" (NSW Police, cited in ABC Radio Australia 2015).

These severe weather events caused by the East Coast Low have occurred frequently in the past causing flood conditions for shorter durations. According to Pepler & Alexander, The Conversation (2015) these events had caused widespread flash flooding in the Sydney region in 2012, increased Warragamba dam levels by 14% in 2007 and caused the wettest day on record for Sydney in 1986 with 328 mm of rain falling in 24 hrs. The storms of April 2015, however, presented a greater challenge to the SES, with its increased intensity and the longer duration of the storm event. "This is one of the most challenging situations that we [State Emergency Services] have been involved in. Historically this kind of low pressure trough hits hard and leaves quickly. That has certainly not been the case this time" (Bagshaw, Aubusson & Fallon 2015).

On 22nd April, 2015, the 24 hr rain event resulted in over 100 mm rainfall in a number of regions. In Tocal, Hunter Valley, 100 mm rainfall was recorded in just one hour (The Conversation 2015). The following table (Table 8.1) shows the estimated rainfall during a 24 hr period in some regions.

Table 8.1. Rainfall records during a 24 hr storm

Location	Rainfall (mm)
Maitland	301
Seaham	152
Tocal	171
Dungog	312

(Carney & Michael 2015; Hannam 2015; The Maitland Mercury 2015)

It was reported that the lower Hunter River, at Belmore Bridge, peaked at 8.91 metres. Average normal levels of Hunter River at Singleton are under 2 metres during non-flood conditions (NSW Government, Office of Water 2015). Thus an intense rainfall event for a short duration of 24 hr increased water levels near Belmore Bridge by several metres. A similar situation was observed in Paterson River at Gostwyck Bridge, where the river levels peaked at 15 metres. Williams River at Mill Dam Falls and Dungog received major flood warnings with river heights expected to reach 11 to 9 metres respectively, while normal river heights ranged less than a metre during non-flood conditions. Hunter River at Raymond Terrace experienced minor flooding, whereas Wollombi Brook at Bulga peaked at 7.2 metres (The Maitland Mercury 2015). The normal river height at this location is less than 2 metres (NSW Government, Office of Water 2015).

Continuous heavy rains and an abrupt increase in river heights led to twelve communities being declared as natural disaster areas around the Sydney and Newcastle regions (Bagshaw, Aubusson and Fallon 2015). Flash floods in the Hunter Valley killed three people with a number of houses swept away by flood waters. This mayhem led to the loss of electricity to about 205,000 houses (Bagshaw, Aubusson & Fallon 2015). Waves three metres high crashed onto Sydney beaches leading to the spillover of Manly Dam (Visentin 2015). Disruption of transportation due to damaged wires and fallen trees led to road closures (Bagshaw, Aubusson & Fallon 2015). About 180 schools were closed and many remained closed for the three days in the affected regions. According to the news report the SES was swamped with rescue operations as the Georges River burst its banks.

Milperra residents were urged to evacuate immediately by the SES Sydney. They were told not to delay the evacuation as roads would be congested or closed and that the people might find themselves trapped. The residents were informed that remaining in the flooded area would be dangerous and would pose a risk to their lives (Beech 2015).

Despite the evacuation warnings, 80% of residents chose to stay. The residents perceived the problem to be under control and not severe enough to take the necessary action (Beech 2015). Some of the extracts from the news reflects the community's response:

> Water doesn't do you any harm, you've got a boat to float.
>
> It's only water, it's not a bushfire
>
> There are a lot of high level houses around here but there are a few low level houses that will bear the brunt of it.

This presents a very relevant example of what this thesis argues—how perceptions can create complexity in dealing with extreme weather conditions.

The Sydney storms also had an impact on the western region where flood warnings were also issued in the Hawkesbury-Nepean region (Kembrey and Robertson 2015). More particularly, the Putty Road reached 5 m with minor flood warning (Hawkesbury Gazette 2015). In addition, minor flood warnings were given to the North-Richmond and Windsor bridges (Kembrey & Robertson 2015). The Sydney Morning Herald photographer reported flooding at the Edmonson Avenue near Thirteenth Avenue in Austral (Kembrey & Robertson 2015) which is part of the South West Growth Centres. Chapter 5 of this research discusses the potential increase in flood issues due to development of these Growth Centres in the next two decades. The Penrith region also experienced 70-80 mm rain in a single day during the April 2015 storm events resulting in inaccessibility to some of the routes (Interview 01, May 2015).

If the full force of this storm had occurred or moved further down south-west hitting the Hawkesbury-Nepean region, the impact would have been catastrophic considering the narrow gorges of its natural topography that would have led to a rapid increase in flood-depth; a large population trapped in the region mainly blocked by rapidly rising flood waters at the North-Richmond and Windsor bridges. A rapidly developing area with increasing risks of flash floods and runoffs would have entrapped the 70,000 residents living in the floodplains. Management would have been difficult with the prevailing low flood risk perceptions of the people living in these regions (See chapter 7 for details on community perceptions). Brief discussions with a council representative from the Hawkesbury-Nepean region and the SES managing the western region provided useful insights on the scale of the problem of managing such a flood, had it occurred in the Hawkesbury-Nepean catchment.

> If we had that sort of rainfall in this region, the main problem that we will have to face is that a number of roads will be cut off. Some parts of Penrith and Emu Plain area will become flood islands. If the Nepean River breaks its banks and follow a different path…then some of the properties will become inaccessible and people will be trapped in flood islands; they won't be able to get out. Some properties are high flood islands where they are above the 100-year flood but [even then] access will be cut off, [whereas] some properties are in low flood island where they are below the flood planning level, they will be hit - Mulgoa and Castlereagh roads will be cut off (Interview 01, May 2015).
>
> The Hawkesbury-Nepean catchment is a large catchment and the potential impacts of such a storm event will also depend on the conditions of the Warragamba dam and they are most affected by the storm. If the entire region is hit by the storm, then a large quantity of water will hit the region (Interview 01, May 2015).

The council representative emphasised: “If we have 70 mm rain throughout the catchment we will experience a large flood. Even 40-50 mm of rain hitting the entire catchment for a couple of days will be a problem” (Interview 01, May 2015).

Sydney and its surrounds have been experiencing frequent extreme weather events either in the form of having the hottest days on record or having the wettest days causing flood issues. Bushfires in the Blue Mountains in 2013, and the floods of April, 2015 present recent examples of the likely weather extremes that this region faces under a rapidly changing climate. This unpredictability places a greater degree of reliance on formal and informal institutions to proactively manage the natural systems and reduce negative impacts. The current barriers to flood management, as described in this thesis, present challenges to adaptation and increase risks to society.

In the light of the barriers identified, chapter 8 and 9 examine two frameworks that manage resources based on natural boundaries. The objective of these chapters is to identify strengths in these two frameworks that address the barriers and provide opportunities for NSW flood management. In doing so, they intend to address the first research question and the respective objectives of this research thesis.

8.2. Method of inquiry

An initial document review was carried out to develop a general understanding of the governance of the Victorian floodplain management framework. It should be noted, however, that at the time of this research, the governance structure for flood management was reforming, hence some organisations and their role at the time was undergoing change and by the time this research was finalised some departments became redundant. This was followed by nine semi-structured interviews with representatives from Councils (four interviewees), CMA (four interviewees) and the State agency (one interviewee) responsible for flood management in Victoria. In order to get a range of perspectives on the current governance, the interviewees selected were either team leaders in floodplain management/hydrology or flood warnings, emergency coordinators or policy officers. The discussions were focused on the following themes:

- Role of their organisation in Flood Risk Management
- Views on catchment-scale versus jurisdictional approach to flood risk management
- CMAs' involvement in planning and development
- Flood information-sharing and coordination mechanisms
- Acceptable flood risk levels and community consultations.

The following is a detailed analysis of the information consolidated from the interviews and the implication of the Victorian floodplain management model for managing floods and its relevance for the Hawkesbury-Nepean catchment.

8.3. Overview of the governance structure

Floods are a common occurrence in Victoria. Since the 1850s there have been 59 moderate to major floods in the state, an average of a major flood occurring every 10-20 years (Parliament of Victoria, Environment and Natural Resource Committee 2012). Recent floods of 2010 and 2011 have been the worst in Victoria with significant floods also occurring in 2012 impacting the North and West regions of the state (Parliament of Victoria, Environment and Natural Resource Committee 2012).

In Victoria, three major agencies played a critical role in floodplain management at different spatial scales described below (Figure 8.1).

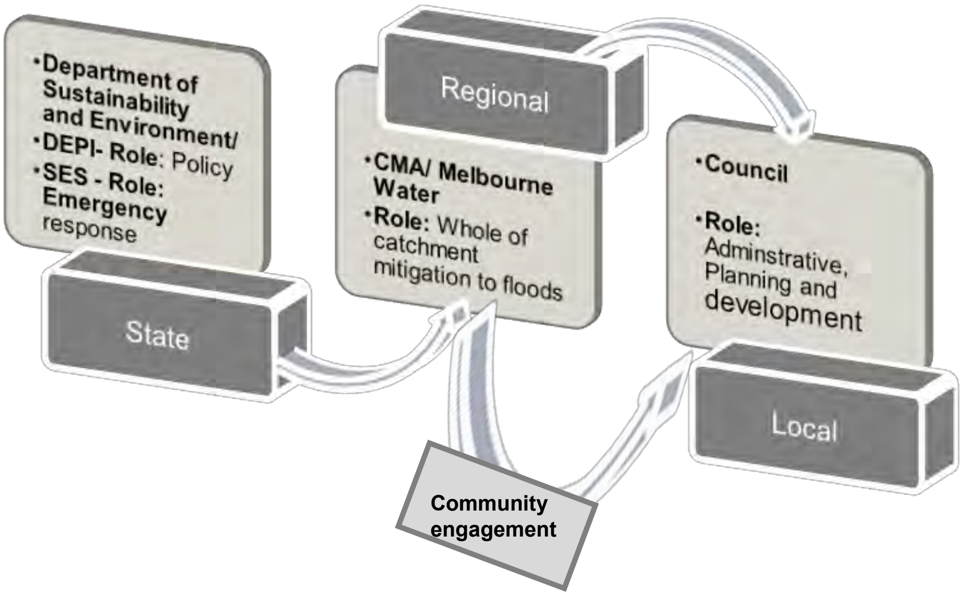


Figure 8.1. Flood management in Victoria

The Department of Environment and Primary Industries (DEPI) was, at the time, responsible for implementing flood policy (Interview 2, July 2014). It provided support to the floodplain management authorities at a regional level. The responsibility of the state government was also to develop legislation and standards for floodplain management and to provide inputs to national policy. This state-level agency also maintained a state-wide database on floods known as the Victorian Flood Database (VFD). At the local level it provided support to local government in implementing mitigation works for reducing flood risks.

> DEPI [was] the floodplain management unit called the water group of DEPI and we provided the policy oversight for the whole state. If there was any tweaking to policy, changes to board rules, regulations, we were responsible for that. It could be a top-down approach where we would say that we need

> to do this or a bottom-up approach where a land owner or CMAs would take the initiative —based on these different parties we would get the big picture of what was going on within the community and then we could tweak policy based on what was happening with the community (Interview 2, July 2014)

The role of the State Emergency Service in Victoria is similar to NSW where the agency facilitates flood emergencies and takes part in community education and awareness of flood risks.

CMAs are central to catchment scale management of floods in Victoria. There are ten floodplain management authorities including Melbourne Water which has a slightly different role—it is responsible for flood forecasting and warnings for the metropolitan area of Melbourne. The Bureau of Meteorology (BoM) has responsibility for this role for the rest of the state. BoM is not a water utility unlike Melbourne Water. It is also a water utility and has the rating powers, unlike the CMAs (Interview 3, July 2014). In Victoria, CMAs hold the primary responsibility for developing floodplain management strategies for their respective catchments. This entails carrying out regional scale flood studies leading to a flood risk management plan. They are also referral bodies that respond to planning and development issues in the flood prone areas. These regional agencies collaborate with the SES in flood emergency situations and monitor flood warning systems and coordinate flood information exchange (Government representative, per. Communication, June 2014).

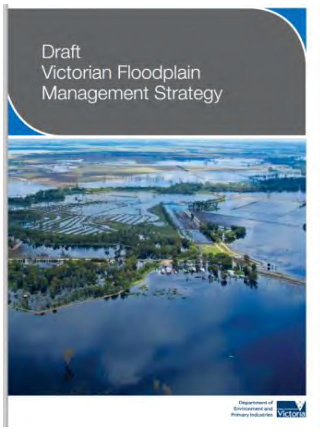
At a local scale councils take on the responsibility of implementing local floodplain management plans, implement development controls, providing flood mitigation infrastructure and monitoring significant flood events as well as managing urban flash floods.

The following section highlights the strengths and weaknesses of the floodplain management framework (Total Catchment Model) of Victoria and its implications for managing floods in NSW.

8.4. Strength I: Mechanisms that increase coordination and connectivity across different scales of governance.

The Panarchy framework dictates the need for a nested set of institutions to manage resources at various scales. Such an arrangement allows for better integration to deal with scale-related problems (Garmestani et al. 2009). The arrangement for flood management in NSW provides two tiers of governance; state agencies that drive policy discourses and local authorities that are bounded by jurisdictions. A regional level governance mechanism to manage at a catchment-scale does not exist. However, in Chapter 6 (section 6.5), the value of a catchment-scale regional strategy was highlighted by some of the flood managers and strategic planners for the Hawkesbury-Nepean catchment. Emphasis was on its benefits to improving consistency and coordination provided that councils continue to implement local floodplain management plans to address local issues.

The Victorian catchment-scale management model provides opportunities in this regard. The framework for flood governance in Victoria is guided by a state-level floodplain management strategy which is informed by a regional strategy thus linking local issues to regional and state level targets, thereby providing a mechanism for double-loop learning. This process allows for an integrated management of floods at different scales of governance.



The development of the current draft Victoria Floodplain Management Strategy (VFMS) was triggered by the recent floods, to ensure a better understanding and preparation for future floods. The draft strategy addresses some of the major issues that have been defined as barriers to flood management in NSW, in the previous chapters of this thesis. The strategy sets guiding principles to address the problem of assessing flood risks and sharing information as well as issues of improving risk communication of communities residing in the floodplains and improving coordination with insurance entities.

The previous chapters (6 & 7) of this thesis provide evidence in the way different groups have perceived FRM and their understanding about 'who's responsible'. Lack of clarity on who should do what in flood management is not unique to the Hawkesbury-Nepean Catchment. An inquiry into flood mitigation infrastructure in Victoria reports that their existing complex regulatory and governance framework has created difficulty in understanding roles and responsibilities of different stakeholders involved (Maddocks 2012). "Review found that the division of responsibilities between agencies was unclear, increasing the risk of overlapping roles, duplication of effort and confusion' (Victorian Auditor-General 2014, p.14).

In the Victorian context the existing regulatory system deals with this predicament through the state-level Draft Victorian Floodplain Management Strategy. The Strategy defines the institutional arrangement through identifying agencies accountable and outlines expected roles of the agencies involved.

The strategy distinguishes between shared responsibility and accountability. Under each problem issue discussed in different sections of the Strategy, it clearly identifies agencies accountable for proposed actions. Some examples of extracts from the Strategy under sections of developing regional strategies and information database appear here. (State Government Victoria 2014). (Figure 8.2)

Accountability 8a:

• DEPI is accountable for setting flood mapping standards to meet the needs of a range of uses, including land use planning, insurance and emergency response.

Accountability 8b:

• DEPI and Melbourne Water are accountable for maintaining and continually improving guidelines for the management of Victoria's flood databases.

Accountability 9a:

• Melbourne Water and the CMAs are accountable for developing and periodically reviewing regional floodplain management strategies in partnership with their local communities.

Figure 8.2: Selected extracts from the Draft Victorian Floodplain Management Strategy

The Strategy identifies accountable authorities, streamlines proposed policy actions required to address a particular issue in flood management in Victoria and identifies the alignment of the strategy with other policies and plan on waterways, flood emergency and recovery, regional growth plans and local flood studies. In doing so, the strategy allows for an improved level of understanding of where and how this fits into the Victorian and national approaches to disaster resilience (State Government Victoria 2014). It can provide clarity on who is doing what and what is expected from whom in the context of disaster management in general and flood management in particular. It also provides opportunity to avoid the overlapping of responsibilities and better resource allocation.

8.4.1. Regional floodplain management strategy

The draft strategy sets the premise for regional authorities (CMAs) to develop a regional floodplain management strategy. It defines the need for a regional strategy to identify and prioritise regional and local issues (Interview 4, June 2014). The process entails the assessment of flood risks across the region and developing mitigation measures to reduce risks where it is possible. In NSW, limited resources and funding issues seem to constrain the development of flood studies as councils compete for funding (discussed in Chapter 6). Consequently, a number of flood studies have been slow in their development or revision (Chapter 5, sections 5.6 and 5.7). A regional strategy could provide a more regional perspective to prioritise the need for identifying areas that require flood studies and the possible impacts of implementing mitigation measures in the entire region. It can also allow for more collaboration across the councils as expressed by an interviewee:

> It provides economy of scales where one shire on that floodplain couldn't afford to do something so two to three shires collectively can afford to do it. [Through a regional strategy] they can see all sorts of things collectively (Interview 5, June 2014).

The development of regional floodplain management strategies is carried out through engagement with other agencies such as the SES, local councils and the local communities, thus providing opportunities for information-sharing and the alignment of priorities of involved agencies with each other (discussed in further detail in section 8.5).

The risk assessment framework described in the VFMS demonstrates a top-down and bottom-up flow where the state sets the framework to assess regional flood risks and where a regional strategy defines regional priorities that derive state-wide priorities for investments (See Figure 8.3 below). The regional strategy defines problem areas that require mitigation solutions and implementation of risk management plans emerging from local flood studies.

The draft strategy is developed at the state level and in that it is indicated that there needs to be regional floodplain management strategies that the CMAs would do and then each council can conduct their flood study within the area that they might have a problem (Interview 2, July 2014).

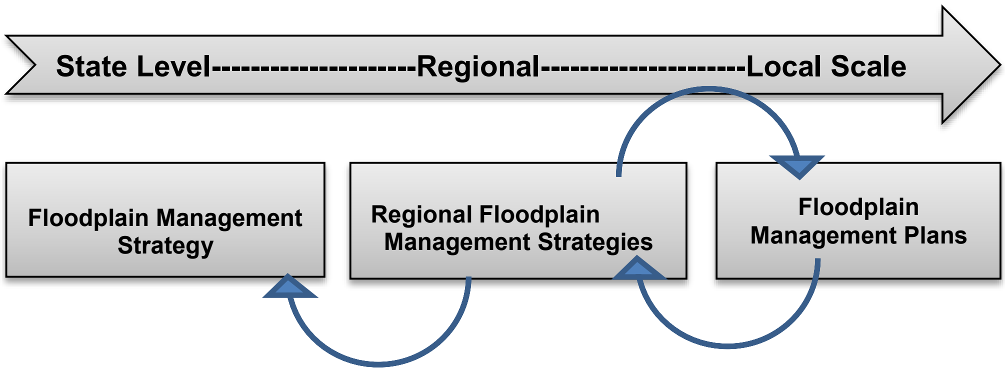


Figure 8.3. Flow diagram representing a bottom-up approach

The process provides an opportunity for consultation and coordination between local communities, relevant agencies and their associated networks thus providing a framework to impart shared responsibilities and a greater level of involvement by all. This ensures inclusivity and encourages learning through a top-down and bottom-up approach, a necessity for establishing adaptive governance for dynamic SESs (Lyle 2015; Wyborn 2015). Chapter 9 elaborates more on double-learning processes.

