‘Relating with Rivers’: Geomorphic river recovery as a relational, physical-and-social process

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Dedicated to

Deborah 'Bird' Rose

(1946 – 2018)

who taught me to love and bear witness

in the face of ecological violence.

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Abstract

In most cases, rehabilitation efforts are most effective when they work with geomorphic processes and support already-occurring recovery processes. However, analysis of river recovery is most often undertaken from a physical science perspective and neglects important social processes, and relationships between physical and social processes, which also contribute to river recovery. This thesis investigates social and physical dimensions of river recovery, drawing on the Macdonald River in NSW, Australia as a case study. The thesis begins by contextualising geomorphic recovery from historical flood impacts within a sociogeomorphic history. This history is used as a basis for developing possible future trajectories in support of river management prioritisation and planning. The thesis then investigates the role of relationships, between people and between people and place, in enabling and limiting river recovery. First, this is achieved with analysis of landholders' motivations and values with respect to participation in river rehabilitation, and the relational factors that enable or prevent translation of those motivations and values into participatory actions. Second, this thesis investigates relationships within professional communities of practice, revealing the critical importance of social networks in the development, sharing and application of recovery-based river rehabilitation practices. Analysis of relational dynamics in communities of practice informs characterisation of 'River Champions' as particularly influential individuals who drive river rehabilitation, along with considerations for supporting them in communities of practice. This thesis concludes with a discussion that aims to advance development of relational practices in recovery-based river rehabilitation. The proposed agenda includes: (i) adoption of integrative frameworks for understanding physical-and-social landscapes; (ii) repositioning of the researcher and practitioner within the system being managed; (iii) investment in supportive communities of practice capable of nurturing productive relationships; and, (iv) prioritisation of dialogue as a means for developing and maintaining the kinds of relationships that enable river recovery. This thesis serves the development of river research and management practices that recognise and work with the physical-and-social nature of river systems in order to achieve stronger environmental and social outcomes in river management.

Statement of originality

This work has not previously been submitted for a degree or diploma in any university. To the best of my knowledge and belief, the thesis contains no material previously published or written by another person except where due reference is made in the thesis itself.

Simon A. Mould

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Chapter 1

Introduction

Rivers around the world are under significant pressure from human activities that risk loss of water quantity and quality, habitat and many other vital resources (Vörösmarty et al., 2010). In response to the need to improve river condition, governments and other environmental decision-makers are increasingly turning toward approaches to river rehabilitation that seek to work with geomorphological, hydrological and ecological processes rather than engineering against them; i.e., embracing dynamism and variability over stability (Fryirs et al., 2018; Wohl et al., 2015; Rinaldi et al., 2011). The UN World Water Assessment Program's (2018) 'World Water Development Report' of 2018 is entitled, 'Nature-based solutions for water', signaling the increasing profile of this new paradigm of river management. These principles also feature prominently in the European Union's references to 'nature-based solutions' for addressing environmental challenges (European Commission, 2018) and the United Kingdom's commitment to 'working with natural processes' in reducing flood and erosion risk (Environment Agency, 2017). Approaches to river rehabilitation that seek to work with natural processes have now been applied in many places around the world (Fryirs et al., 2018; Gurnell et al., 2016; Rinaldi et al., 2011; Beechie et al., 2010; Brierley and Fryirs, 2009; Dufour and Piégay, 2009; Surian et al., 2009).

1.1 Recovery-based rehabilitation

Many 'nature-based' approaches to river rehabilitation aim to work with processes of geomorphic river recovery. Geomorphic recovery processes are those that occur in rivers following some kind of disturbance (e.g. flood-induced erosion, change in discharge regime, loss of stabilising vegetation or introduction of a sediment pulse; Fryirs et al., 2018; Phillips and Van Dyke, 2016; Scorpio et al., 2015). 'Recovery' as it is applied in this thesis refers to a change in trajectory, following disturbance, toward an improved geomorphic condition (Fryirs and Brierley, 2016). 'Improvement' here does not necessarily mean return to a previous condition, but rather acknowledges that recovery trajectories may be emergent, variable and novel. Recovery processes can be supported and enhanced with passive or low-impact management actions such as removal of pressures like livestock grazing or use of vegetation plantings to stabilise sediments. Recovery-based river rehabilitation approaches have advantages over engineering-based approaches in that they

are typically less costly to implement, more likely to be appropriately targeted to a particular river type in a particular setting and may require less costly maintenance over the long term (Groll, 2017; Moore and Rutherfurd, 2017; Brierley and Fryirs, 2009).