Although the Victorian state government does not have a floodplain development manual that defines the process of identifying local flooding issues via flood study, resulting in a flood risk management plan, the process is consistent with the NSW Floodplain Development Manual. Interviews with the local council in Victoria confirmed this.

> There is a three step program that the council runs. The first is the flood study; the second step is another study that involves the creation of a digital model for the flood and answers the question about what may be done about the flood in terms of mitigating it. The third step is to carry out those program programs and or civil works that are identified in the second study. The council seeks funding for the first one and then the council seeks funds for the modelling and flood mitigation. Community consultation with the second stage plan is done quite extensively. Normally we have some sort of a steering group and a technical group and at the end of that process, once you have a document that says something, you then consult again with the general community (Interview 6, August 2014).

For the Victorian floodplain management the recent floods served as a catalyst to instigate action and critically assess current flood management issues. The development of the state level strategy also emerged from an audit conducted to assess the effectiveness of CMAs (Victorian Auditor-General 2014). The audit highlights a number of shortcomings that resonates with the limitations highlighted in this research thesis in the context of the Hawkesbury-Nepean catchment. Primarily, there is a need for a long-term vision and goals that can be established through the development of a state level strategy emerging from regional priorities of flood management. The development of a regional strategy would require competently equipped regional agencies to coordinate and manage the development of a regional strategy, such as the Catchment Management Authorities. The state level strategy also addresses issues of accountability thus providing clarity on roles and responsibilities of the organisations involved. There is a need for triggers that put in motion actions that serve to provide a better understanding of natural disasters. In the Victorian context, the recent floods of 2010 to 2012 led to the revision of the existing strategy to address institutional issues in the current flood governance framework. In NSW, massive development in floodplain regions of the Hawkesbury-Nepean catchment have resulted in a state-led review to identify opportunities for better flood management. Despite the ongoing research, the development of an umbrella strategy that would guide state-wide priorities and address local flooding issues has yet to be determined.

8.5. Strength II: A regional model to managing floods across jurisdictions

Institutional arrangements are a very critical aspect of determining the extent to which adaptive capacity can be mobilised for flood risk management (Wilby & Keenan 2012,

p. 357). Regional scale flood risk analysis supports long-term planning and creates an enabling environment for adaptation (Gouldby et al. 2008; Lamb et al. 2010; Jeuken et al. 2015). The Catchment and Land Protection Act 1994 and the Water Act 1989 provide the legislative framework for Catchment Management Authorities in Victoria to manage waterways and have control over floodplains, drainage and environmental water (Victorian Auditor-General 2014, p.4). This regional model provides the following opportunities.

8.5.1. Community engagement and partnerships framework

Developing a regional strategy is about prioritising what information is available and what is needed—it helps to define future works (Interview 5, June 2014). In addition, with regard to the role regional strategies play in prioritising activities, it also provides for a community participation framework to create an enabling environment for adaptation. McEvoy et al. (2010) & Smith et al. (2011) emphasise the need for developing frameworks that encourage community involvement, acquire local knowledge and engage in flood risk management to enhance community resilience and adaptation.

In the Victorian catchment-scale flood management model, community engagement takes place at two critical levels. First, during the flood risk management process, communities are engaged to provide anecdotal information of their experiences that helps to build flood models to forecast future flood events (Interview 4, June 2014). This process is similar to the NSW floodplain management model. The second level is through the development of a regional strategy that links landholders and people to direct regional action which in the interim informs state-wide strategy (Figure 8.3, above). In general, this bottom-up approach to floodplain management takes place through a steering committee which has representatives from state, regional and local agencies involved in natural resource management. The committee receives technical support from experts and other inputs from various community groups (Mallee Catchment Management Authority 2013).

The *Community Engagement and Partnership Framework* defines an approach for CMAs to engage and develop partnerships with various community groups in all its interventions to gain the desired outcomes for natural resource management (Victorian Government and Victorian Catchment Management Authorities 2012). CMAs' role is to facilitate partnerships and coordinate interventions to improve catchment health. The framework helps to set out expectations and defines a process to review and evaluate community engagement effectiveness. The framework allows for engagement of various community groups in the development of a regional strategy so an integrated approach to management takes place rather than one driven by a one-party or group agenda. Survey results on community perception (Chapter 7) showed that around 42% of the respondents had no idea about CMAs in the Hawkesbury-Nepean Catchment. Out of the 172 respondents, only 12% actually participated in CMA-held meetings. In addition, 11% of the respondents felt that having a regional agency to manage floods was a waste of tax payers' money and rather, local flooding issues at council level should be dealt with instead. Additionally another 10% expressed their lack of understanding about the value of having a regional agencies to manage floods (Chapter 7). These results indicate that there is a need for more effective engagement of communities to increase their knowledge and understanding about flood issues on a broader scale. Developing a regional strategy through a *Community Engagement and Partnership Framework* might be a viable option to increase the understanding and involvement of communities living in floodplains, but also to facilitate more cooperation from residents towards local and regional catchment management interventions.

8.5.2. CMAs as referral bodies for planning

CMAs make a direct contribution to planning at the local level by bringing regional perspective and knowledge to enable more informed decisions in relation to floodplain management. Discussions with interviewees provided information on what this entails. As a requirement of the Victorian Planning and Environment Act 1987, if there is a flood zone or overlay where development is proposed, then the council is obliged to forward the application to the relevant CMA (Interview 2, July 2014). This process allows councils to gain expert opinion from other government agencies. It enables CMAs to act at a statutory level for a particular development of concern and provide inputs, and also at a more strategic level in terms of shaping new areas of development (Interview 4, June 201). The CMAs as referral bodies have the authority to permit development or prescribe conditions to development in floodplains or reject applications based on the flood risk to the location under consideration. This process has been in place to ensure that broad-scale impacts are being considered and incorporated in the existing system for flood governance.

Recent reforms in Victoria, however, have changed this critical role of CMAs from a referral to an advisory authority. This has been implemented to expedite the approval process for planning and development (Maddocks 2012). Since the referral process was designed to ensure that development does not occur without consideration of the broader impacts, this change is being critically viewed by some.

In the past, the role of CMAs as referral bodies meant that the council had to abide by their decisions for development in floodplain regions. Under the most recent government reforms, this role has been changed and the council is not obliged to follow-through the recommendations of the CMA (Interview 5, June 2014). As expressed by an interviewee that councils have fewer resources and limited staff, CMAs are meant to be the experts in understanding the flood risks; hence, their decisions in planning would be based on better judgment (Interview 5, June 2014).

Another interviewee highlighted that this change may place councils under political pressures where they might be forced to take decisions in favour of development despite the risks involved:

> It's certainly not strengthening floodplain management on our (CMA's) account, because it gives councils flexibility to respond to competing demands so they might think that a particular development is worth a risk whereas in the past they didn't have that discretion. So in the Victorian model, we (CMA) had that decision-making role. We have now become more like the NSW model where we are just advising councils on risks (Interview 4, June 2014).

While the role of CMAs as a referral body provides opportunities for NSW, the recent change in their role within the Victorian flood management context may create problems of state agencies by-passing council decisions—a situation similar to the planning and development processes in the Hawkesbury-Nepean region, described in Chapter 4 of this thesis within the context of the Blue Mountains region.

8.5.3. Catchment approach versus jurisdictional management of flood risks

This thesis bases its argument on a framework which suggests that SESs are complex embedded systems. Therefore, SESs are seen as nested panarchic systems that are influenced by multiple factors from other levels and scales (Garmestani et al. 2009; Wyborn 2015), as discussed in Chapter 2 (Section 2.4). The current management of floods in the Hawkesbury-Nepean takes into account a more jurisdictional approach to flood management. This section examines the implications of a catchment-scale approach.

In this context, mixed responses were received from floodplain management experts and the residents of the Hawkesbury-Nepean catchment (Chapter 6 and 7). Nevertheless, the majority expressed the view that a catchment-scale model for flood risk management was a more suitable approach. Around 73% of the 172 Hawkesbury-Nepean catchment residents agreed that a regional agency was needed to help improve coordination for floodplain management. Most of them expressed the view that the current governance system has burdened councils which have limited resources and expertise to effectively manage flood issues (Chapter 7, section 7.6). Others viewed the current approach of having a limited understanding of flood impacts on a broad scale as acceptable. In general, having a single entity to manage floods was seen as a practical approach for improved coordination between agencies, better utilisation of resources and an effective means to provide more integrated information. Flood management experts and risk assessors in the Hawkesbury-Nepean Catchment argued that having a single regional plan would allow for better integration of natural resource targets and a more centralised information flow, and it would help develop consistency and standard sets of controls for floodplain management. Some interviewees however, indicated that to have a regional entity to manage floods at catchment-scale will present a problem in terms of its ownership and funding.

In the light of these concerns and interests, flood management experts from some of the councils and CMAs in Victoria were contacted to gather their views on the feasibility of a catchment model and the challenges it presents. They deemed a catchment-scale model to be the most practical approach. It was argued that council cooperation was much easier when CMAs are in charge of the flood management process across the catchment (Interview 6, August 2014). CMAs were considered to drive the process of flood management due to their technical expertise in the area (Interview 7, July 2014). A council representative expressed that CMAs in Victoria have helped to bring agencies together to work with each other. Since there is no legislative requirement for agencies to come together and in most cases they are working in parallel, dealing with the same issues, CMAs have helped to coordinate interventions between agencies (Interview 8, July 2014). CMAs were seen as having more control over assessing impacts as they have a better understanding of the bigger picture whereas councils only work in their constituency (Interview 2, July 2014).

> We support that model we have that broader, whole of catchment perspective whereas individual councils would only be interested in individual areas. The rivers cross councils' boundaries so you obviously need that broader perspective to understand the system properly. And again in my view what it does bring is economy of scales so it is more efficient for us to have 4-5 specialists in our region, instead of having one in each council (Interview 4, July 2014)
>
> CMAs provide technical expertise, and I actually doubt that all the councils in NSW have the relevant expertise in their staff; they will still need to outsource. So one way of outsourcing that expertise is having a government agency that has the expertise in-house which makes it a lot cheaper to access without having to go to a new proponent (Interview 2, July 2014).

Discussion with an interviewee who had flood management experience in NSW and Victoria, highlighted the benefits and challenges of the approach. From this respondent's point of view, a catchment-scale approach for the entire Hawkesbury-Nepean catchment was deemed critical to have a whole-of-catchment understanding. The respondent expressed the view that the Victorian model is a good 'technical' model whereas in NSW it is a better 'political' model (Interview 4, July 2014). While drawing comparisons between the two models, the interviewee elaborated that councils in Victoria effectively outsource flood management to CMAs due to this; they seldom are as engaged in the process as they are in NSW. In comparison, in NSW, council laws are motivated by flooding as the councils have the responsibility to manage floods in their region, whereas in Victoria that risk is being outsourced to CMAs. One of the challenges that were highlighted in the Victorian model of flood management was engaging councillors and councils to make sure they understand flood risks and respond to them.

> I think the Victorian model is certainly a better model. I also think it is important if you do have that structure in place that you retain those decision-making responsibilities; that you don't give the discretion to council because if you want a consistent quality of floodplain management decisions then that decision-making power has to be taken away from the council because of the political pressure that they are often put under. In my view that is the critical step, and that is the step backwards that Victoria has recently taken, that we've handed that decision-making power back to councils, and now it is open to that political interference whereas in the past it wasn't so (Interview 4, July 2014).

The interviewee emphasised that the critical aspect of flood management is to have the decision-making power with a regional entity to overcome political pressures. This was considered as a positive outcome of having a catchment-scale flood management model. Political pressures might discourage councils to conduct flood studies. An open and fair process could jeopardise the ability of the council to continue rating for certain areas of its land, so councils at times are reluctant to initiate flood studies (Interview 2, July 2014)—a problem also highlighted in the NSW context. In a catchment-scale model, having an entity like a CMA presents a solution to overcoming political barriers and decisions based on the prioritisation of areas in the regional strategy. This could help to push for developing flood studies in problem areas and oblige councils to make that information available. Chapter 6 of this thesis indicates that similar political barriers exist in the Hawkesbury-Nepean catchment where councils have control over floodplain development and management.

In NSW, different approaches to the management of floods by regional and local government entities have challenged collaborative interventions. In the Victorian model, the CMAs help define regional priority areas where flood studies are required whereas the council seeks funding from DEPI (state government) to carry-out flood studies. The funding arrangement includes one-third federal, one-third state and one-third local government. CMAs help identify flood regions and councils, and in most cases are the funding applicants

(Interview 6, August 2014). More often cooperation from councils is based on 'good will' rather than a legislative obligation. For instance, councils at the bottom end of a creek would have higher priority for flood studies then councils at the top end.

> There is no forcing of hands, some councils are very proactive and some are not. The ones that don't want to comply are usually left for last. If the council doesn't fund then that is an issue (Interview 3, July 2014).

> So what we find is towards the bottom end of the creek the council would consider [floods] as a big issue and will seek funding from the government and the CMA will then be involved in the prioritising of that funding within the catchment, where it is more needed. Currently the CMAs are at the side of the process, whereas in fact they should be running it' (Interview 6, July 2014).

The Victorian government does not have a floodplain development manual as is the case in NSW but the general process of flood management in Victoria follows similar stages, as explained in the section above. Some of the interviewees felt that CMAs should be given more autonomy in terms of seeking funds for flood studies.

> The state government puts it upon councils to organise these things. What should happen is that if the CMA is responsible for what happens in the creek systems and that can go over several councils, then the CMA should carry all these studies and then the mitigation can be done in conjunction with the council …the whole thing is completely upside-down. What they are doing is that the state government is pushing it [flood studies and their funding] on to the councils. When councils have no jurisdiction! (Interview 6, July 2014).

A representative from the state government argued that having councils involved in the process ensures their ownership. It is a struggle but their involvement is critical.

> We prefer that councils should be the entities initiating the flood study because they are the ones that determine land-use planning in the end. They are the ones that manage the land of the municipality. If the CMAs become applicants for a flood study project then the council sometimes partially disagree with it but we are trying to make councils take ownership of this. The issue is sometimes it works, sometimes it doesn't (Interview 2, July 2014).

Other challenges in the CMA model presented by interviewees were of cost and resources. For instance if a region has a flood warning system set-up then it becomes an issue of 'who would pay for what'? Which gauge they should pay for and how much? It is a real challenge as the council's interest is at a jurisdictional level rather than the entire catchment (Interview 5, July 2014). Another issue is to retrofit mitigation works in certain regions which were developed without any consideration for floods. Being a catchment-scale authority, there is a need to be prepared at all times if an event escalates to an entire catchment, which is unusual, but it requires catchment authorities to be prepared and have all hands on deck at all times (Interview 2, July 2014).

8.5.4. Implications for NSW

The New South Wales government was the first to institutionalise the whole-of-catchment management approach. The philosophy of adapting a holistic approach to NRM began in the 1980s and was brought about through the enactment of the Catchment Management Act 1989 (Natural Resource Commission 2010). The 2003 reforms identified thirteen Catchment Management Authorities (CMAs) across NSW (Natural Resource Commission 2010). The then established Catchment Management Authorities were responsible for managing natural resources within their jurisdictional boundaries through the development of Catchment Action Plans (CAPs) designed to allow achievement of NRM state-wide targets (Natural Resource Commission 2012). The following diagram (Figure 8.4) illustrates the position CMAs held in NSW for developing catchment-scale action plans for natural resource management in relation to other state and local agencies involved.

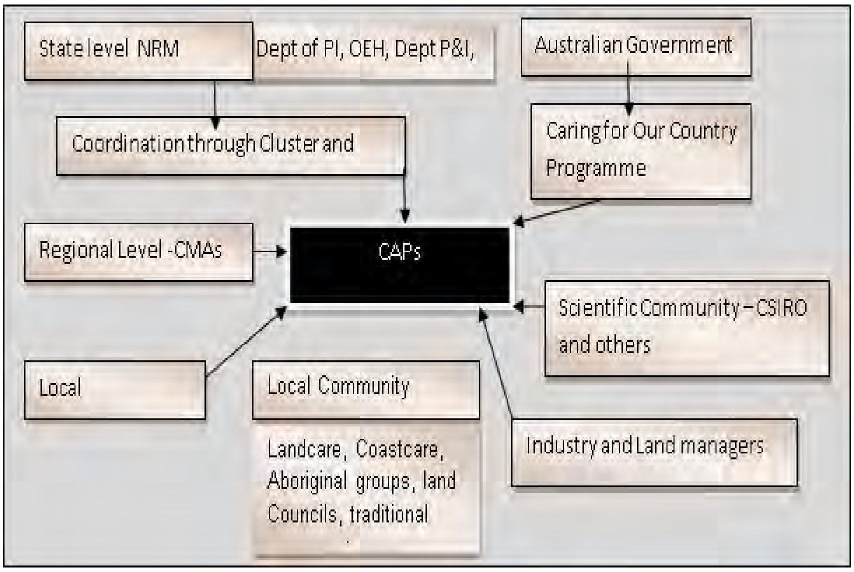


Figure 8.4. Organisations linked with CMAs' CAPs

Although former CMAs in NSW were catchment-scale entities for NRM they had no role in floodplain development or their management. With the governance reform these catchment-scale entities have now become part of the Local Land Services. The following flow diagram (Figure 8.5) represents the current governance framework where councils are central to flood management. CMAs or Local Land Services, the two regional scale organisations, are excluded in the current system of flood governance in the Hawkesbury-Nepean catchment.