The term, 'river rehabilitation' is used here as opposed to 'restoration,' although they are commonly used interchangeably in different regions. Whereas 'restoration' implies the visionary recreation of a past state, 'rehabilitation' implies adaptation to new conditions (Fryirs and Brierley, 2013; Kondolf, 2011), as in its use when referring to medical rehabilitation following injury. Many rivers have now been so significantly modified by humans, directly or indirectly, that restoration of prior states would neither be possible nor desirable; we cannot 'turn back the clock' (Wohl et al., 2015; Balaguer et al., 2014; Higgs et al., 2014). However, we can help rivers to improve in condition within the bounds of what is biophysically and socially achievable under altered boundary conditions (Piégay et al., 2018; Brierley and Fryirs, 2009; Dufour and Piégay, 2009; Hobbs et al., 2009; Palmer et al., 2005; Eden et al., 2000). Although recovery-based approaches are not retrospective in their aims, this does not render historical information irrelevant to the task of recovery-based river rehabilitation; the distinction is in how historical information is used. Whereas restoration-based approaches use historical information prescriptively (e.g. with historical reference conditions), recovery-based approaches use historical information as context for understanding a river's previous trajectory of adjustment and in planning for multiple possible future trajectories (Brierley and Fryirs, 2015; Cook et al., 2014; Higgs et al., 2014) within the bounds of what is biophysically and socially achievable. Analysis of historical trajectories can help to identify the causes of geomorphic change and to understand triggers for improvement or deterioration in river condition (Fryirs and Brierley, 2016; Wohl et al., 2015).

1.2 Integrating physical and social processes

The question of what is biophysically and socially achievable in river management requires research that is capable of integrating knowledge from the physical and social sciences in study of what is now commonly referred to as 'coupled human and natural systems' or 'CHANS' (Liu et al., 2007). This type of research is characterised by framings that recognise close relationships between biophysical processes (e.g. geomorphology, hydrology, ecology) and social processes (e.g. economic, cultural, political). These relationships are

complex and include feedbacks, contingency and variability in space and time (Poeppl et al., 2017). Thinking in terms of CHANS has contributed to scholarship examining physical and social process relationships in hydrology (Bouleau, 2014; Lane, 2014; Linton and Budds, 2014; Sivapalan et al., 2012) and geomorphology (Mould et al., 2018; Ashmore, 2015; 2018; Wohl et al., 2015; Wilcock et al., 2013). Previous work has demonstrated some of the important ways that social processes interacting with physical processes have produced particular outcomes for river morphology and behaviour; for example, the effects of changing imaginations and perceptions of particular landscapes (Urban, 2005), differences in stream restoration outcomes under market-based and non-market schemes (Doyle et al., 2015), the politics of knowledge production and use in policy and practice (Blue and Brierley, 2016; Haughton et al., 2015) and the influence on river management practice of the social dynamics of science (Lave, 2016). These works highlight emerging interest in finding more integrative and holistic ways of understanding the complex interrelatedness of social and physical processes and its relevance for environmental scientific research and management.

'Sociogeomorphology' is a key area of focus in this thesis because of its close relationship to the concept of geomorphic river recovery and recovery-based rehabilitation, providing a philosophical framework for understanding geomorphic and social process relationships. The premise of sociogeomorphology is that geomorphic landscapes emerge through interactions between physical and social processes, not in isolation but inextricably linked (Ashmore, 2015). Whilst geomorphological research has for some time been concerned with human-environment interactions, sociogeomorphology is an effective articulation of an agenda to understand the underlying social processes that influence human interactions with rivers; i.e., the 'why' of human impacts, not only the 'what' and 'how' (Ashmore, 2015). Sociogeomorphology and related approaches to understanding physical-and-social co-emergence can be seen to fit within a broader frame of research known as 'critical physical geography', which applies critical geographical theory, along with a firm grounding in physical geography, in order to understand physical-and-social landscapes in an integrative way (Ashmore, 2018; Lane, 2016; Lave et al., 2014). These framings for understanding landscapes as inseparably physical-and-social provide opportunities to re-examine and extend many aspects of environmental research and practice, including analysis of social dynamics and power relations influencing – and being influenced by – physical elements

of landscapes (Lave et al., 2018). Application of critical physical geography is particularly relevant in the context of river management, which is characterised by close and often-fraught relationships between people, and between people and rivers (Hillman et al., 2008; Karr, 1999; Holling and Meffe, 1996).

1.3 Relationships in river management

River rehabilitation, and management more generally, are increasingly participatory processes in many parts of the world. For example, participation is a requirement of the European Water Framework Directive and the United Nation's Commission on Europe's Aarhaus Convention (Hassenforder et al., 2018; Horangic et al., 2016). A requirement for river management to be participatory ensures that human and environmental factors both be considered in decision-making; however, integrating understandings of each of these is a significant challenge for river management and care must be taken to avoid 'train wrecks' when different knowledges collide (Benda et al., 2002).

River management is about much more than managing a technical, environmental problem; it is as least as much about managing relationships as it is about managing rivers (Mould et al., 2018; Natcher et al., 2005). The critical importance of relationships has been explored previously in investigation of knowledge sharing. For example, Roux et al. (2006) make the important distinction between tangible 'information', which may be readily transferred between people or organisations, and tacit 'knowledge', which is much more difficult to document and transfer. Their analysis redefines knowledge as a 'process of relating' rather than a 'thing', requiring that careful attention is paid to relationships in environmental management. In meeting this need, the concept of 'communities of practice' provides a framework for examining the relationships that support collaboration and communication. Communities of practice are self-organising social networks of people who do not necessarily belong to the same disciplinary groups or organisational units, but work together because of a shared interest in a particular issue or problem (Wenger, 2010). An important characteristic of communities of practice is that they are often forums for social learning, in which people learn together through social interaction (Cundill et al., 2011; Reed et al., 2010; Pahl-Wostl et al., 2007; Bouwen and Tallieu, 2004), thus positioning communities of practice as sites of knowledge co-production (Lane et al., 2011; Roux et al., 2006). Since river management is inherently cross-disciplinary, and

increasingly participatory, investigating communities of practice can provide insight into the ways that river management is a relational process.

1.4 River management in the Australian context

Australian rivers are well known for their highly variable, event-driven flow regimes and generally low sediment delivery ratios (Bunn et al., 2006; Rutherfurd and Gippel, 2001; Finlayson and McMahon, 1998). This physical variability places particular limits on what can be realistically achieved in terms of river rehabilitation (Fryirs et al., 2008) and means that the task of river management is often to manage for extremes rather than predictable regimes. The majority of rehabilitation efforts employed in the last few decades have been passive in nature, with managers focusing on provision of environmental flows, maintenance of riparian vegetation and catchment connectivity rather than project-based engineering works. Overall, the amount of money spent on river rehabilitation in Australia is much smaller than in many other OECD countries (Fryirs et al., 2008; Rutherfurd and Gippel, 2001).

Australian government structures are divided into three main levels: Federal, State/Territory and Local Governments. River management is characterised by a federalised system (c.f. Doyle et al., 2013) in which states and territories have a large amount of control in developing and implementing environmental policies. Responsibility for river rehabilitation activities typically lies with regional branches of State Government agencies, such as Local Land Services in New South Wales (NSW) or Catchment Management Authorities in Victoria. These activities tend to be a mixture of agency-led and community-led efforts (Fryirs et al., 2008; Jennings and Moore, 2000). River rehabilitation works on private land are financially incentivised by regional branches of State Government agencies to be carried out or contracted by private landowners (Curtis and De Lacy, 1996). River rehabilitation works on public land are typically the responsibility of Local Governments, also supported by State Government agencies, unless those public lands fall under State or Federal legislation (e.g. state-managed National Parks or federally-legislated RAMSAR wetland sites). Reaches of river may consist of a mixture of private and public lands, and ownership of bed and banks is inconsistent, dependent on when the land title was last surveyed.

River management in Australia has been characterised as having a 'middle-ground' structure, in which State Government agencies occupy the space in between 'bottom-up' and 'top-down' structures (Hassenforder et al, 2018; Gregory et al., 2011). Middle-ground decision-making is often exercised through regional branches of State Government agencies, who develop management plans for their areas of responsibility and deliver programs (e.g. incentive schemes for voluntary river rehabilitation). This structure ideally balances local specificity and the needs of local communities with higher-level (e.g. State) management priorities. However, it has also been criticised as a solution for 'passing the buck' on to landholders (Curtis and De Lacy, 1996) and in reality, the challenge of integrating 'top-down' and 'bottom-up' priorities and actions is far from straightforward (Hassenforder et al., 2018; Fryirs et al., 2008). Much of this thesis examines the particular challenges – but also opportunities – that are inherent in this particular setting.