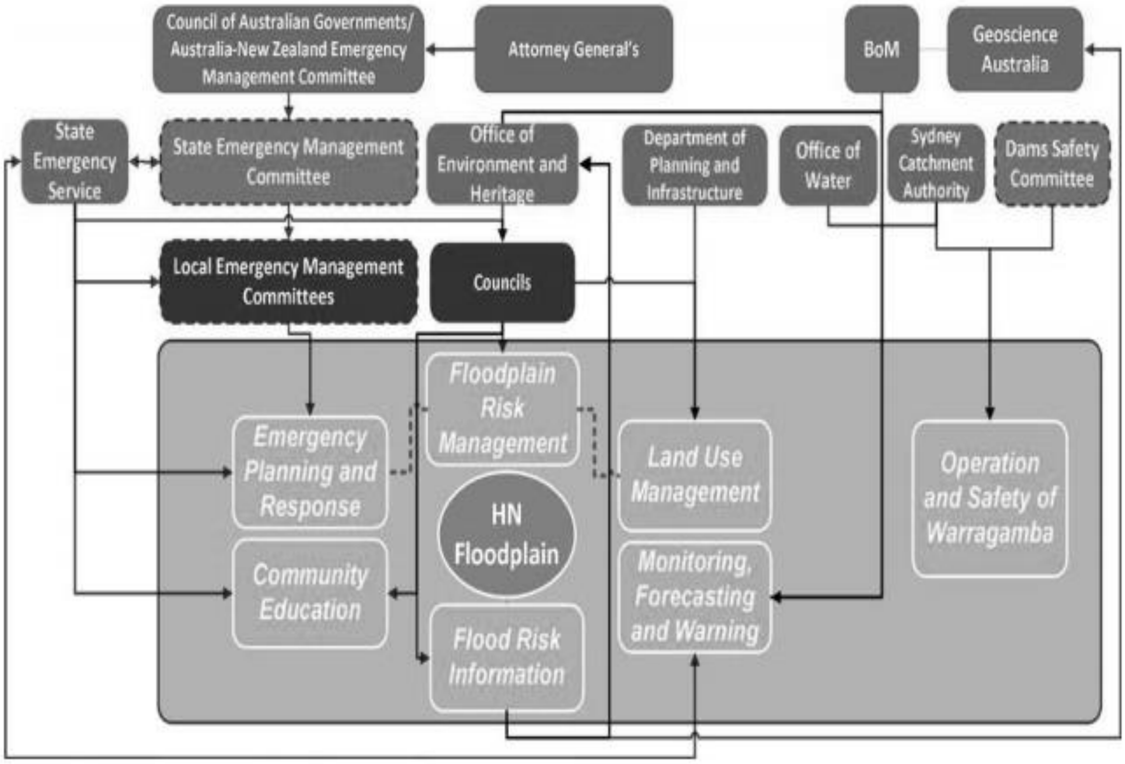


Figure 8.5. Existing flood governance framework of NSW (NSW Office of Water 2014)

This leaves limited opportunities for establishing a new agency or reinstating CMAs as regional agencies for flood management. The review of the Victorian catchment-scale flood management model represents an example of a workable framework. It also provides insights to key performance issues that can serve as critical lessons to overcome in order to increase the effectiveness of regional-scale flood management. Current socio-political drivers in the Hawkesbury-Nepean catchment can present opportunities for management of floods to exist at a catchment-scale. Ambitious development agenda in the western region of Sydney has led to an increased focus on floodplain councils to develop flood studies to assess potential flood impacts. In 2014, a flood management review was initiated as a result of growing concerns about flood risks (NSW Office of Water 2014). The review is intended to recommend practical solutions to reduce flood risk in the Hawkesbury-Nepean Catchment. Recent survey (Chapter 7) and views expressed by flood managers (Chapter 6) indicate that there is a general consensus that having a regional agency would ensure more effective flood management and its governance. While the current review provides an important trigger for reforms in NSW, the Victorian model provides important lessons that need to be considered for sustainable flood management in the context of NSW:

1. A regional body should have autonomy over planning decisions to overcome political barriers. The role of a 'referral agency' needs to be explored further in this context.
2. The community engagement and partnerships framework for Victoria's CMA with its monitoring and evaluation of the process provides a useful reference for enhancing community awareness and involvement in flood risk management.
3. A catchment-scale agency could increase opportunities of coordination and integration between councils and community groups strengthening social capital and system resilience.
4. A regional agency can serve as a single point source for expert opinion and information on floods for the wide range of stakeholder groups with different interests curbing problems of duplication, overlapping and effective resource utilisation.
5. Challenges in flood management presented to the CMAs as a regional agency in Victoria can provide important lessons to take measures to overcome them that would encourage council engagement in the process.

8.6. Strength III: Custodianship and increased access through centralisation of data—community education strategy to improve risk communication

Flood information in Victoria is centralised through an online portal. According to Molino (Molino 2009) the need to develop a flood information portal was to provide easy access to communities and other agencies to enhance preparedness to future floods. The Victorian Flood Database (VFD) was developed as a dynamic information source that provides GIS-based information. To ensure consistency, new information is updated and is streamlined against a prescribed format to aid consultants in developing standardised information. The *Draft Victorian Floodplain Management Strategy* identifies DEPI and Melbourne Water as accountable agencies for continual improvement and maintenance of the database (State Government Victoria 2014).

Through semi-structured interviews with representatives from Councils, CMAs and State, access to flood data, issues of custodianship, VFD utility and information exchange between different entities were discussed.

In Victoria, funding for flood studies is shared between federal, state and local governments; therefore, custodianship of data is also shared between these agencies. The councils would receive data as they have a contractual relationship with the consultants. The information is then shared with CMAs and the State agency. Council's responsibility is to receive the latest flood research information and upload it in the online record system for use by CMAs (Interview 6, July 2014). The purpose of having a VFD is to have one source of information. For public entities, information is provided for free and for others such as insurance companies, or consultants hired by a private developer there is an administrative fee for the use of this information. So if an insurance company goes to a CMA, Council or DEPI, they will be provided the same information through this centralised VFD (Interview 2, July 2014).

The CMAs also provide a flood advice service to anyone who needs to know the risk to their property. Such information is available on the website but in most cases it is difficult for people to comprehend the risks; hence, a flood advice service is available for use (Interview 7, July 2014). In addition, at the local level, councils generally have provided a web service based on a property or street name—information on flood water depth or floor level of the building can be acquired (Interview 8, July 2014). Councils are required to provide any new information that could affect mapping, to be uploaded on the VFD (Interview 2, July 2014). Any public entity is able to contact the council, CMA or DEPI directly for information. If they contact some other agency they are re-directed to the custodians of the VFD (Interview 2, July 2014). So information on floods is accessed through a single centralised source to ensure consistency and ease.

Molino (2009) suggests that communities play an important role in flood management but more often lack awareness about their flood risks and the subsequent actions to be taken. Risk perception survey results in Chapter 7 of this thesis highlight the different perceptions of residents in the Hawkesbury-Nepean catchment. Around 35 percent of residents living on the floodplains of this catchment perceived their property to be of low to medium risk. About 39% felt that their property had no flood risk at all, all residing in the 1% AEP flood zone. One of the challenges currently faced by floodplain experts in the Hawkesbury-Nepean catchment is the effective communication of risks to communities (NSW Office of Water 2014).

The development process of the VFD provides important lessons to address issues of community access and how their need to acquire flood information can be enhanced. As technical advisors in the development of VFD, Molino (2009) argued that centralisation of flood information can provide a critical point of contact between risk assessors and the community. The process of developing a centralised source of information necessitated understanding community views and their knowledge about flood risks. To increase the utility of the VFD, a preliminary community survey was conducted to gauge community perception and awareness of risks before, during and after a flood. The survey provided a greater level of understanding for increasing the utility of a web portal for flood information. More particularly, the survey helped defined parameters of the VFD, identify effective means to direct people to the portal, locate specific information that people will need with regard to flood risks to their property, understanding when it is more likely that individuals will access the portal and who else (e.g., councils) needs access to the portal to increase the accessibility of the information.

The development of the VFD demonstrated that people tend to 'look for' information about flood risks when purchasing or making alterations to their properties. To address this issue, the design of the VFD incorporated prompts that help people get the information they need. The prompts were designed so that people looking for specific information can easily find it, and people who don't have any idea about their flood risks can also be informed through further prompting, and use of information buttons. As Molino (2009) states "it lets people start with something which they know to guide them to what they do not know and probably did not realise that they needed to know" (p. 5). This is very relevant to the findings of the risk perception survey described in chapter 7, where a wide range of risk perceptions about floods can be potentially influenced by gender, age group and proximity to the flooding rivers, thus providing important information on triggers that shape perceived risks. The development of an information portal for NSW will need to take into account the current understanding of 'at risk communities' in relation to floods, the information that they think they need, and the opportunity to also learn what they did not know but needed to learn.

The development of the VFD portal also addressed the need to link information, as often information is available on different websites. Due to the large content of these websites it becomes difficult to identify the relevant information. Including links to these websites in the portal enabled easy access to relevant information. The VFD provides a continual improvement mechanism through the evaluation of its contents by the users and incorporating feedback.

Disclosure of information and access to flood risk at property level via this portal can help community members to make informed decisions when purchasing and selling properties in the floodplains. Access to information from this portal is also provided to insurance companies. The Victorian Floodplain Strategy clearly identifies the core agency, which in this case is the DEPI, to ensure that access to the required information is provided to insurance agencies to assist the insurance industry to calculate premiums that are realistic (State Government Victoria 2014). Survey results of residents' perception (Chapter

7) in the Hawkesbury-Nepean catchment also indicated the need for access to information by new and existing residents interested in purchasing or selling their property. During the face-to-face surveys, (see chapter 7, section 7.6.2) many residents felt that information about properties at risk is scarce and that real estate agencies fail to provide sufficient information. In addition, access to data in a form or language that would be easy to understand was also identified as an important requirement. The FVD establishes a process that addresses issues of the type and form of information needed and where can it be accessed. It takes into account the communities' concerns in its design to enhance its utility. Issues of concern are quite similar to information needs highlighted by the participants of the survey conducted in the Hawkesbury-Nepean catchment, as explained in the previous chapter of this thesis.

Studies suggest that there are a number of physiological factors that hamper an individual's response to internalise risks and be motivated to take action (Molino 2009). This has been discussed in Chapter 2 (section 2.2 & 2.5) under *vulnerability, resilience and adaptive capacity of Social Ecological Systems (SES)* which highlights that knowledge and information is not entirely sufficient to sustainably manage complex SESs; rather, the context in which learning takes place is more critical. Henceforth, social and institutional barriers influence the up-take and utilisation of information (See Chapter 2, socio-cultural and political dimensions of learning in NRM). The assumption that increased access to information would create more awareness leading to action, fails to address the heterogeneity of communities with different priorities, needs and values (Boura 1998; Paton et al. 2003). This is also demonstrated in the first section of Chapter 7 (Section 7.6) where different communities perceived risks to their property based on a number of other socio-economic factors and low risk perceptions. In most cases, where there is low community response to preparedness for hazards there are a number of psychological perceptions that drive their indifference. Communities may have low perceptions of the risk, safety or mitigation options because it conflicts with their belief systems or that the communication of risk is ineffective and they fail to understand the messages—a situation identified during the Sydney storm events of April 2015. There is also a perception that no amount of preparedness will be sufficient to avoid a disaster or the expectation that the relevant public authority would take the necessary actions to avoid any disasters (Boura 1998; Finnis 2004).

COAG (2011) provides national guidelines to manage disaster through 'shared responsibility' that enables agencies and other stakeholders including communities to work towards developing resilience to natural hazards. Dufty (2011) established that to improve disaster resilience there is a need for disaster resilience learning (p. 36). This would require moving away from the traditional top-down model of learning where information is supplied to individuals with the assumption that it will direct community action towards preparedness (O'Neill 2004). This reality is evident in Chapter 6 of this thesis, where most of the state and local authority representatives interviewed related that communities are incapable of making informed decisions about flood risk and that the responsibility of defining flood risks should be left to the experts. The results of the community survey in Chapter 7 also suggest that some of respondents were in agreement that they lack the capacity to provide inputs in defining flood risks. A large majority, however, agreed that they would like to be part of the process to assess flood risks. The potential benefits they perceived were greater levels of ownership, increased knowledge about the issue through a participatory process and being part of a plan to deal with hazards. Dufty (2011) states that resilience to disasters requires 'preparedness' and an important element of 'preparedness' is community education. Education and engagement processes should be embedded in strategic plans for their long-term implementation. Education program programs should also include communities and the evaluation of these programs is a critical process of ensuring a meaningful learning process for behavioural change (Molino & Huybrechs 2004).

8.6.1. Implications for NSW

In the context of NSW, developing an information portal through a community consultation process can provide useful information about their needs. Survey results on community perception in chapter 7 of this research thesis have served to provide useful insights into the residents' perception. Although the response of 172 participants does not reflect the views of all, nevertheless, it can provide critical parameters for launching better education and awareness program on flood risks. For instance, survey results in chapter 7, show that around 23% of the respondents indicated the internet as their primary source of getting flood risk information. The majority, about 41% suggested that they would expect their local councils to provide this information and a very small portion (only 5%) and less respectively indicated SES, BoM and other agencies like the CMA as useful sources of information on flood risks. Another 5% indicated that they did not need information on flood risks as they preferred to rely on their experiences and lower risk perceptions of flood in the region. These results reflect a similar situation in Victoria where a survey of residents in Melbourne and regional Victoria indicated that the majority, 77% of the community identified councils as the primary source of information, CMAs (5%) and SES (6%) were given relatively less importance as information providers (Molino 2009). Around 50-55% identified the internet as a primary source of information. These results are important indicators to demonstrate that communities use different sources for information. Increasing the utility of web portals by councils is critical, along with internet access throughout the region. Without having such understanding, developing a comprehensive information portal may not necessarily increase the utility of that information source by the floodplain communities. Communities may prefer to rely on their own experiences or if they have a lower risk perception, they would more likely ignore flood intelligence.

The purpose of providing a detailed explanation of the VFD development process, in this section was to develop an understanding about the critical aspects of designing this portal that may increase the utility of such an information source among the public and other users. Through learning about VFD, two critical aspects of developing a web portal can be identified: understanding the needs of communities and other stakeholders including insurance companies for information; and defining ways to direct communities to access this information pool. It is not sufficient to have a web portal to assume that it will be readily used by communities 'at risk'. It is important to understand the barriers that render the utilisation of such information for people to take appropriate actions. Molino (2009) advocates that a comprehensive flood education strategy is needed that addresses the psychological barriers and measures to overcome them—an education strategy that connects people to information via the website (pp. 2). This systematic process where education interventions are long-term, are embedded within an education strategy that encourages people to 'look for information' when making decisions and interlinking regional and local flood management plans can increase the need to access flood databases for meaningful information that is relevant and easy to understand.

8.7. Inadequacy of the existing Victorian floodplain management framework

The strategy outlines that the existing 1% AEP flood level will continue to be used for planning and development purposes in Victoria. The responsibility lies with local council to ensure that the 1% AEP flood standard is adhered to in planning schemes (State Government Victoria 2014). Through discussions with interviewees, it was emphasised that this standard was considered to be more economically viable and practical to implement despite the fact that communities would want zero flood risks.

> The design flood of 1% AEP hasn't occurred yet. It will be pretty significant. What the community would say is that they won't ever want to be affected by a flood. Any community would say that, even ours would, but the cost of trying to do that would be just astronomical even questionable if you could do it, physically. The costs are absolutely millions. If a person in a rural area says we don't want to be flooded the cost would be in billions because it is not built. So you need to set-up something which is reasonable—that is where the 1% AEP came from (Interview 6, July 2014).

> 1% AEP has been a standard used in Victoria. In the past it has been set by engineers. The document 'Australia rainfall and run off' developed by the Institute of Engineers [is the guide being used for planning] (Interview 7, July 2014).

The interviewees were also of the view that engaging communities in identifying their acceptable risk is not workable as communities would want zero tolerance to risks. They were considered to be lacking in expertise to make such decisions.

> I did a survey among the community about what protection they wanted from a flood or drains. We did 100 surveys. Most said they don't want the street flooded in a 100 year storm. To protect the streets against a 1-in-100-year storm, the cost would be over five times what the community is currently spending (Interview 6, August 2014).

According to a state-level representative, the floods of 2011 have raised questions as regards letting the communities decide what risks are acceptable to them.

> The thinking is changing a bit that the users pay and so the user should take the risk as well. Others around the world are adapting a much more cautionary flood risk levels to 500 or 1000 years flood levels in places like the Netherlands and England. One of the recommendations from the Victorian floods was to do just that, and the 1% AEP flood level be reconsidered. At this point there has been no real response to that. It would be interesting to see where this is going. What is coming around is highlighting people about their flood risks rather than just saying your property is above 100 year flood levels, so you are safe (Interview 5, June 2014).

The transition towards planning beyond 1% AEP is currently not in practice in the Victorian catchment management framework for some of the reasons mentioned above. The recent floods, however, have put in motion the need to communicate all types of risks to the community and creating a niche to impart a more shared-responsibility paradigm.

> So for instance if the levee was to be proposed and the community could only propose to construct it for a 1 in 50 and they were happy with taking that chance then I think now that is a viable option (Interview 5, June 2014).

8.8. Evaluating governance framework of Victorian Catchment Scale model

The following is an assessment of the Victorian Catchment Scale framework. The framework is evaluated against Lockwood et al. (2010) criteria for good governance. An additional rating column is also added. The (+) represents the good governance attributes of this model as per the assessment criteria. The (-) symbol represents the shortcomings in the existing models and also highlights areas that need further investigation to rate it. Overall this model fulfills the criteria for good governance fulfilling most of its attributes.

#	Principles	Good Governance Attributes in Victorian Catchment Scale Framework	Rating
1	Legitimacy	A valid organisation exists to govern flood risk management. • The legal organisation exists in the form of the *Department of Environment and Primary Industries* at state level, which oversees regional implementation. • Legislations and policy standards are developed at state level under this organisation. • The governing role of this authority is to provide national policy inputs, which lower levels of governance dictate. • Provides support to local levels in mitigation works. • Stakeholders can influence decisions through policy inputs at regional level.	+
		• Degree of quality of dialogue and consultation requires further analysis. • Decision structure is semi-rigid.	–
2	Transparency	• The decisions made by the responsible authorities are displayed on the website. Documents for public viewing are also available. • The responsible authorities claim that information is provided to whomever requests for. • The regional authority is responsible for	+
		• The degree to which stakeholders are comfortable with the provision of information on organisational performance needs to be explored further.	–
3	Accountability	• A very strong feature of this model is accountability which is defined by clear roles and responsibilities of agencies involved through its state-level strategy. • The strategy is informed through a regional strategy that incorporates local context.	+
		• The governance process are to a large extant still controlled through a top-down management structures	–

4	Inclusiveness	• Another strong feature of this model is its inclusiveness. • • Figure 8.3 demonstrates the degree of inclusiveness in this framework. development process for floodplain management plans engages different stakeholder groups. These plans are then incorporated in a regional strategy which brings in regional stakeholders at multiple-level within a particular scale. This in turn informs state-level policy objectives and engages state actors. • This catchment scale model also supports a community engagement and partnerships framework. See section 8.5.1 for details.	**+**
5	Fairness	• A genuine respect for others was observed through discussion with different interviewees. There exists a certain degree of satisfaction with the performance of agencies involved in flood risk management. • The biases are controlled to an extant as a result of the referral role formally performed by the CMA to control development.	**+**
		• There is, however, a need for further investigation to explore conflicts and biases for an in-depth analysis of the framework under this criterion.	**–**

6	Integration	• The Victorian model supports a catchment scale as oppose to jurisdictional management model. This allows for better integration across different scales of governance ensuring horizontal and vertical connectivity and coordination (See section 8.5.3).	+
7	Capability	• The development of a floodplain management authority at catchment level, which is solely responsible for managing flood risks, is the highlight of this model. Unlike NSW flood governance model where councils are expected to have the capability to manage floods in addition to fulfilling other responsibilities, the CMA model in Victoria provides the required set-up to enable informed policy decisions due to its dedicated technical staff. It provides an effective business-knowledge system to deliver flood management obligations. • The referral role of CMA planning demonstrates the capabilities of this organisation (Section 8.5.2)	+
8	Adaptability	• The Victorian Flood Database serves as a dynamic source of knowledge for all stakeholders. The database is constantly updated thus providing critical information, which is a strong prerequisite for adaptability (See Section 8.6 for details).	+
		• The use of 1%AEP is in place that deters the degree of flexibility to a certain degree in order to adjust to a rapidly changing climate.	–
[1]According to Lockwood et al. (2010) this overlaps with the first principle but the primary focus of the first principle is representation and acceptance where as inclusiveness focus of opportunity for participation.			

8.9. What does this mean for SES resilience and adaptive capacity?

An examination of the Victorian flood management model has been conducted in this chapter to highlight practices that create an enabling environment to increase understanding of coping with system dynamics. Wilby & Keenan (2012, p. 352) suggest that such enabling measures are 'low regret' as they yield benefits regardless of the climate outlook but are not cost-free. 'Systems that exhibit resilience to system shocks have structures and behaviours that appear to correspond to the characteristics of complex dynamic systems' (Davies 2015, p. 237). The Victorian model provides social and institutional mechanisms that can enhance systems' adaptive capacity. For instance, having a strategy that streamlines accountability, roles and responsibilities inculcates important questions such as 'who decides', 'who acts' and 'who is responsible'. It creates a context where system resilience is examined by defining acceptable thresholds and working towards maintaining those thresholds (Wiering et al. 2015; Li et al. 2016). The need for catchmentisation and regional scales has been explicitly discussed and argued in this thesis (see Chapter 2,4,5,6 and 7). These approaches provide a better understanding of a complex system to increase their resilience, evaluate institutional mechanisms and encourage an environment of learning and participation across different scales of governance (Abesamis et al. 2006; Wang & Blackmore 2009; Newig & Fritsch 2009; Mostert 2012). Davis (2015) elaborates that increased levels of interaction of communities with managers and scientists can help to develop a more realistic understanding of disasters which can enhance communities' adaptive behaviour which then can be linked to regional scale strategies. The Victorian flood information model provides opportunities to communicate critical information to all. 'Climate risk information is arguably the single most important asset for adaptation planning' (Wilby & Keenan 2012, p. 5). Engle (2011) argues that developing adaptive capacities requires recognition of social and political processes where learning requires interpretation to inform different interest groups. This is possible if local communities are engaged in the process and local interventions are linked with regional strategies as demonstrated in the Victorian floodplain model and further elaborated in Chapter 9.

8.10. Conclusion

The Victorian floodplain management framework provides important lessons and opportunities for improving governance of floods in NSW. More particularly, aspects of this framework pertaining to a state and regional floodplain strategy which defines responsibilities and accountability; catchment-scale flood management; community engagement framework; and development of a centralised flood information portal that enhances community knowledge and access to relevant information on flood risk are significant features of this framework. These require further examination for assessing the feasibility of such opportunities to improve flood management in the Hawkesbury-Nepean in particular, and in the Sydney basin of NSW in general. The following chapter examines another regional scale framework that places a greater level of emphasis on local governance and community-centred approaches to managing nature resources—a much needed feature of flood management in the NSW.

Chapter 9: Analysis of a Biosphere Framework and its Implication for Flood Management in NSW

9.1. Introduction

This chapter examines another regional model that although specifically does not address flood management, it serves as a useful model for NRM governance at an appropriate scale for addressing flood issues discussed in this thesis.

To analyse the opportunities and strength in a biosphere framework, the Noosa Biosphere Reserve (BR) has been taken as an example case for this purpose. This chapter mainly focuses on the participatory governance and learning component of this framework. A detailed assessment of changes in the governance framework is described within the context of socio-political barriers that have influenced the structuring of its management model. Changes in the reformed governance model are discussed to lay emphasis on a double-loop learning process implemented in the Noosa Biosphere and the opportunity it presents for flood management in the Hawkesbury-Nepean catchment.

9.2. Method of inquiry

A review of online documents and information acquired from the Noosa BR were reviewed to determine the geographical features of the region and its governance system. In addition, five 30-minutes interviews and two email correspondences were conducted with representatives who had been involved in different capacities to manage this Biosphere. As with the Victorian model at the time of this research thesis, the Noosa BR was undergoing de-amalgamation and reforms in its community-based participatory governance model. This provided an ideal opportunity to hold discussions with members involved in the previous, as well as the current model of governance to draw comparisons and understanding about how a BR functions and what changes have been prescribed in the new governance model and why. The contents of discussion broadly revolved around the following:

- Involvement of the representative in the Noosa BR management
- Views on the de-amalgamation of the Noosa BR
- Old and new governance model, how it worked and what were the challenges?
- What the new model has to offer?

9.3 The concept of learning laboratory and what it means for Noosa's Biosphere Reserve framework.

Chapter five of this thesis explored the significance of the ecological components in a Social Ecological System to maintain ecosystem health. In this context, a case study of the hanging swamps in the Blue Mountains was discussed. The need to protect hanging swamps as vital ecological systems when faced with management issues was explored. This was critical to demonstrate the significance of interdependency of a SES such as the Hawkesbury-Nepean catchment as one complex but inter-connected system. Biosphere reserve models, in principle, harness a governance model that goes beyond confined protected areas (SEQ Catchments 2011). Its objective is to harmonise conservation and economic development.

One of the socio-political barriers discussed in chapter 2 (section 2.5) was the prevalent command-and-control governance paradigm under the scientific management approach which leads to single-loop learning to address all problems. Examples of this prevalent paradigm are evident in Chapter 5 where conservation issues and local concerns are often ignored in the interests of economic growth. This approach limits the need for social interactions as integral part of a learning process and hence fails to address anomalies through science. The preceding chapters demonstrated the application of such a paradigm prevalent in the case study area where flood models are used to frame mitigation options. The community engagement process is merely a consultation exercise to prioritise mitigation options. Decisions on flood risks remain centralised and are left to the 'experts'.

Chapter 2, of this thesis, defines conditions that strengthen the adaptability of a SES, one of which is building on the social capital, to have institutions and well-established networks to share and utilise information. Two conditions of an adaptive process of governance were described earlier in this research (Chapter 2, section 2.6); the principle of learning by doing, and having different scales of governance that allows for a more flexible decision-making process to include a diversity of knowledge and values. In principle, the governance model of Biosphere Reserves relies on the above mentioned adaptability principles for effective management.

The context of a biosphere reserve is set in the back-drop of protecting core regions of national and international importance through sustainable development. The framework addresses the interconnectivity between nearly pristine natural systems to progressively developing ones. In theory, it intends to achieve this through establishing a predominant culture of an actively learning community, knowledge generation through innovative research, and strengthening of local governance that builds on and encourages the growth of existing social capital—pre-requisites of an adaptive system. This section examines the application of these principles in the Noosa Biosphere Reserve. The objective is to explore how principles of a biosphere are applied in practice and to determine the feasibility of such an approach to address issues discussed in managing the Hawkesbury-Nepean catchment.

9.4. Why the Noosa Biosphere?

Noosa is one of the fourteen Biosphere Reserves in Australia (Richardson & Davis n.d.) and was established in 2008. The Noosa Biosphere boundaries include the Noosa Shire council and its adjacent coastal waters, three kilometres offshore (Noosa Biosphere Ltd 2009).

Conservation of this Biosphere needs to take into account influences of extreme weather conditions. The region is potentially under threat from inland flooding and sea-level rise as a result of climate change. South East Queensland has been identified as a hotspot for climate change with increased growth pressures (Noosa Biosphere Ltd, n.d.). Sea-level rise and future storm patterns can potentially change the geography of coastal communities in Queensland, including regions such as Noosa (Hoffman 2011). A flood map generated by the Noosa Council indicates that areas surrounding inland lakes such as Lakes Cootharaba, Coorolbah and Weyba, are likely to be inundated in a major flood. In addition, Noosaville and areas around the Noosa River, which is the main waterway of the Biosphere, are likely to be seriously impacted in a major flood scenario (Noosa Council 2012). As a biosphere, it is required to address challenges identified by the UNESCO Man and the Biosphere program. A biosphere's management framework, therefore, should respond to issues of climate change, conservation, rapid urbanisation (Noosa Biosphere Ltd 2009). These issues encapsulate management challenges discussed in the Hawkesbury-Nepean catchment thus providing justification to review the Noosa Biosphere. A preliminary interview with a former employee of the Noosa Biosphere Limited in 2012 formed the basis of considering the Noosa Biosphere Reserve as a case study to identify best practice, owing to its unique local governance model and learning laboratory institute concept.

9.5. Strength I: Polycentric form of governance that builds on social capital

'One of the central tenets of adaptive management is polycentric governance' (Mostert 2012). Chapter 2, section 2.6 of this thesis defines the polycentric form of governance. This form of governance matches the 'management scale' with the 'scale of the problem' that requires management (Mostert 2012). Advocates of polycentric governance establish that this aids in addressing local needs, encourages local participation, implements learning through experimentation framework and allows governance systems to be flexible and capable of self-organisation (Abesamis et al. 2006; Herva's-Oliver & Albors-Garrigos 2008; Ostrom 2010; Biggs et al. 2012; Mostert 2012). Public participation at different scales of governance can help to develop efficient and effective environmental polices (Newig & Fritsch 2009). In addition, cross-level interactions with different stakeholders are critical in building social resilience (Abesamis et al. 2006).

This section describes how polycentric governance has been established in the Noosa Biosphere. At the beginning of this thesis in 2012, the Noosa Biosphere operated on a different governance model which transformed into a new management model in 2014 (Interview 1, March 2015). Both models (old and new) work on multiple levels of governance. A detailed explanation of the governance system is explained in this section to demonstrate how multi-level governance systems can be established to address issues of scale.

Noosa's biosphere management extended across several local government areas. Prior to its de-amalgamation in 2014, it was managed by the Sunshine Coast Regional Council that provided financial support to the Noosa Biosphere Limited (NBL) – a company with an organisational framework to work on behalf of the community to manage the biosphere.

The old and new Noosa Biosphere models rely on a community partnership governance model (Noosa Biosphere Ltd 2009). In the amalgamated model (old model), the biosphere was governed by a main board that brought together members from council, community and six sector boards: Cultural, Economic, Social, Environmental, Tourism, and Education, Research & Development (Richardson & Davis n.d.). One of the critical prerequisites of managing a Biosphere Reserve is the involvement of communities as main stakeholders. Pujadas and Castillo (2007) state that social participation in biosphere management is critical and can be advantageous to both managers and local inhabitants. Noosa Biosphere governance through its six sector boards helped to open channels of communication and collaboration with the communities of this biosphere as highlighted in its vision statement.

> NBL will fully and openly engage the Noosa community through the sector boards, public consultation and other means, to promote sustainable development' (Noosa Biosphere Ltd 2009, p. 6).

This was further elaborated by a former NBL member:

> [Building on] social capital, is a really big part of why we are doing the Biosphere Reserve. Before it, we were in a situation where we were already going through continuous improvement but like I said all the environmental groups would work with each other and all the social groups like social development groups were linked, but what we have gotten through the Biosphere Reserve model is not just to link different sector groups but to work more collaboratively (Interview 2, April 2012).

The driving principle of the Noosa biosphere governance model (both old and new) is that sectoral integration is necessary to achieve sustainable outcomes. To achieve this, the sector boards would serve as useful instruments to coordinate and bridge between socio-cultural, environmental and economic interests and address issues of conservation through them. This is underpinned by a dynamic research and education process that facilitates implementation of new learnings.

> When we started [the idea was that all] sector boards work together, now they realised that it is much easier to get things done if they collaborate with one of the other boards so no one sector benefits (Interview 2, April 2012).

> There are quite a number of organisations, hundreds of organisation doing their own things. There are very few that look across the entire sector which was the benefit of the sector boards' (Interview 3, March 2015).

This community-based governance model is based on strong volunteer support. As such, the sector boards did not have any legislative authority and their responsibilities were defined by the council but, in most cases, projects were identified by these sector boards and endorsed by the NBL (Noosa Biosphere Ltd 2009).

> The model [enabled] people to contribute at a level that suits their interest and lifestyle. At the same time this model ensures that there is a close and productive relationship with the council and that there is a high level of governance in the operations of the overall process' (Interview 2, April 2012).

> 'The strength [of the sector board model] was the reach. By having a sector board model it was quite easy to see that [the sector board members] wear different hats, they [were] out there engaging people. It would go across many different groups so it went to Catchment Associations, we had people involved in development in the greater Sunshine Coast area and really touched on a decent part of the active community. So I guess that was one of the main positives of that model that it actually did do quite well to reach out to a vast array of stakeholders and people who have an interest; in that way it was quite a successful tool' (Interview 4, April 2015).

While the sector board model was seen as a governance model that provided a greater community outreach, such a model with its broad outreach didn't create efficiency in delivering the outcomes of the biosphere. 'The model was a good communication tool [but] it probably was not the most effective tool to get projects out of the ground pretty quickly' (Interview 4, April 2015).

9.5.1. Governance issues in the Noosa Biosphere

Section 9.9 of this chapter discusses some of the challenges for successfully implementing the biosphere reserve frameworks. A number of these issues existed in the Noosa Biosphere Reserves.

The old governance model of Noosa Biosphere Reserve was considered a workable model, as evident in its adaptation after the establishment of Noosa as a biosphere reserve. Socio-political pressures, however, led to the disintegration of this model. Some of the issues highlighted by the interviewees are listed below:

> The amalgamated council's councillors made principal decisions and a large majority of them represented areas that were not Noosa' (Interview 3, March 2015).
>
> This management was considered to be demeaning the values of Noosa by making decisions that detracted from the essential values for the way Noosa was created and the way it had been managed prior to amalgamation (Interview 3, March 2015).
>
> Its governance model was too convoluted to be understood by the community (Interview 4, March 2015).
>
> There was a perception out there that because the previous entity was owned by the council, it did not have independence' (Interview 4, March 2015).
>
> The sector board was also seen as just a collection of directors selected by the Mayor for NBL. '[Without an organisation] they were just a group of people. With NBL gone they didn't have any standing, without the support of the council (Interview 3, March 2015).

Ravindra (2004) suggests that biosphere reserve management is confronted with issues pertaining to institutional resistance, lack of conceptual understanding, conflict between different interest groups and simple fatigue. These are common road-bumps that locals experience while establishing and implementing this framework. Others have also identified issues of gaining multi-jurisdictional government support; lack of priority of this framework across scales; absence of regional and national leadership; and commitment to encourage public participation as bottlenecks (see section 9.9 for details) (Matysek 2006; Stoll-Kleemann & Welp 2008; Borsdorf 2014).

Ravinda (2004) argues that successful implementation of this model and building a coordinating framework requires time and commitment. Noosa Biosphere in this regard presents a good example of local interests that helped to implement a polycentric governance regime and continued to strive towards improvement. Consequently, the new model was envisaged to maximise community involvement and ameliorate the problems of the previous model. The revised governance model gives more control to communities to manage the biosphere in the form of an independent foundation and trustee that is more likely to overcome the challenges of implementing these regional frameworks in Australia.

The following section describes the new governance model in detail to understand the mechanics of a community-based governance model at regional scale that aids in enhancing the adaptive capacity of a SES and consequently its resilience.

9.5.2. Opportunities for the new governance model

The reformed management model would work at three tiers of governance levels: strategic, coordination and grassroots levels (see figure 9.1 below). At the strategic level the former NBL was transformed to a Noosa Biosphere Reserve Foundation Ltd. The appointed board of the Company oversees the Noosa Biosphere Reserve Trust on behalf of the community. The provision to re-organise the Noosa Biosphere Company to a Trust has been carried out under the premise that the Trust would provide a governance framework that more suitably met the goals of UNESCO's Man and the Biosphere Program, under a trust deed that guides the working of a board of trustees for the Noosa Biosphere Reserve. The re-organisation was also carried out in view of increasing funding opportunities through grants and other private donations (Noosa Biosphere Working Group 2014; per. Communication, 13 March 2015). This will ensure the development of a more self-sustaining and independent organisation. In addition, by having different stakeholders on the board of trustees, it was envisaged to address the issue of the council's sole ownership, thus moving away from a single authority to devolve power and authority to the communities involved.

In the new reformed management model, the Company will be governed by five board members and only one representative will be designated by the council (Noosa Biosphere Working Group 2014). This provides a greater level of autonomy to manage at regional scale.

The council does not own the biosphere company and the council will appoint only one director. The other directors will be appointed by the members of the company and those members are the existing and the former directors unless they had resigned from being members. The council will own 1/8th of the company instead of owning all of it, so that it is a different structural arrangement. Additionally, it is a new company operating as a trustee of the Noosa Biosphere Reserve Trust which is intended to achieve the charitable status from an environmental angle, and thereby obtain some independence from the council. The previous model which the council owned couldn't apply for grants from the government as it was a part of the council nor was it able to receive tax deductibility. "Two key changes to the structure, but in practice I think it will be very similar in its style of operation as the Noosa Biosphere Limited" (Interview 3, March 2015).

The second coordination tier of this new model is more community focused. For this purpose a *Community-based Incorporated Association* is planned to be formed to enhance community representation in the Noosa Biosphere's management. The *Community Incorporated Association* is anticipated to perform a coordination and bridging role that will provide a direct interface between communities and Noosa Biosphere Foundation Ltd., to promote activities and facilitate project submissions. The role of a bridging organisation in improving coordination, enhancing cohesiveness, conflict resolution and facilitating knowledge across multiple levels and between different actors is well recognised in literature (Cash et al. 2006; Olsson et al. 2007; Schultz 2009; Hanspach et al. 2014). The premise for establishing this middle tier was that it would form a hub for Noosa Biosphere whereby grassroots community groups can be part of the decision-making process (Noosa Biosphere Working Group 2014). This would provide a space for dialogue, discussions and a forum for collaborative action as is a prerequisite for nested governance (Wyborn & Bixler 2013). The members of this coordination level will come from the grassroots level. Once again the control of decision-making will not reside with the council but rather with the community.

The third tier is defined as the 'doing level' where projects will take place, where learning is generated and partnerships formed. The management model is organised as such that the flow of learning is guided by both top-down and bottom-up processes. Opportunities of engagement exist between people involved in project delivery and implementation and the strategic board which directs the biosphere management. This is made possible through the coordination level as well as setting provisions to enable the grassroots to join or belong to one of the other tiers. Hence, in principle, learnings from the grassroots transpire to the strategic level. Through this 'open' two-way channel, representatives from the third tier can help prioritise projects and influence other decisions for managing the Noosa Biosphere Reserve.

> The intent is that the new entity will come up with idea or filter the ideas and rather than under the old model where the idea flowed up from the sector boards it works the other way around that people under the new Community Association will effectively be cast as doers…the people who get the time to do surveys, speak to people [broader community] and do those kind of actions (Interview 4, March 2015)

> The Noosa Biosphere foundation will perform at a strategic level but we will need people to do things, organise events, to learn how or whatever the doing side of the biosphere of the future is…so if the Association is up and running they can have their own workforce and structure to coordinate activities [across discipline] (Interview 3, March 2015).

The arrows in the diagram represent information flow (Figure 9.1). The first tier plays the strategic role in carrying out the vision of the Noosa Biosphere as set by UNESCO's Man and the Biosphere program. The middle tier identifies projects that represent the goals of the Biosphere, seeks funding from the first tier, evaluates potential projects and engages the third tier to implement projects. The third tier can influence the selection of projects through joining the other two tiers of management. Thus community members have access to participate in decisions at all levels of governance – a very different scenario to flood risk governance in NSW.