1.5 Thesis aims and methodological approach

Given the challenges of managing rivers in a context of physical, social and political variability, there is a need to develop practices in research and management that can support holistic and effective river management. The overarching objective of this thesis is to apply relational thinking to the subject of geomorphic river recovery so to contribute to development of river management practices that are physically and socially appropriate. Figure 1.1 outlines the broad research themes in this thesis and the relationships between those themes. This thesis is driven by the following research questions:

- In what ways is geomorphic river recovery a physical-and-social process?
- How do relationships between people, and between people and place, contribute to geomorphic river recovery?
- What are the implications of the relational nature of geomorphic river recovery for river management practice, and the relationship between geomorphic research and river management practice?

The interdisciplinary nature of these research questions is challenging from a methodological perspective, requiring an approach capable of questioning and interpreting geomorphological, historical (documentary) and social sources of information. Additionally, this thesis serves an applied purpose in terms of generating clear outcomes that can be enacted at intersections of research and environmental management practice.

The focus in this thesis on understanding the importance of relationships necessarily involves engagement with particular and nuanced relationships between research subjects (including people and rivers). The data that are relevant to understanding these relationships are often codified in people's life experiences and personal stories in ways that make the data inaccessible via a methodological approach that aims for measurement or statistical representation (e.g. through a 'sampling' frame). Social science methods that prioritise broad coverage over in-depth understanding of individual information-rich cases were considered inappropriate for the purposes of this research. Such approaches do not typically allow the development of relationships of trust between researcher and informants, which are critical for accessing, understanding and translating individuals' personal relationships and relational values (c.f. Tadaki et al., 2017; Gould et al., 2015). This thesis adopts a qualitative methodology which places relationships at the centre, in terms of both data and method. Rigour was established through purposeful selection of respondents (information-rich cases who could share relational experiences), ongoing engagement prior to and following interviews, and verification of data with respondents (Baxter and Eyles, 1997). The approach taken is one where the researcher must, themselves, build relationships with individuals over time in order to share trust and become an informed audience for a diverse set of human experiences. Such an approach could be described as 'doing research through relation', wherein emerging relationships with people and place enable access to data concerning nuanced and personal relationships, and also provide the basis for interpreting and understanding those data within the context of a dynamic network of relationships. Such considerations for the particular nature of relationships and their meanings are, themselves, an important outcome of this thesis.

In order to address the thesis' research questions, the following specific research objectives will be addressed:

- Using a case study, demonstrate application of a sociogeomorphic framing, investigating river recovery in terms of emergence through interactions between physical and social processes;
- Explore relational dimensions of participation in river management by local landholders to understand motivations and values influencing local participation;

- Investigate development, sharing and application of recovery-based river rehabilitation practices in communities of practice in order to understand how social relationships shape practices in the professional river management sector;
- Draw on case studies to characterise and highlight effective uses of relational approaches to leadership by individuals working in river management; and,
- Advance a relational approach to recovery-based river management through explorations of its implications for river management at the intersection of science, practice and society.