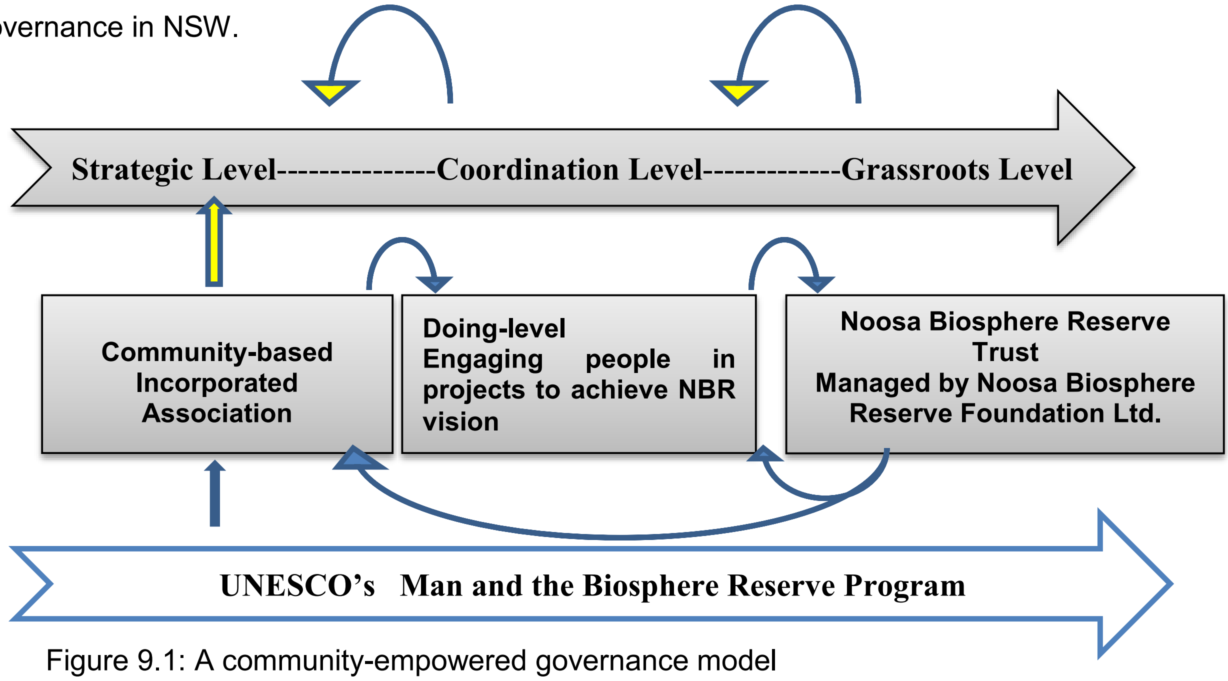


Figure 9.1: A community-empowered governance model

This model provides several components that conform to building adaptive capacity and resilience of a SES. According to Biggs et al. (2012), a broader level of governance can step forward when lower levels collapse or fail. Access to all governance levels, by locals, also enables learning through a diverse pool of knowledge and encourages broader levels of participation (Ostrom 2010). 'This is particularly evident in local and regional water governance where polycentric governance structures facilitate participation by a broad range of governance actors, experimentation and the incorporation of local, traditional and scientific knowledge' (Neef 2009, cited in Biggs et al. 2012, p. 438). This model advances on developing nested platforms where legislative, collective and operational levels work interdependently to deliver a collective action (Sarker et al. 2008). The resultant fortification of social, human and financial capital enhances the adaptive capacity and the subsequent resilience of SES.

The newly transformed Noosa Biosphere model appears promising. However, there are some reservations based on prevalence of negative political influences of the previous model that can be detrimental. Two former directors of NBL expressed concerns indicating that the Foundation, although now independent of the council, is effectively directed by people who are currently involved with the council.

> It essentially means that the ability to totally recast itself and free itself of flavours that it wants to get rid of are highly limited. It is quite likely that the directors that are involved now could have significant influence on how this company acts (Interview 4, March 2015).

In addition, although the company would now be in a position to secure grants from other government agencies, it will also depend on the funding from the council. 'If we don't perform structurally or manage it, the council will not fund' (Interview 3, March 2015).

A representative from one of the partner universities, however, views the new model as an efficient one. While drawing comparisons between the new and old model of Noosa biosphere governance, the interviewee described the new model as more independent in making decisions on fund allocations to projects.

> There is clear separation of responsibility in its new structure that perhaps wasn't the case in the previous structure. Previous sector board members could actually propose projects and also approve them. So I think the roles weren't clearly delineated. Whereas in the new model the board sets the strategic direction and approves funding of projects so it clearly defines their role. (Interview 5, April 2015).

Further commenting on the independence of the new governance model, the interviewee elaborated that the new set-up enables greater level of autonomy to the company in making decisions with regard to funding projects which didn't exist in the old model.

> The council won't have control over the funding. There is a funding agreement that we have signed off now, where the council has granted the money to the company and that the allocation of these resources is up to the 18 independent directors on the board. So it is certainly not driven by the council. In the old model the council had to approve the expenditure but in the new model the council does not approve the expenditure so this is a totally different approach. The directors of the board are all legally accountable and allocate the resources as any company board of directors would allocate resources (Interview 5, April 2015).

The transformation to the Noosa Biosphere Management Model occurred in 2014 and is currently still in process. The effectiveness of this new model will require a time lapse to review what has worked and whether or not this new model has emerged to harness a greater level of community engagement, cooperative partnerships for conservation, sustainable economic growth and increased learning opportunities within and outside the biosphere. It is generally viewed as a timely reformed model that delivers more control to the community. As Ravindra (2004), Pujadas and Castillo (2007) emphasise, there are socio-political barriers in implementing biosphere frameworks as it brings different groups of people and nature together and building relations and coordinating networks across this framework will take time. Every biosphere framework is unique and issues are context-specific (Schultz & Lundholm 2010; Elbakidze et al. 2013).

What the Noosa Biosphere Reserve framework offers is an independent community-driven model which is very different to that found in NSW. In comparison, community engagement models for flood management in NSW involve community representation in the floodplain management committee. The committee comprises council, SES and other state and local government agencies. The process is driven by government agencies and community involvement remains at a representative level. Other consultative processes are carried out during preliminary studies for floods and also as part of prioritising mitigation options for flood-risk management plans but consultations do not empower communities or allow independent action by communities to pursue projects that support their values on what is an acceptable risk to them. The NSW's CMA model and the Victorian framework remains predominantly a government-led process. In contrast, the Noosa Biosphere model offers a more community-led model and has in principle, the autonomy to deliver and implement projects, become involved in strategic planning, coordinating and implementation processes.

Olsson (et al. 2007) identifies one of the challenges in the adaptive governance of Social-Ecological Systems (SES) as the sectoralised and compartmentalised multilevel governance system. This has been demonstrated throughout this thesis in the context of flood management in the Hawkesbury-Nepean region.

> The ability to create the right links, at the right time, around the right issues in multilevel governance systems is crucial for fostering responses that build socio-ecological resilience and maintain the capacity of complex and dynamic ecosystems to generate services for human well-being (Olsson et al. 2007, p. 7).

The Noosa Biosphere governance framework offers bridging opportunities between different stakeholder groups, which are valuable for generating new knowledge and identifying new opportunities (Olsson et al. 2007). Bridging is seen as an extremely critical function in complex SES for dealing with uncertainty. It allows for feedback and the generation of new learning, which is critical for a complex adaptive system.

The Noosa Biosphere governance model demonstrates that implementation of an adaptive management framework requires a culture that values mutual learning and encourages a framework that enables different forms of learning to take place as described in Chapter 2 of this thesis. It has to depend on a process that establishes two-way channels from grassroots to strategy levels (Mendis-Millard & Reed 2007; Levrel & Bouamrane 2008; Axelsson et al. 2013). It has to support an environment where learning can take place in different settings and continues to readjust direction and provide feedback, as new knowledge is generated through trialling and experimenting (Du Toit, Rogers & Biggs 2003; Hahn 2011). The 'top-down' government-led frameworks, as seen in the NSW flood management process (see Chapter 5), advocates adaptive management in principle, but in practice remains caught-up in a scientific management paradigm where scientific knowledge derived from flood modelling guides development agendas and other flood management decisions. Best knowledge is understood to remain with experts and scientific inquiry seems to be the most appropriate approach to tackle issues of extreme weather conditions. The prevailing mindset reflects the lack of acceptability of knowledge gaps that comes with an uncertain future.

9.6. Strength II: Learning laboratories—a critical principle of adaptive management

The Noosa Biosphere vision statement defines the environment in which a biosphere functions: “Your Noosa Biosphere will be a learning community that cultivates harmony between people and nature for both conservation and sustainable development” (Noosa Biosphere Ltd 2009).

Lebel (et al. 2006) talk about ‘openness to learning’ cultures that are defined by practices enabling decision-makers to acquire and integrate knowledge. Learning by doing and multiple-loop social learning at different governance levels strengthens the resilience capacity of a social-ecological system (Schultz & Lundholm 2010).

Discussions were held with the interviewees involved in the Noosa Biosphere Reserve to define what the concept of a learning laboratory means to the Noosa Biosphere and how it is applied. Learning laboratories were seen as a space (virtual or physical) where local knowledge and relevant science are used to derive innovations and to combine the two to gain better results—to create an environment that allows experimentation through the use of different forms and medium of learning.

As one of the interviewees describes:

> I study martial arts. The way you learn martial arts is you take old knowledge, very rigid and very formal. Once you master the movements of the old system, in the next stage you let go of your self-consciousness, and do those things that are your interpretations. So that is what a learning laboratory is. The idea of a Learning Laboratory here is that it really is not just formal old scientific knowledge but it is everything. For example there was a project called floating land, it was art in the environment. This idea was to use artists to interpret contemporary issues of the environment. Last year it was floating land in rising seas so it was about climate change. So this is an experiment as to how can you use art as a medium to communicate complex issues like climate change, climate refugees and climate change adaptation simply in a more universal language. The results were gathered, documented and communicated and that was an experiment (Interview 2, April 2015).

The learning laboratory for the Noosa Biosphere was defined as a place which would allow the application of particular projects and where one could observe the reactions to such interventions.

> In a diverse community with a regional-scale management model, having a learning laboratory meant to trial an intervention in a relatively controlled environment and if the intervention generated useful results, pursue further research and share the outcomes with a much more diverse community (Interview 4, March 2015).

It was perceived as conducting initial trials and sharing success practices with not just a broader regional community but also internationally through biosphere networks.

> Having a learning laboratory culture enforces the realisation that there is a need to do things better and develop an understanding as to how things can be better managed. I think it is all about the communities understanding a little bit more about what it means to be a biosphere and then committing to it and finally demonstrating that commitment through changes of habits and bad practices. A biosphere is simply where communities prosper enough to be able to look after the environment (Interview 3, March 2015).

> The bottom line is that Man and the Biosphere Program is not just about conserving natural environment; it's about people living in harmony with natural environments. So it is not about a national park area, it is about a place where people live, recreate, conduct businesses compatible with the environment. I think it is part of that process of understanding, that relationship that it has to be an on-going learning process. It is supposed to be about improving the relationships of people and the environment. I don't think it can be defined as one entity or one organisation (Interview 5, April 2015).

The concept of a learning laboratory is in contrast to the knowledge-sharing and risk communication ideals of flood risk management in the NSW. The idea of having a centralised information hub in flood-risk management is seen as a mode to increase common understanding of flood risk and provide standardised information to mitigate risks. The source of the information is derived through hydrological models that would require technical knowledge from experts in the field. The prerequisites and parameters of the flood models are defined by the experts based on the intended desired results of mitigating flood risks. The flood management model in NSW is about information-sharing whereas the learning laboratories lay emphasis on mutual learning by connecting people involved in grassroots projects to its application in a broader community. The Catchment Management Model, discussed in the previous chapter, advocates the need for an education strategy to give 'meaning' to the information provided to the communities. This suggests that community engagement through the learning process is a key to increasing understanding and improving cooperation within communities and helps to readjust different risk perceptions.

The learning laboratory at Noosa Biosphere was also envisaged in the form of a *Biosphere Institute for Sustainability: Noosa*. The concept at the time, prior to de-amalgamation was to bring together an international community of experts, researchers and practitioners to collaborate in different projects (Noosa Biosphere Ltd 2012). Thematic areas of research and learning were anticipated to be developed through consultation with partner agencies in view of the objectives of the biosphere and UNESCO biosphere program's mandate. Recognising the diversity in knowledge, it was envisaged that the Institute would facilitate education, research, innovations and learning through collaborations between science, policy, practitioners and communities. Collaboration was deemed an imperative for learning and sharing science and sustainable practices. “The basic idea was to make Noosa a research hub that would collaboratively see Universities coming together” (Interview 3, April 2015)

It was also seen as an important platform to link research and practice to initiate an iterative process of trial and learning.

> Information-users develop a new topic where information and new knowledge is required, researchers designed the methodologies of analysis of the subjects, and practical users do projects themselves and bring funds and grants. There is an information need, when you teach, you understand in a different way; when you are practising on-ground you understand it in a different way; when you are a researcher you understand in a different way, so it is all of these things coming together in this sort of iterative process. It is almost like an on-going dialogue. People learn stuff by doing practice, quite often people will get a problem in practice and they will break through the problem through an experimental process of practice (Interview 2, April 2012).

The Biosphere Reserve framework provides a learning network that draws on different forms of knowledge and increases social capital through collaboration and partnerships. In principle, it enables a more adaptive governance paradigm for management. The Noosa Biosphere identifies some promising initiatives for dealing with a scientific management paradigm, through establishing a culture of learning laboratories, developing community-led climate change action plans to address issues around climate change denial, and also through the proposed *Biosphere Institute for Sustainability: Noosa*—linking science with practice. In addition, the governance of the biosphere continues to strive towards maintaining a more grassroots focus.

While the Noosa biosphere presents a better adaptive management model, this case study also demonstrates the socio-political barriers that influence Socio-Ecological Systems. Social pressures from the Noosa community let to de-amalgamation. The de-amalgamation formed the basis of a change in governance of the Noosa biosphere which on one hand, provided a more promising community empowered structure, but on the other hand, discarded the skills and experience of people involved in the sector board model, missed out on the opportunity to learn what worked in past practices through the State of the Biosphere Report card and failed to capture the opportunity to establish the *Biosphere Institute for Sustainability: Noosa.*

> There was a fair amount of momentum in 2013, a lot of preparatory work was done on [the *Biosphere Institute for Sustainability: Noosa]*. There was a moment in time when it could be formed and successfully commenced but the council announced its review, so the people who have been involved in putting it together were no longer part of the current biosphere management (Interview 3, April 2015).

Although the Noosa Climate Change Action Plan was an initiative that demonstrated extensive community involvement with the communities setting goals and values to address issues of climate change, the endorsement of the community-presented framework failed to materialise under the council.

> The problem with the Noosa climate action plan was that it was a very community-driven project but it unfortunately came up with the action plan that mostly gave the responsibility for driving action back to the council, and it hasn't involved councils enough in that process. So that meant when the biosphere folks presented to the council, the council said that 'it's fantastic but you have given us responsibility for implementing things that we weren't involved in drafting' (Interview 2, March 2015).

From the above, it can be inferred that governance and management of resources require an inclusive process. Be it conservation or flood management, socio-cultural influences are a major driving force for change either positive or negative. In the case of Noosa Biosphere, a change in the political party triggered the restructuring of the governance model, promising an improved locally governed management model at the economic cost of de-amalgamation and loss of expertise and experience of people involved in the previous governance model. Analogies of political influences can be drawn from the Hawkesbury-Nepean catchment where ambitious development goals in the Western region of Sydney have provided concessions to developers to accelerate development by expediting the approval process and standardisation of LEPs discarding local concerns of context-specific LEPs. Chapter 5 of this thesis demonstrates the exclusiveness of the Blue Mountains Council's concerns with the standardisation of LEPs as detrimental to the conservation of the Blue Mountains World Heritage area. As a reactionary response to communities' growing concern about future flood risks due to development on the floodplains, a review has been conducted to evaluate mitigation options. In the case of the Noosa Biosphere, the community's growing concern for the lack of regard of the management of the Biosphere in the light of its vision led to the re-examination of the existing governance model. Unlike a biosphere governance model, management of floods in the Hawkesbury-Nepean catchment lacks an understanding of the 'big-picture', governed by reductionist views led by individual sectors. There is a need for a 'biospheric' perspective of management—a system thinking approach to deal with the management issues.

9.7. What Noosa Biosphere has to offer—implications for NSW flood management

The Noosa Biosphere model is a conservation model. By design, a critical component of this framework is conservation, development and logistical support (learning, education and training). The framework does not focus on issues of flood management so, Noosa Biosphere management did not engage in activities involving flood management. Similar to NSW, flood management in Noosa Biosphere is the responsibility of the councils. The process of public consultation and assessing risks follow a similar framework to that of the NSW flood management model.

> To understand flood risk we do a lot of modelling. That modelling produces mapping that mapping informs our planning schemes in terms of flood hazard overlays and a flood overlay code. Through land-use planning we manage flood risks by regulating the flood likelihood and above that level is the regulating level for buildings. The decision to set a flood planning level is solely on the council. We have retained the 1% AEP [level for planning] (Interview 1, March 2015).

Review of the Noosa Biosphere model does, however, provide lessons for improving practices of flood management in the NSW.

A biosphere offers a system-thinking approach to its management. It is considered as a system in itself comprising of various natural, cultural and socio-economic components (Tran & Le 2014). It is also seen as part of a bigger system through connections with other biosphere networks regionally and internationally. A biospheric framework is propelled by improving interaction among different stakeholders within a human-environment interface. One of the learnings that emerged from this research is the lack of coordination and interactions with different stakeholders for whom flood-risk matters. A biosphere framework is based on the premise of developing partnerships across different sectors of people to facilitate a system of governance that is inclusive. The Learning Laboratory approach aids in the integration of academic, management and local knowledge (Tran & Le 2014).

> …that is part of what the biosphere is all about is sharing with other communities. The council (Noosa) has traditionally provided substantial support to the Biosphere. They have provided admin support, project money. That is a key element to a successful biosphere (Interview 3, March 2015).

In the Hawkesbury-Nepean catchment there is a need to institutionalise a system-thinking approach where managers, decision-makers and the community learn to characterise this catchment as one complex system. Models like the biosphere promote the need to govern natural resources at a scale that encompasses local boundaries. Governance of a geographical landscape embedded with natural resources and social institutions, where adaptive management can be practised, requires an understanding of setting up a management system that is resilient to socio-political barriers and supports a strong community driven paradigm.

This should involve an understanding and acceptance of exploring different aspects of the system that can be adversely impacted by management decisions. Likewise, regarding the Hawkesbury-Nepean catchment, such a paradigm should entail: examining the influence of natural systems such as the hanging swamps on the catchment hydrology; impact of climate change on these sensitive systems and its short-term and long-term effects on the entire catchment; a cross-sectoral analysis of development and how it will influence the natural environment more particularly the Blue Mountains World Heritage site as a result of urban sprawl and addressing community perceptions on how decisions are made and risks assessed. A system-thinking approach needs to be understood and practised. To achieve this, a broader level of understanding is required for managing floods in the Hawkesbury-Nepean catchment. Some important discussions to consider would involve developing a common understanding on what encompasses a system; what would be appropriate boundaries of this system; and assessing the feasibility of considering the entire catchment as a system? This thesis offers arguments in support of managing this catchment as one integrated system. Other aspect to be considered would include the evaluation of technical and non-technical resources that will be required to manage it as an integrated system, and planning for the institutional policies and processes required to achieve this. Secondly, there is a need to develop an understanding of what factors influence the hydrology of this system and how development poses a threat to changing its hydrology. More importantly, in what ways the loss of natural assets such as the hanging swamps can impact the system, and how significant is this impact in the context of future climate change. In summary, there is a need to identify relationships among different factors and what it means for the entire catchment and its flood management. This is only possible if it is viewed as a single system influenced by factors within as well as from the external larger surrounding systems.

In principle, biosphere reserves are generally defined into three zones outlining their appropriate functions and limiting the type and amount of human activity in each zone. It prescribes a way of thinking to manage land that is surrounded by diverse habitats, both human and natural. A “biospheric” way of managing floods in the Hawkesbury-Nepean catchment does not necessarily imply that the catchment is best managed if zoned into the classifications of a biosphere. The implication is to think how goals of conservation should be central to making decisions on development in this region. As with a biosphere, the

Hawkesbury-Nepean catchment has internationally recognised natural assets in the form of the Blue Mountains World Heritage Site. Currently, management decisions reflect economically driven incentives rather than a conservation-based economy and are bounded to narrow jurisdictional views. Decisions are made within the local context but the potential for adverse impacts are regional and in most cases not accounted for.

A biosphere model also provides the 'how to' knowledge on local governance. Looking at the example of the Noosa Biosphere, both models, prior to de-amalgamation and after de-amalgamation provide a framework that identifies issues across different sectors: socio-cultural, economic, research and environment. Figure 9.1 depicts a top-down and bottom-up approach while promoting community engagement. The management boards of the governance models are made up of volunteers representing different sectors with representation from the council to ensure support and funding to undertake innovative projects. Sector boards or coordination agencies (as is the case with the new model) allow opportunities for a strong community involvement whereas support from the council allows for coordination across different governmental entities to drive financial and other forms of support. In contrast, the flood management model has the majority of its representatives from the public sector and no representation from private entities such as real estate agencies and insurance companies.

9.8. Lessons from the Biosphere

The biosphere reserve concept acknowledges two essential components of a complex SES that is necessary for maintaining resilience (Taylor 2004, p. 84). The first is that there is recognition of the interdependence of human and natural systems. Secondly, it recognises a local institutional framework as essential for guidance and management.

For any governance system to work at a regional scale, it would require:

1. A bridging organisation that connects communities to other levels of governance. The governance structure of the Noosa Biosphere model connects the 'doers' to the strategic board of governance and the framework itself supports international and regional networks.
2. A governance structure that provides complete autonomy to the regional organisation or entity to make decisions independent of any political influences. This will require having financial independence, and establishing a system of governance that empowers local communities to make and direct management decisions, be part of that system of governance and participate

in the implementation of those decisions, and to allow a system of learning and reporting back. The benefits of such a system will help to address management barriers discussed in previous chapters such as:

a. facilitate to bridge the gap between policy makers and those affected by these decisions—the communities
b. allow the addressing of perceptions and expectations of different stakeholder groups
c. improve coordination and communication of such information which is valued and used by a range of diverse groups concerned with the catchment.

3. A governance system that invests in building partnerships and connects research and innovations across the region.

A biosphere model overcomes the jurisdictional management issue through a strong locally driven governance model that emphasises partnerships between people and its learning laboratory principles that serve as demonstration sites for best practices to be replicated at regional, national and international scale.

An implementation of a learning laboratory concept for flood risk management in NSW would entail recognition of an organisation, possibly a regional organisation that fosters the following:

1. Provides an active forum for discussion on emerging issues with regards to flood management and propose further research in collaboration with different public and private sectors.

2. Forges partnerships with research and learning institutes in the region and outside such as local and international universities to develop outcome orientied research.

3. Provides a forum to share emerging research on the issues through conferences, media and other modes of information sharing.

4. Develops an education and communication strategy through participatory process that needs to be trialled, tested, and reviewed to identify effective mechanisms to communicate flood risks, determine what needs to be communicated and to whom.

5. Collaborate with local schools to enage in flood risk awareness projects thouse expanding on learning and awareness component of flood risk management in the region.

6. Establish a consistant monitoring and evaluation framework as an adaptive learning process and ensure that knowledge is disseminated to all interest groups in a language and form that is best ustilised by them.

The learning laboratoray concept relies on the priciples of creating awareness, generating knowledge, implementing projects through good governance and forging partnerships. These principles as mentioned above can be adapted to address flood risk management in the case study region.

9.9. Evaluating governance framework of Biosphere reserve model

'New governance' as defined by Howlett and Rayner (2006) and adopted by Lockwood et al. (2010, p. 987) presents a framework of governing that shows a preference for collaborative approaches along government and nongovernment actors from the private sector and civil society' The Biosphere framework as reviewed in this chapter presents an ideal example of new governance. The following is an analysis of the governance system in place for Noosa Biosphere Reserve as per Lockwood et al. (2010) criteria. As mentioned earlier in the introduction of this chapter, Biosphere Reserves model are conservation models and are examined due to their participatory governance system and will be analysed as such against the criteria.

Table 9.1. Governance Assessment of Noosa Biosphere Reserve

#	Principles	Good Governance Attributes in Noosa Biosphere Reserve Framework	Rating
1	Legitimacy	• The Noosa biosphere framework demonstrates the establishment of Noosa Biosphere Ltd. as part of the Nations commitment under the UNESCO's Man and the Biosphere Program (Chapter 2, Section 2.7). • Devolved level of power exists through polycentric governance resulting in 'shared rule by the community' (Lockwood et al 2010), see section 9.5 for details.	+
2	Transparency	• The reformed governance model allows engagement at all levels where decision-making is open to all interest groups. Figure 9.1 demonstrates the decision-making process and opportunities for engagement at all levels under the reform governance model.	+
		• It should be noted that at the time of this study, the reform process occurred recently and the new governance set-up was in its infancy stage. It would take at least a year to evaluate the extent of success in stakeholder engagement in decision-making and the quality of transparency practiced in the new framework.	–

3	Accountability	• The Noosa Biosphere presents a community driven model that enables participation of citizens at all levels i.e local/implementation to regional and strategic level. • The board members are selected by the community with only one representation from the government and also include members working at the local/implementation level, hence ensuring clear accountability to the citizens (Section 9.5.2 elaborates on this aspect). • Decision processes are open and consultative.	+
4	Inclusiveness	• A very strong feature of this model is its inclusiveness and devolution of power. • It is an independent community driven model where participation drives the mandates of the biosphere reserves (details are provided in section 9.7).	+
5	Fairness	• The reform model provides a greater level of autonomy with regards to funding projects that fulfill the organiations mandate due to very little involvement of state representatives. • The decision-making process involved citizens therefore fairness is a key attribute in this devolved governance model.	+
6	Integration	• The biosphere model by default is based on a multi-level and multi-scale governance system due to its transnational and international context (Section 9.8).	+
		• In terms of cross-disciplinary integration with other policies it is limited. In this context, it primarily focuses on NRM and any integration in policy with floods is very limited.	–
7	Capability	• The biosphere reserve model works through the learning laboratory concept. The Noosa Sustainable Development Institute was conceived with the intention to bring diverse knowledge and skills and extend collaboration with policy and the scientific communities. It therefore presents the pre-requisites to build on resource capabilities.	+
		• The governance reform has halted the development of this Institute with uncertainty in-terms of its actual application in future. The concept has yet to be launched to assess its workability.	–

8	Adaptability	• A community driven model that focuses on openness to a learning culture. • The biosphere framework provides a learning network. Section 9.6 elaborates on the learning and adaptive capacities of this framework which is one of the strongest feature of this framework.	+
[1]According to Lockwood et al. (2010) this overlaps with the first principle but the primary focus of the first principle is representation and acceptance where as inclusiveness focus of opportunity for participation.			

9.10. Challenges in the implementation of Biosphere Reserve Models

A review of literature on existing biosphere reserves helped to identify some limitations that can prevent reaping full benefits of this management model.

Although the flexible framework enables the biosphere concept to align with local and national policy and practice, it is argued that its abstract concept can be misleading and challenge stakeholders' 'buy-in' (Francis et al. 2004; Borsdorf et al. 2014). The term 'reserve' can threaten social acceptance assuming that communities need to reserve the land for protection and conservation only. Tension between administration, management and the community have also accounted for the lack of success in this framework (Stoll-Kleemann& Welp 2008; Rescia et al. 2010; Elbakidze et al. 2013).

Community-driven biosphere reserves require financial independence from the public sector. This means that fundraising for biosphere reserves becomes a central and constant activity and there is a tendency for it to be driven by the available funds rather than the biosphere reserve priorities (Francis et al. 2004). In contrast when biosphere reserves are funded by the government, they are often delegated to an administrative government authority. This has the tendency for government staff to ignore the Biosphere Reserve objectives that are beyond the organisation's mandate (Francis et al. 2004). The lack of political will and legislative support for biosphere reserves at different scales has been one of the major challenges in the successful implementation of these frameworks (Stoll-Kleemann & Welp 2008; Borsdorf et al. 2014).

An important element of adaptive capacity is continual learning through monitoring and evaluation. Periodic reviews and reporting on progress or lessons learned have been slow to achieve in this framework, not only at a national scale but also at a global biosphere reserve network scale (Francis et al. 2004; Schultz & Lundholm 2010; Schultz et al. 2011; Jessel 2011).

Adaptive strategies in some biosphere reserves have been counterproductive mainly because of insufficient understanding and the interrelations of the social and ecological systems within and outside the reserve —see literature on Urdaibai Biosphere Reserve, Spain; Maya Biosphere Reserve, Guatemala; and Wolong Biosphere Reserve, China—(Xu et al. 2006; Rescia et al. 2010; Rodriguez-Solorzano 2014). This is the case especially in biosphere reserves where there is a lack of integration of socio-economic and environmental planning (Stoll-Kleemann& Welp 2008; Rescia et al. 2010). Also, for their successful implementation, institutional flexibility is required for adaptive governance where learning sites for sustainable development can collaborate with informal institutions to cater to the norms and expectations of multiple stakeholders (Elbakidze et al. 2013)

Matysek et al. (2006) identifies a number of challenges to implementing the biosphere reserves model in Australia. These include an unwillingness to invest in refining the model for improved implementation; lack of understanding by program stewards about the approach or its implementation, inconsistent strategies and the multiple protected area designations resulting in competing interests between park management and biosphere reserves. Political drivers have also hindered successful implementation of these reserves in Australia. Political responses to conservation have resulted in strict confinement of areas as protected parks. 'Decisions about land-use planning, development and management are made as if these activities outside parks and reserves are not part of the fabric of conservation or key to the wellbeing of communities in the long term' (Matysek et al. 2006, p. 94). This is evident in the case study of Noosa Biosphere Reserve. Although floods are an important concern for this region and the risks fall within the biosphere area, there is no integration of biosphere reserve management entities with flood planning. Flood management is left to the councils. Despite the understanding of having regional, cross-scale regional models, the on-ground practices tend to segregate and compartmentalise interdependent socio-ecological issues.

The biosphere reserve framework offers opportunities to enhance resilience and the adaptive capacity of complex and multi-scale Social-Ecological Systems; it is, however, limited in scope in various aspects as discussed above. It is significant to understand these limitations as critical lessons learned.

9.10. Conclusions

There is no 'one-size-fit-all' framework that can provide an easy solution to addressing problems of managing complex large catchments like the Hawkesbury-Nepean. The Catchment Scale Model and Biosphere Reserve Framework provide certain opportunities that can be adapted to overcome the barriers of flood risk management in the Hawkesbury-Nepean region. It would require a dedicated process of trialling and readjustment to the existing flood risk management framework to define what is feasible and what can be adapted. While the Catchment Scale Management Model offers very relatable strengths that can be examined in managing floods in the case study area, the Biosphere framework offers governing principles that centre on inclusiveness, adaptive learning and a system-thinking approach to tackle problems in the Hawkesbury-Nepean Catchment. The subsequent concluding chapter will summarise the research issues and propose a governance framework with recommendations based on the two management models discussed in this chapter.

10.1. Introduction

This chapter provides a brief background context of this research and a summary of major findings. It provides a reflection on the implications of the theoretical frameworks used to understand issues discussed in this study and proposes improvement in the existing flood management framework through a set of recommendations as a way forward. It should be noted that chapter 8 and 9 provide a detailed account of feasible options that can address the flood management problems in this thesis; therefore, to avoid repetition, chapter 10 of this thesis summarises the major findings of this thesis and recommends a modified framework to address barriers of flood management in the case study.

10.2. Context of research

The need for the current research emerges from the complex nature and management issues of large Social-Ecological Systems (SES). Unplanned urbanisation, increasing population, resource exploitation and environmental degradation are impacts on the biosphere that have given way to a high level of uncertainty and unpredictability (Gunderson & Holling 2002; Ostrom 2009; Anderies & Janssen 2013). On top of this, climate change presents a challenge to the sustainability of environmental systems through creating greater uncertainty about the future of natural resources and the effective role societies need to adapt, in order to function. This uncertainty of the future threatens to reduce the adaptive capacity of these social and environment systems through the loss of its resilience.

This thesis has focused on the Hawkesbury-Nepean region, which is one of the major catchments of the Sydney Basin. The catchment provides an ideal example of complex Social-Ecological Systems that are faced with competing needs of development and natural resource management. It serves as a good case study where the changing morphology of natural systems is being impacted through anthropogenic activities. This allows for an examination of how competing use of resources is being addressed in the light of high flood risks. The system on one side is enveloped with natural assets such as the Greater Blue Mountains Area and on the other side is pressured by increased demand for supply, increase inflows due to urban development on floodplains and discharge of sewage treatment plants. The hydrology is further impacted by storage infrastructure in-streams and more intense weather events. Another essential geophysical component of this ecological system is the Warragamba dam that drains rivers from the Southern and Western region of this catchment, supplies drinking water to the Sydney metropolitan area and is central to controlling flows downstream (see Chapter 2 for details on the case study area). The natural dynamics of this system are further complicated by the fragmented management of this catchment through a sweep of agencies, as highlighted in this thesis.

10.3. Summary of findings from the case study

A brief summary of conclusions is provided in this section.

The literature review of this thesis provides the theoretical context of the research. The concepts of resilience, adaptive management, panarchy, risk societies and different management paradigms, are discussed in Chapter 2, which characterises the behaviour and functioning of a SES. The examination of past literature also provided the contrast in application of these theoretical concepts within this empirical study. It helped to examine where failures in understanding these concepts, which are integral to any complex SES, result in creating management gaps.

The systematic process required to dissect the problems in this thesis have been explained in the methodology chapter (Chapter 3), and provided the framework to conduct this empirical study.

As mentioned earlier, in the introduction of this thesis (Chapter 1), the subsequent chapters analyse the problem areas and attempt to answer the research questions. The idea that systems are interlinked and that state-level policies are more likely to influence several different component of a large SES—in this case the Hawkesbury-Nepean catchment—is evident in Chapter 4. The changes in development approvals in the growth centre downstream of the Warragamba dam and their likely influence in the Blue Mountains region is taken as an example. The significance of hanging swamps as a critical ecosystem for the Blue Mountains and its influence downstream as a result of extreme weather conditions signifies the need for collective management of this system as a single entity. Management decisions fail to address these issues due to lack of communication, coordination inconsistencies and more importantly, as a result of conflicting interests.

Chapter 5 provides a detailed situation analysis of current flood management practices. The analysis highlighted critical barriers to flood management. While the conceptual framework of flood management implemented in the catchment advocates an adaptive management paradigm, in practice, issues of maladaptation exist. Some critical barriers to flood management identified include: Standardisation of flood-risk level for planning; lack of preparation for rare or unanticipated impacts; exclusivity in engaging interest groups; and a jurisdictional approach to flood management.

Chapter 6 and 7 demonstrate the value of perceptions in creating and bridging policy implementation gaps in the case study area. Differences in perceptions require inclusive processes of flood management without which there will be failures to: Access flood data, formulate an integrated approach to flood management, establish effective risk communication and promote community engagement to implement risk mitigating strategies exist.

Opportunities exist in catchment or regional scale management frameworks. There are of course limitations within these frameworks. Nevertheless, they provide some feasible options that can help to bridge the gaps in flood management. Chapter 8 and 9 addresses broader options such as the need to develop regional strategies, centralisation of flood data to increase access, development of education strategies to increase community response and a more participatory local governance to complement the science-based decision-making culture. The analyses of regional frameworks discussed in Chapter 8 & 9 have informed the recommendations of this thesis.

10.4. Application of theoretical frameworks in the case study

The concepts of panarchy, ecological resilience and adaptive capacity, discussed in the literature review (Chapter 2) which also formed the basis of this research, are frameworks that explain the tendency of complex SES to undergo abrupt changes as a result of disturbance (Gunderson 2010). Understanding the dynamic factors of a complex SES that cause these abrupt changes will result in improved policy responses (Ruhl 2012). These concepts have been extensively discussed in other research but have had limited practical applications due to their complexity and dynamism (Allen et al. 2014).

The transition from panarchy theory to practice is only possible when it gains endorsement by interest groups and a legal acceptability (Ruhl 2012). The panarchy framework connects social institutions, economic activities and environmental systems (Adger et al. 2005; Moen & Keskitalo 2010). Panarchy recognises a hierarchical system of arrangement (both social and environmental) which is different from other typical hierarchies (Allen et al. 2014). The critical difference is that it acknowledges the top-down larger scale influences, but at the same time it recognises the significance of processes that are small scale and bottom-up (Allen et al. 2014). Problems discussed in the case study of this thesis demonstrate the existence of these dynamics in flood-risk management. As discussed in Chapter 9, bioregions challenge administrative boundaries that fail to address biodiversity conservation and that biodiversity planning needs to be managed at a landscape scale. In contrast, flood management in NSW does not recognise this. Through examination of flood issues in this case study, it can be inferred that on-the-ground implementation of these conceptual frameworks is limited and that certain practices have created negative resilience (see Chapter 2)—an undesirable state of a system that is resilient (Áez-Luna 2008; Phelan, Henderson-Sellers & Taplin 2013). Consequently, weak legislative frameworks have failed to implement processes to maintain this balance between social institutions at different scales and influences of management decisions on environmental systems. Political drivers that pursue economic interests overriding conservation interests is an example of how power relations create chronic dysfunction within a SES leading to loss of adaptive capacity and perverse resilience. With reference to the Hawkesbury-Nepean case study, this was observed in the approval of massive development in a floodplain region to meet the demands of economic growth; expediting the development approvals prior to flood impact studies; and a top-down decision-making process. Phelan et al. (2013, 207) have argued that dominant positions, favouring particular set of interests within a political economic system can influence the management of a SES which may not be consistent with the stability of the system. Levey and Newell (2005, cited in Phelan et al. 2013) indicate that this dominance of a particular interest is exercised through the bureaucratic system of government, within the legitimacy of civil society and within the economic realm.

In chapter 2 of the thesis, three conditions of a scientific management paradigm were discussed. The first condition supports a 'business as usual' stance, where environmental problems are tackled as a reactive response to a system failure or collapse. The inter-relationships of social and ecological systems are either ignored or not completely understood. Through the hanging swamps case study, Chapter 4 identifies the lack of understanding and influences of policy decisions on environmental systems. The 'business-as-usual approach' to deal with large and rare floods and low perceptions of flood planning levels for existing and future development represent a linear pattern of management which is in-line with the traditional system of management, rather than the principles of panarchy, resilience and adaptive management.

The second principle is the notion of efficiency. It supports the idea that efficient utilisation of resources will eliminate conflicts. It tends to ignore that managing resources is a social process where local values need to be endorsed. It advocates a rigid 'one-size-fits-all' framework of policy implementation. This has been discussed throughout the thesis especially in Chapter 4 with regard to the standardisation of Local Environmental Plans for the Blue Mountains World Heritage Site, one set standard of flood planning levels, failures to plan for accumulative impacts at scale and planning for rare but extreme flood events (Chapter 5). Issues discussed in Chapter 7 and to some extent in Chapter 8, demonstrate how public institutions involved in flood management fail to encourage innovative practices. This is strongly driven by the way these institutions view a certain problem—in this case, flood risks. There is persistence in maladaptive practices set by an institutional culture that discourages change as discussed in various chapters of this research (Chapters 5, 6 and 9).

The third principle is the top-down management process where flood management is predominantly governed by scientific and engineering knowledge and limited community engagement. Issues of policy and scale mismatch, resulting in jurisdictional approaches to flood management that ignore the larger scale impacts of such policy decisions; their implementation is discussed extensively in this thesis. Chapter 7 demonstrates the different needs, expectations and values of interests groups and especially those of local communities.

Application of these conceptual frameworks requires a dynamic system that moves away from the rigid top-down approach as observed in the flood management of the Hawkesbury-Nepean Catchment. A panarchy framework implemented through adaptive governance challenges the norms of government institutions involved in natural systems. In contrast, adaptive policy frameworks recognise uncertainty and dynamism; hence lays the challenge of institutionalising the principles of panarchy, positive resilience and adaptive management.

10.5. Theoretical implication of management at scale

Advocates of bioregional, landscape or ecosystem scale approaches to management argue that ecological integrity and biodiversity conservation is possible if protected areas are linked with their surrounding landscapes and corridors (Batisse 1997, Dick 2000). The panarchy framework helps to examine the problem at different temporal and spatial scale (Angeler et al. 2012). In the context of a variable climate, management of natural resources is needed at a scale that provides for a better understanding of the impacts of factors influencing complex SES. The system needs to be looked at holistically from a catchment or a biosphere perspective that fosters management through natural ecological boundaries and encompasses political boundaries and legal jurisdictions. Panarchy as a conceptual framework was critical for addressing problems in this case study area because it addresses problems at two different scales.

- It focuses on management at regional scale – long-term planning, overarching strategies to monitor change and evaluate economic and environmental targets of the state.
- It addresses issues at local scales—deals with the impact of smaller systems. Factors that can change local dynamics (e.g., sub-catchments, vulnerable eco-systems) and local economic drivers of change, community response and decision-making.

An examination of Lawrence et al.'s (2003) adaptive framework that constitutes six core components, (discussed in Chapter 2), provides additional insights into the limitation of adaptive practices in the Hawkesbury-Nepean catchment. The first core component prescribes that catchment-scale management through an adaptive framework requires establishing regional-scale processes and institutions, agreed by different stakeholder groups including the communities, government agencies, industries and other sectors within the catchment. In retrospect, the core institution to guide catchment-scale flood management processes in the Hawkesbury-Nepean does not exist nor do regional scale processes to facilitate catchment-level flood management.

The second component of an adaptive framework as described by Lawrence et al. (2003) requires the establishment of mechanisms that allow pooling of research and information and its communication to all concerned, in such a way that it is widely understood. Discussions in the preceding chapters of this thesis have attempted to highlight the communication and information barriers in the current system of flood governance in NSW. Challenges of information exchange and coordination exist especially where risk assessors require more standardised information on flood risks. Barriers to learning exist due to prevailing socio-political interests that drive resource management agendas.

The third phase of an adaptive management framework is a critical stage where mutual agreement on the catchment goals, visions and targets need to be established. According to Lawrence et al. (2003) this would encourage collaborative efforts, increase participation to broaden understanding of different groups to catchment systems and define aspirations for catchment objectives. This would require a governance system that is inclusive and caters to the interests and values of all. Chapter 5 identifies the current trends of flood -risk management in the Hawkesbury-Nepean catchment which demonstrates the lack of involvement of other stakeholder groups in setting targets and goals. These barriers to effective management are created due to difference in perceptions on flood risks, acceptable level of risks and expectations of various stakeholder groups including community groups, real estate agencies, insurance companies and policy decision-makers at state and local levels as elaborated in chapters 5 to 7.

The Kruger National Park experience, introduced in Chapter 2, presents an on-the-ground framework that interlinks the spatial-temporal heterogeneity especially in river management through establishing a hierarchy of goals and objectives embedded in values identified by different interest groups (Mcloughlin et al. 2011). The framework enables the alignment of community values and scientific inputs through establishing TPCs.

> The TPCs were originally seen as flowing from high-level vision and objectives, forming 'low-level goals….providing a manager on the ground with targets of ecosystem conditions…scientifically rigorous, spatially and temporally bounded….acting as amber lights to warn managers of possible unacceptable environmental change (Biggs et al. 2011, p. 61).

Flood-risk management has strong scientific and social dimensions. As demonstrated in this thesis, perceptions of risks often clash with information acquired through modelling and technical analysis. There is a need to adapt a framework that incorporates values and establishes benchmarks to achieve these value-oriented goals through local interventions. Establishing TPCs is one possible option that allows state-level and regional-scale goals to be achieved through management intervention at the local scale (Rogers et al. 2013).

The fourth stage of a catchment-scale adaptive management framework outlined by Lawrence et al. (2003) suggests that after mutually agreed targets and aspirations are set for the catchment, the next stage is to conduct system analyses and impact assessments to define a suitable context-specific strategy. The outcome of this stage would be mutually agreed management actions that were derived from multiple sources and multi-disciplinary knowledge. In contrast, the Hawkesbury-Nepean flood management is defined by jurisdictionally bounded flood studies informed by bio-physical scientific methods of inquiry and an absence of a regional strategy.

The last two phases of an adaptive management framework at a catchment-scale would involve the implementation of the agreed plan with clear responsibilities resulting in improved governance and finally the monitoring and reviewing of the implemented plan (Lawrence et al. 2003). As for the Hawkesbury-Nepean region, the management plans are jurisdictional and localised rather than regional or catchment-scale. The absence of an integrated strategy also creates duplication and a lack of clarity in roles and responsibilities.

The management of natural resources presents a governance challenge which requires political will to support adaptive policies, scientific inputs to promote research and knowledge and logistical support through established institutions. Adaptive management can succeed in an institutionalised NRM governance system when policy legislations and different interest groups allow it. Implementing a system of governance that encourages public, private and social sector engagement as discussed in chapter 8 & 9 within the context of a biosphere or catchment-scale framework presents these opportunities. Currently, in the case study area, flood management that involves engagement of interest groups is limited through comments on exhibited documents, mere representation in flood management committees and providing consultations in prioritising mitigation options. This conventional framework of management limits the effective introduction of adaptive management systems.

The following section outlines a framework that can bridge the gaps identified in flood management and recommends future actions to assess the feasibility of the framework.

10.6. Recommendations and future research

In Australia, NSW experiences the most variable climate and within NSW the Hawkesbury-Nepean catchment has the most climate variability (Department of Environment, Climate Change and Water NSW 2010). This variability creates complex dynamics of weather extremes that makes management of its ecosystems a challenge. Based on the climate change projection of the IPCC 2014 report (Pachauri et al. 2014), a possible scenario in the Hawkesbury-Nepean region could be that the increased vulnerability and deterioration of hanging swamps in the Blue Mountains, through increased fire, dry weather and intense rainfalls could potentially release large volumes of water. Also rain events that increase runoffs from a highly urbanised landscape could lead to entrapment of people causing a flood disaster that is just waiting to happen. There is an obvious need to address these issues to prevent a socio-economic and environmental catastrophe. An integrated catchment management strategy that addresses issues of a rapidly changing landscape and a catchment-scale agency with technical and financial resources to analyse accumulative runoffs is critical to implement adaptive strategies to manage floods in the Hawkesbury-Nepean region. There exists an institutional policy failure that has overlooked this critical gap.

The recommendations for the problems of flood managed in the case study region emerges from Chapter 8 and 9 of this thesis. Biosphere or catchment-scale models provide examples where a greater level of autonomy is given to regional governance processes. This has been recognised by many (Brunckhorst 2001; Du Toit, Rogers & Biggs 2003;

Matysek, Stratford & Kriwoken 2006; Halliday and Glasar 2011; Nguyen, Bosch & Maani 2011; Williams 2010; Williams 2012) and is also elaborated in chapter 2 of this thesis.

Within the biosphere approach the communities are central to the decision-making and policy implementation process, whereas a catchment-scale model focuses on enhancing coordination between different scales of management and provides planning and technical support. The critical component of these frameworks is connectivity and strengthening of linkages between different scales of management.

This section proposes a framework that can address issues of scale and improve communication and subsequent coordination for effective flood risk management. It is a framework that can advocate a higher degree of engagement among different interest groups and encourages local governance.

Figure 10.1 below provides a simplified version of the flood management framework in terms of scales and institutional responsibilities in NSW. Chapter 6 provides a more detailed assessment of the roles and responsibilities of organisations involved. The issue of management at scale for the NSW floodplain management model lies at the regional scale. As described in Chapter 5 and Chapter 7 the existing regional-scale entities (Local Land Services (LLS) and Western Sydney Regional Organisation of Councils (WESROC)) are involved primarily in land management and advocacy on NRM issues respectively.

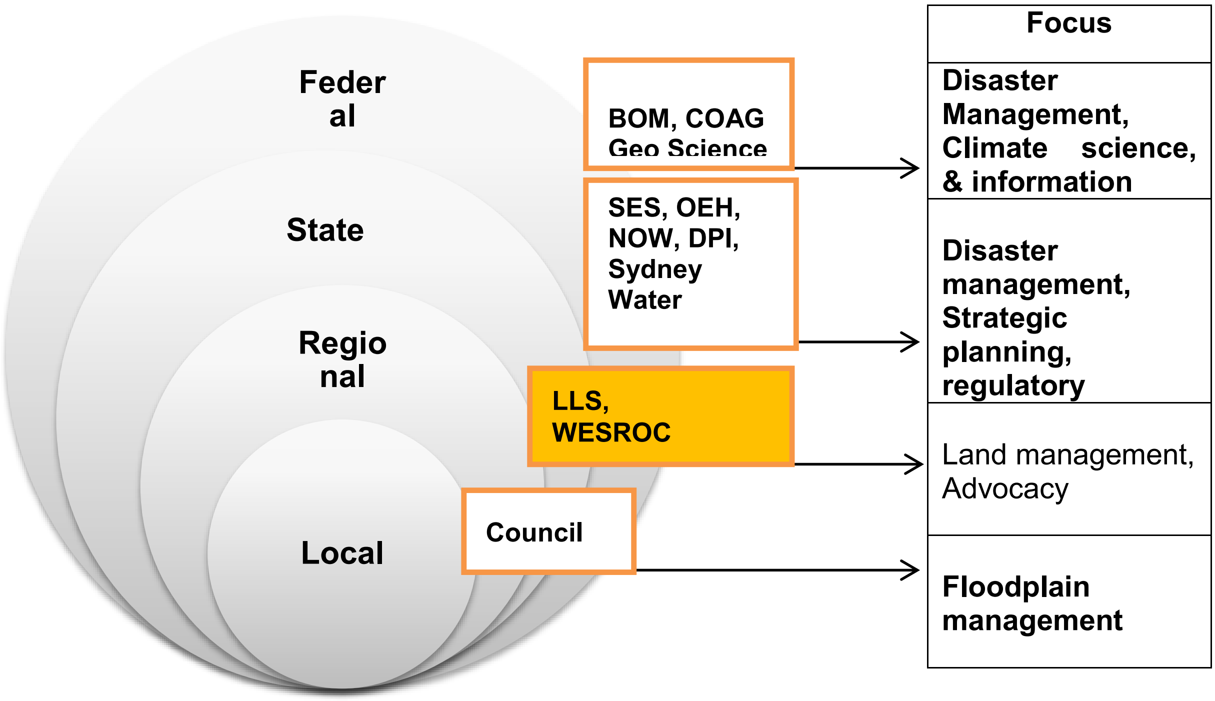
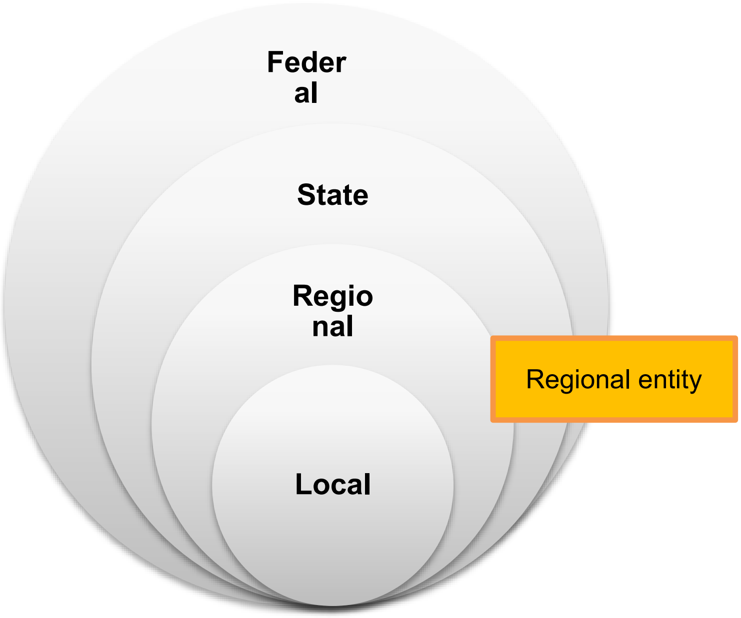


Figure 10.1. Simplified flood management framework in NSW

Currently, floodplain management at a regional scale does not exist. Chapter 6 and 7 which focused on expert and community perceptions identify a number of desirable components for a regional entity, if established, for the case study area. Since these suggestions are derived from important stakeholders, they can be used as recommendations and also as selection criteria for establishing a regional entity. In addition, regional frameworks discussed in chapter 8 and 9 can provide additional recommendations to improve the existing flood management framework in the NSW. The following recommendations, based on these research findings, are summarised in Figure 10.2.



Focus
Information hub for flood risk data
Integration of an education strategy to increase community participation,
Supports a framework that fosters local governance, Consultative process to set-up TPCs.
Regional flood management plans linked with local flood plans
Implementation of a floodplain management strategy

Figure 10.2. Recommended flood management framework

- **Establishment of a regional entity**

An autonomous regional entity can provide the economy of scale where limited resources can be utilised to manage floods in priority areas. The regional entity can constitute representatives from councils that are at risk of flooding so that relevant representatives including different community groups are involved and ‘have a say’ in the decision-making process.

There is, however, a strong need to plan, trial and test different frameworks of community engagement to ensure an inclusive process at regional scale. Engaging community groups who are more in tune to local issues will be a challenge. Operational and administrative issues of a regional entity need to be examined.

- **Augmenting an existing regional agency**

To avoid further bureaucracy in an already very complex governance system, existing regional scale entities need to be examined. For instance, WESROC currently does not have the technical or financial support to act as a regional floodplain agency; however, possibilities to upscale and its feasibility as a regional entity when augmented with the necessary technical and financial resources should be examined.

There is a need to review other exiting regional agencies such as Local Land Services as well, although the challenge exists to not overburden existing agencies with additional responsibilities that can potentially be ineffective. The scope and capacity of an existing regional agency needs to be thoroughly investigated.

- **Encouraging a local governance model**

A framework of local governance that encourages community engagement is critical to reduce political influences. Strengthening channels to and from the local and regional decision-making forums will increase participation. Increased participation in regional strategy development that links landholders and locals, can help to incorporate local interests and values. Processes that allow residents of flood risk areas to participate at regional level can facilitate local participation and engagement in decision-making processes, especially resource utilisation, identifying priority regions, defining acceptable levels of risks—all of which can empower local communities and create a greater level of ownership. The objective of shared responsibility can be rightly achieved when a consistent understanding is established about acceptable risks. This needs to be addressed to allow for the identification of 'true risks' and acceptability of flood-risk in a wider community for better flood-risk planning, management and cooperation between public, private entities and the affected communities.

Lessons from the biosphere and catchment-scale frameworks discussed in chapter 8 and 9 can be assessed for developing a participatory model of flood management in NSW. A successful community engagement process needs to be closely linked with efforts to increase their perception of risks. This would require inculcating education strategies that increase flood awareness and efforts to create a consciousness of bringing different Flood Risk Management groups together, especially local entities, public and private, to understand how their interventions will contribute towards a catchment-scale approach. A participatory process of incorporating different values and expectations and subsequently identifying and benchmarking acceptable thresholds of the system can be established (Rogers et al. 2013).

As demonstrated in this thesis, perceptions about risks drive political decisions and individual action. There is a need to further investigate how resident communities in flood risk areas form their perceptions. There is also a need to evaluate how realistic these perceptions are to actual risks? How risk communication can be improved to inculcate participatory action to mitigate risks need to be explored.

Science in flood management is critical but community values need to be not only acknowledged but given a higher degree of motivation and investment of resources to determine ways to incorporate them more effectively. As with the Biosphere model, balancing government representation with non-government entities and increased channels for community inclusion can provide opportunities for a more participatory decision-making process.

- **Setting-up thresholds through an inclusive process**

The adaptive management framework for Kruger National Park can provide an opportunity to benchmark and establish thresholds that are determined by local interest groups (Rogers et al. 2013). As discussed in Chapter 2 and earlier in this chapter, the management framework of Kruger National Park provides an opportunity to merge science with local values. The process requires communities and interest groups to be involved in developing a shared vision that translates into a hierarchy of objectives. These objectives are technically translated into monitoring end-points called the Threshold of Potential Concerns (McLoughlin et al. 2011). These TPCs define the environmental thresholds that need to be monitored and maintained in order to continue to provide the desired ecosystem goods and services highlighted in the vision statements (McLoughlin et al. 2011). Through consistent monitoring, the framework is set for continual learning and improvement as new knowledge about the system emerges (Du Toit, Rogers & Biggs 2003). From a flood management point of view, an inclusive process can help determine societal values and acceptable level of flood risks that can be defined and monitored as thresholds. This inclusive process can help to connect science, policy and the management processes. Setting up environmental thresholds can present opportunities for adaptive management but needs to be explored further in the context of flood management in the Hawkesbury-Nepean catchment.

- **Regional strategy and floodplain management plan**

Development of an umbrella regional plan or a catchment-wide floodplain management strategy that also links local floodplain management plans can enhance coordination and improve understanding of flood risk management—interpreting a biosphere framework where local context informs regional agendas and vice versa. Consequently, state-level strategies are tailored through these regional plans. At the same time councils continue to implement local flood management plans to address local issues.

This is not a simple task. It will be a challenge to develop a single regional plan where different local plans from different councils can easily be aligned and contribute to regional and state objectives. On one hand, it will enable the development of a common resource pool; on the other hand, commitment may vary between different councils based on their locations and perception about flood risk— upstream or downstream. The system may heavily rely on 'good will', as has been the case in the Victorian catchment-scale framework. This can be addressed through policy implementation that imparts a legal obligation for all councils involved to contribute towards local and regional floodplain management; however, further investigation is necessary to assess feasibility.

- **Establishment of a regional-scale information hub**

A culture of learning requires openness and access to knowledge (Lebel et al. 2006). Standardised processes of information and data collection at the catchment-scale are required. The responsibility to manage and update information can be carried out by the regional entity. This is critical especially when there are a number of councils managing one river system. Access can be provided to different interest groups from one centralised source to avoid discrepancies. Transferring this from council to a regional scale will allow a greater level of consistency and easier access to information. Chapter 8 describes this in detail.

Managing and providing access to critical flood risk information should be a shared responsibility. In the Victorian model, centralisation of data has also led to reduced involvement of local councils in flood management. The burden of management is left with the Catchment Management Authority. While centralisation can increase access, it can also increase the knowledge gap if there is less value seen by local entities.

A centralised information system for flood information will fail to be optimally utilised until or unless information that interests communities, such as information on flood-risk to property can be integrated with flood-risk information. Lessons from the Victorian Flood Database (Chapter 8) can be useful to implement. Investigation to increase the utility of the centralised knowledge pool is needed as increased access does not mean increased utility.

Lessons from the biosphere and catchment-scale frameworks and their implications for NSW floodplain management as discussed in chapter 8 and 9 can be explored further for feasibility. Further research is needed on the following broad accounts to address the barriers of flood management in this case study.

- An in-depth analysis of empirical studies that utilise the principle of adaptive governance, specifically in flood-risk management to help determine a common understanding on what encompasses a system and what would be appropriate boundaries of this system.
- There is also a need to examine how a political culture that inculcates a rigid scientific management paradigm can evolve to implement principles of adaptation such as institutionalisation of adaptive management through policy supported by a legal framework (Ruhl 2012).
- Avenues to address funding issues are critical to drive flood-risk management independent of political influences. Adapting a context-specific local governance model that incorporates local perceptions of communities and experts is also very critical.

10.7. Limitation of the research and way forward

This thesis provides in-depth analysis of barriers to a SES in the context of flood management. Certain aspects however are viewed at a broader level as part of a preliminary analysis due to the multiplicity of the problems discussed, making it difficult to review every aspect of the problem in detail. In addition, in certain cases, data issues and access were a challenge. For instance, information to calculate the actual contribution of flows from hanging swamps and the potential impact due to deterioration of these swamps on the hydrology is an area that needs to be researched further. Other areas of research to assess the actual impacts would be the determination of concrete/impervious surfaces before and after development and the resultant changes in the run-off volumes. Calculating these volumes in combination with different rain-fall scenarios would be a critical research element to determine the changes in flow and flood risks.

The contents of this research emerged predominantly from the qualitative data through semi-structured interviews. Although this research was able to identify and interview key informants, a larger number of interviewees would have been desirable, especially when analysing regional frameworks. This was an exploratory research and as with any research the need to review Catchment Management Authorities in Victoria emerged at a later stage through discussions with the interviewees. Hence a preliminary assessment has been carried out to examine the regional frameworks. A more detailed feasibility study is needed to review these frameworks for application in addressing issues of the Hawkesbury-Nepean

Catchment. It should also be noted that the regional frameworks discussed are not perfect or ideal but provide options that tackle issues of scale. Through further examination of these models it is likely that other positive as well as negative components would emerge.

10.8. Contribution to scholarship

As made clear in Chapter 1, the purpose of this research was to explore the factors that create barriers to managing a complex SES. The motivation was to identify bottlenecks and emerging problems that lead to poor governance under extreme weather conditions and identify management gaps that result in policy implementation failures. This was carried out through an organised and systematic research process that provided opportunities to conduct an in-depth analysis in order to identify practical solutions and recommendations. For this purpose this research explored two broad questions with a sub-set of objectives as described in Chapter 1. Chapter 3, (Section 3.7) provides details on how the research questions are linked with the different thesis chapters.

The case study selected for this research study serves an example of a typical wicked environmental problem entrenched by diverse perceptions of experts and public views, contested conservation and economic goals, policy challenges under dilemmas of risk and uncertainty spread across a large scale (Balint et al. 2011). Wicked problems are complex and multiple and need to be understood and tackled through an adaptive management framework across scales. This thesis answers the questions of how and why through a case study approach:

- How adaptive principles fail to be implemented in practice
- Why issues of scale are critical and failure to address them can lead to management failures of natural systems that are inherently complex

In doing so, it elaborates on the theoretical frameworks such as panarchy and characterises SES as a system that needs to be understood within the context of resilience, vulnerability and adaptive capacity for its sustainable management. These concepts as discussed in chapter 2 serve to provide a context in which communities, policy implementers and scientific communities make decisions that invariably influence SES dynamics. There is extensive literature on the value and significance of understanding the dynamics of SES. This thesis examines the social-political dynamics of these systems in the context of unpredictability that threatens natural systems, against a rapidly changing climate. In doing so, this thesis provides an in-depth understanding of barriers to managing complex systems, an alternate framework to improve their management and avenues for further research. It also aims to contribute to scholarship through research publications to support the critical value of research in the discipline of risk perception and risk communication.

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Annexure I: Discussion points for semi-structured interviews

Topics for the semi-structured interviews were broadly organised under the following discussion points

1. Organisational role in flood risk management.
2. Issues of flooding in the area.
3. Process of flood risk management.
    - How risks are measured.
    - Who assesses these risks.
    - Studies available on flood risks and perceptions.
    - How climate change aspects are incorporated.
4. Community engagement.
    - How and to what extent communities are involved in flood risk management.
    - Perception on community engagement in flood management.
5. Collaboration with other agencies involved.
6. Issues of coordination and communication of flood information.
7. Management at different scales and perception on regional scale flood management.
8. Perspective on the current state of flood management in NSW and Victoria.
9. More specific discussion on hanging swamps, operation of Warragamba Dam, development plans in the growth centres and future impacts of extreme weather conditions were carried out with subject matter experts.

Annexure II: Survey questionnaire sample

School of Biological, Earth and Environmental Sciences
Approval No **HC13124.**

UNSW
THE UNIVERSITY OF NEW SOUTH WALES

Note: This survey takes about 10 minutes to complete. The details of participants will remain confidential. Your participation will contribute to a research study, on flood management and will provide valuable feedback in terms of what communities want for effective flood management.

Occupation	
Postcode	
Duration of living in the suburb	
Age	☐ 18 – 25 ☐ 25 – 35 ☐ 36 – 45 ☐ 46 – 55 ☐ 56 years or older
Gender	☐ Male ☐ Female
Where did you hear about this survey?	
Do you live close to a water body? (e.g. river, creek or stream) 500m to 1KM.	

Information on Flood Risks

1. Choose the following that best describe your situation? (please tick one box only).

☐ My property is under high flood risk area ☐ There is no flood risk to my property

☐ My property is under moderate to low flood risk area ☐ I am not aware about the flood risk

2. Do you participate in meetings held by government/local councils, concerning flood issues in your area? (please tick one box only)

☐ Most of the time ☐ Sometimes

☐ Not at all ☐ I am not aware of any meetings

3. If you require information on floods, where would you, more likely, get the information from?

____

Interaction with Catchment Management Authority (CMA) and Local Land Services (LLS)

4. Do you know what a Catchment Management Authority (CMA) is?

☐ Yes ☐ No - go to question 6.

5. Level of your interaction with CMA. Tick one or more that best describe your situation?

☐ I have worked with my local CMA.	☐ I was aware of what work my CMA did.
☐ I have attended their meetings.	☐ I knew a contact person at my CMAs.
☐ I was aware of my CMA but never needed to contact them.	

Page 1 of 4

6. Are you aware of Local Land Services (LLS)?

☐ Yes ☐ No - go to question **11.**

7. Are you aware of the role of your Local Land Services?

☐ Yes, I am very clear about their role ☐ I have some idea about their role

☐ No, I have no idea - go to question **10.**

8. Please answer the following.

Tick Either Yes or No	**Yes**	**No**
Have you attended any consultation meetings of your local land service?		
Are you aware that your local CMA has been merged into a Local Land Service (LLS)?		

9. Do you agree with this change? (please tick one only).

Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree	Don't know

Please explain your answer:____

____

Role of Local Land Service in Flood Risk Management

10.Please indicate your opinion to the following statements by ticking the most appropriate box.

	Strongly Agree	Agree	Neutral	Dis-Agree	Strongly Dis - Agree	Don't Know
Do you think the LLS can provide a more integrated approach to flood management?						
Please explain your answer.						
Do you think your LLS should help define an acceptable level of flood risk[1] for your region?						
Please explain your answer.						

Role and Responsibility in Flood Risk Management

11. Do you think you need to be informed of flood risks in your region? (please tick one only).

Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree	Don't know

12. Whose responsibility should it be to provide such information? (please specify an agency(s)).

____

[1] A benchmark, which you or the society at large, is willing to accept as acceptable damage caused by a flood.

13. What type of flood information do you require?

____

14. Please indicate your opinion to the following statements by ticking the most appropriate box.

	Strongly Agree	Agree	Neutral	Dis-Agree	Strongly Dis - Agree	Don't Know
Do you think local communities need to be involved in defining an acceptable level of flood risk for their region?						
Please explain your answer.						
Do you think technical flood risk data should be available publically?						
Please explain your answer.						

Catchment Scale management

15. Looking at the map below, please identify the following on the map. You may provide a rough estimate.
  a. **Your location on the Map. Mark it with an 'x' sign**
  b. **Your Local Government Area. Please encircle on the map.**
  c. **Hawkesbury-Nepean Catchment. Please encircle on the map.**

(Source: Hawkesbury-Nepean Valley Flood Management Review, 2014)

Page 3 of 4

Annexure III: Ethical approvals

HUMAN RESEARCH ETHICS COMMITTEE (HREC)

05-Jun-2013
Associate Professor John Merson
Sydney NSW 2052

Dear Associate Professor Merson,

HREC Ref: **# HC13124**
A biospheral approach to managing large catchment systems: a case of flood management in the Hawkesbury-Nepean region under climate change conditions

The Human Research Ethics Committee considered the above protocol at its meeting held on 04-Jun-2013 and is pleased to advise it is satisfied that this protocol meets the requirements as set out in the National Statement on Ethical Conduct in Human Research*. Having taken into account the advice of the Committee, the Deputy Vice-Chancellor (Research) has approved the project to proceed.

Would you please note:-

- approval is valid from 04-Jun-2013 to 03-Jun-2018;
- you will be required to provide annual reports on the studys progress to the HREC, as recommended by the National Statement;
- you are required to immediately report to the Ethics Secretariat anything which might warrant review of ethical approval of the protocol (National Statement 3.3.22, 5.5.7:http://www.nhmrc.gov.au/_files_nhmrc/publications/attachments/e72.pdf) including:
    - serious or unexpected outcomes experienced by research participants (using the Serious Adverse Event proforma on the University website at http://research.unsw.edu.au/human-ethics-forms-and-proformas ;
    - proposed changes in the protocol; and
    - unforeseen events or new information (eg. from other studies) that might affect continued ethical acceptability of the project or may indicate the need for amendments to the protocol;
- any modifications to the project must have prior written approval and be ratified by any other relevant Human Research Ethics Committee, as appropriate;

- if there are implantable devices, the researcher must establish a system for tracking the participants with implantable devices for the lifetime of the device (with consent) and report any device incidents to the TGA;

- if the research project is discontinued before the expected date of completion, the researcher is required to inform the HREC and other relevant institutions (and where possible, research participants), giving reasons. For multi-site research, or where there has been multiple ethical review, the researcher must advise how this will be communicated before the research begins (National Statement 3.3.22, 5.5.7: http://www.nhmrc.gov.au/_files_nhmrc/publications/attachments/e72.pdf);

- consent forms are to be retained within the archives of the HP - School of Humanities and made available to the Committee upon request.

Sincerely,

Michael Grimm
Presiding Member
Human Research Ethics Committee

* http://www.nhmrc.gov.au

HREC RESEARCH ETHICS COMMITTEE (HREC)

24-Jun-2014
Associate Professor John Merson
Sydney NSW 2052

Dear Associate Professor Merson

HREC Ref: **# HC13124**
A biospheral approach to managing large catchment systems: a case of flood management in the Hawkesbury-Nepean region under climate change conditions

Thank you for your request for modification submitted on 19-Jun-2014.
The Executive of the Human Research Ethics Committee considered the above request for modifications at its meeting held on 24-Jun-2014, and is pleased to advise it is satisfied that this modification meets the requirements as set out in the National Statement on Ethical Conduct in Human Research*. Having taken into account the advice of the Committee, the Deputy Vice-Chancellor (Research) has approved this modification to proceed.

Sincerely,

Professor Heather Worth
Presiding Member
Human Research Ethics Committee

* http://www.nhmrc.gov.au

Institute of Environmental Studies

School of Humanities

THE UNIVERSITY OF NEW SOUTH WALES

Shafaq Masud
PhD Student
Institute of Environmental Studies
University of New South Wales, NSW 2052
Tel: +61 93854186
Email: shafaq.masud@student.unsw.edu.au

Participant Information Statement and Consent Form

Project Title: *A biospheral approach to managing large catchment systems: a case of flood management in the Hawkesbury-Nepean region under climate change conditions*

Participant Selection and Purpose of the Study

You are invited to participate in a research study that examines the processes involved in water resource management in the Hawkesbury-Nepean Valley. My research intends to explore how issues of flood are being addressed against a highly invariable climate and what are the existing challenges of water resource management in the region. As part of my research I am interested in understanding the current governance mechanisms for water management in the region (who is involved, what their role is and how management is carried out?). Another element of my research is to understand and identify how exchange of information takes place between agencies and what are the existing knowledge gaps. You are requested to take part in a one-to-one discussion primarily because your agency/organisation plays an important role in managing water resources in the region and you represent an essential stakeholder group in this regard. Your inputs will be highly valuable in gaining a clear understanding of the research study area and its management.

It is also anticipated that experiences shared through my research are intended to provide important insights for the resource management of complex catchments. More particularly, it will provide an extensive and in-depth review of on-ground management practices and how future planning and development be guided.

If you decide to participate, you will take part in a semi-structured interview. The focus of discussion will be your experiences about how flood management is taking place in your organisation. Your suggestions as to any improvements that are needed and how processes of flood management can be facilitate further. The semi-structured interviews are expected to last for approximately 30-40 minutes.

During the interview, you may stop the interview at any time if you do not wish to continue, the audio recording will be erased and the information provided will not be included in the study.

All data will be kept for a minimum of seven years in a secure locked cabinet or password protect computer and then disposed of by shredding or erasure as part of the UNSW ethical requirements.

Confidentiality and disclosure of information

Discussions will be tape recorded to ensure accuracy. Provided that you have signed the accompanying consent form, any information that is obtained in connection with this study that can be identified with you, will remain confidential. As with any research the findings of the will be reported at conferences and in journals where possible and will be made part of my PhD dissertation. In any publication, information will be provided in such a way that the participating individuals or groups will not be identified.

Financial Costs

Please note that there will be no financial cost incurred by you or any payment received for your participation.

Complaints may be directed to the Ethics Secretariat, The University of New South Wales, SYDNEY 2052 AUSTRALIA (phone 9385 4234, fax 9385 6648, email ethics.gmo@unsw.edu.au). Any complaint you make will be investigated promptly and you will be informed out the outcome.

Feedback to participants

A summary of research findings will be offered to research participants at the completion of the study in the form of e.mail.

Your consent

This is solely a volunteer participation to contribute to a research study. Your decision whether or not to participate will not prejudice your relationship with any of the organisations cooperating in this study. If you do decide to participate, you are free to withdraw your consent and to discontinue your participation at any time without prejudice.

This project has been ratified by The University of New South Wales Human Research and Ethics Committee. If you have any further questions please do not hesitate to contact me. My contact details are provided at the top of this Information sheet.

This information sheet is for you to keep.

THE UNIVERSITY OF NEW SOUTH WALES

PARTICIPANT INFORMATION STATEMENT AND CONSENT FORM (continued)

Project Title: *A biospheral approach to managing large catchment systems: a case of flood management in the Hawkesbury-Nepean region under climate change conditions*

You are making a decision whether or not to participate. Your signature indicates that, having read the information provided above, you have decided to participate.

☐ *Please also tick the box to agree that you have given consent to audio-tape this discussion.*

…………………………………………………….

Signature of Research Participant | Signature of Witness

…………………………………………………….

(Please PRINT name) | (Please PRINT name)

………………. | **…………………………………………………….**

Date | Nature of Witness

Researcher's Contact Details to send this form:

Shafaq Masud
PhD Student
Institute of Environmental Studies
University of New South Wales, NSW 2052
Tel: +61 93854186

REVOCATION OF CONSENT

A biospheral approach to managing large catchment systems: a case of flood management in the Hawkesbury-Nepean region under climate change conditions

I hereby wish to **WITHDRAW** my consent to participate in the research proposal described above and understand that such withdrawal **WILL NOT** jeopardise any treatment or my relationship with The University of New South Wales.

…………………………………………………….

Signature Date

……………………………………………………

Please PRINT Name

Shafaq Masud
PhD Candidate
Institute of Environmental Studies
University of New South Wales, NSW 2052
Email: shafaq.masud@student.unsw.edu.au

UNSW
THE UNIVERSITY OF NEW SOUTH WALES

Your Participation Requested

You are invited to participate in a research study that examines the need for a catchment-scale management of Floods in the Hawkesbury-Nepean region.

Title of the Research Study: *A biospheric/total catchment approach to managing large catchment systems: a case of flood management in the Hawkesbury-Nepean region under extreme weather conditions.*

WHY Participate?

Your survey response will be highly valuable in understanding what gaps exist in flood management in your region and how these can be improved. As someone who resides and (or) works in the Hawkesbury-Nepean Catchment, you are requested to provide your valuable inputs through participating in this survey because **Your views matter!**

By participating, you are adding value to a research that takes into account issues of flood management in the Hawkesbury-Nepean valley and local perceptions on floods. Your identity will remain anonymous and only consolidated findings will be used in the research to assess communities' perspectives on flood risk management and identifying a centralised agency to manage catchment scale flood risks.

How to participate?

Please return the enclosed survey to the postage paid envelop also provided. Please note that all type of responses (including 'don't know' no) is valuable research data.

Likewise you can follow the link below to submit your response online

http://www.surveys.unsw.edu.au/f/159164/200b/

or provide a sanned copy of the survey to the researcher's e.mail address:

shafaq.masud@student.unsw.edu.au

Why Knowing Flood Risks Matter?

The 2010-2011 floods in Australia have resulted in renowned focus towards reducing flood risks to communities. A flood damage assessment report for the Hawkesbury-Nepean region estimates a loss of 7,000 homes and significant structural damage as a result of a reoccurrence of a large flood event, historically experienced in the region. Estimates indicate 3 Billion dollars damages and possible evacuation of 50,000 people[10]. With additional development in the Western Growth Centres, the risks could be higher.

[10] Molino Stewart Pty Ltd, 2012, Hawkesbury-Nepean Flood Damages Assessment.

In states like Victoria, Catchment Management Authorities take on the responsibility of flood management and informs planning. In NSW, flood management is carried out by the Local Councils. There is an absence of a regional scale agency that can look at the entire catchment and provide a more holistic view of the condition of the catchment in terms of flood risks and prioritise areas that require attention. There is a need to identify who should take on the responsibility? Or Is there a need for a regional agency that looks beyond the councils? An organisation, which sits under the state agency, coordinates and integrates flood information for the entire Hawkesbury-Nepean Catchment. An agency that can provide a bigger picture of what is happening in the entire catchment and advice state agencies as to what regions need priority.

Confidentiality and disclosure of information

The surveys will be anonymous to avoid personal identity of any participant. As with any research the findings of this will be reported at conferences and in journals where possible and will be made part of my PhD dissertation. In any publication, information will be provided in such a way that the participating individuals or groups will not be identified and all the participant information will be coded. General references of the consolidated result of these surveys will be communicated only.

Financial Costs

Please note that there will be no financial cost incurred by you or any payment received for your participation. There is a return postage provided to you along with the survey for your use.

Complaints may be directed to the Ethics Secretariat, The University of New South Wales, SYDNEY 2052 AUSTRALIA (phone (02) 9385 4234, fax (02) 9385 6648, email humanethics@unsw.edu.au). Any complaint you make will be investigated promptly and you will be informed of the outcome.

Your consent

This is solely a volunteer participation to contribute to a research study. If you do decide to participate, you are free to withdraw your consent and to discontinue your participation at anytime without prejudice.

This project has been ratified by The University of New South Wales Human Research and Ethics Committee. If you have any further questions please do not hesitate to contact me. My contact details are provided at the top of this Information sheet.

This information sheet is for you to keep.