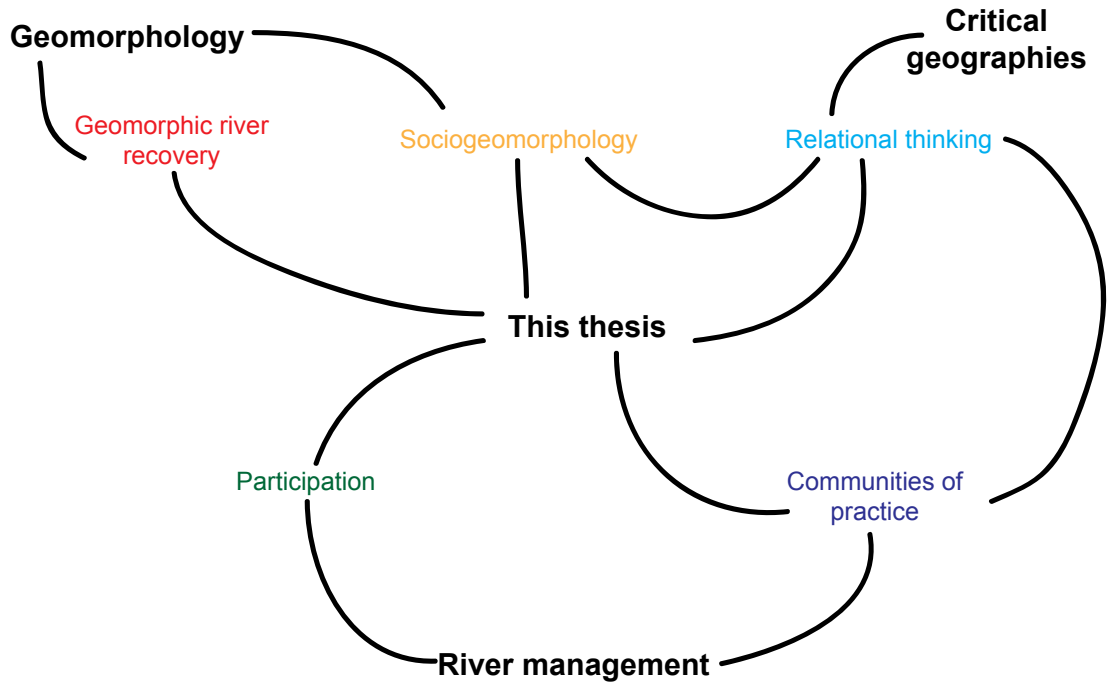

Figure 1.1: Graphical representation of major themes underpinning this thesis.

1.6 Structure of thesis

Following this chapter, the thesis begins with a 'visual narrative' introduction to the study site at the centre of this research, the Macdonald River. This takes the form of a photo essay and is intended to situate the research in place. Chapter 2 also provides some reflection on geographical research as a process of building relationships with place, giving relational context to the following research as an artefact of the author's relationship with the river. The research aims of this thesis are addressed through Chapters 3 to 6. These chapters are co-authored and structured as discrete papers for publication in academic journals. As such, some minor overlap can be expected from the introduction sections of these papers and the thesis introduction. However, each chapter makes a unique contribution to the overall thesis aims. Chapter 3 to 5 are written in the style of a standard journal article and Chapter 6 is intended as a 'short communication'. The final chapter, Chapter 7, is the thesis discussion, which highlights the significance of contributions made by each preceding chapter relative to the thesis aims. A summary of the relative contributions made by each author of the papers comprising Chapters 3 to 6 follows below.

Chapter 3: 'Contextualising the trajectory of geomorphic river recovery with environmental history to support river management'

Mould, S. A., & Fryirs, K. A. (2018). Contextualising the trajectory of geomorphic river recovery with environmental history to support river management. Applied Geography, 94, 130-146. Doi: 10.1016/j.apgeog.2018.03.008

Conception: SM (90%); KF (10%). SM provided a majority of the intellectual contribution and oversaw conceptual development of the paper. KF provided ideas and guidance in presentation of results and guided framing of the discussion.

Data collection: SM conducted all desktop and field investigation with fieldwork assistance for topographic surveying.

Analysis: SM conducted all data analysis, including historical research, preparation of survey data and calculation of stream power analysis.

Writing: SM (90%); KF (10%). SM wrote the majority of the manuscript, produced and organised figures and organised manuscript structure. KF contributed to the introduction, discussion and manuscript organisation.

Chapter 4: 'Managing social enablers and barriers for landholder participation in river rehabilitation'

Mould, S. A., Fryirs, K. A., & Howitt, R. (Submitted). Managing social enablers and barriers for landholder participation in river rehabilitation. Submitted to Journal of Environmental Management.

Conception: SM (90%); KF (5%); RH (5%). SM provided a majority of the intellectual contribution and oversaw conceptual development of the paper. KF and RH provided ideas and guidance in presentation of results and guided framing of the discussion.

Data collection: SM conducted all interviews.

Analysis: SM conducted all analysis of interviews.

Writing: SM (85%); KF (10%); RH (5%). SM wrote the majority of the manuscript, produced and organised figures and organised manuscript structure. KF and RH contributed to the introduction, discussion and manuscript organisation.

Chapter 5: 'Supporting on-ground river recovery: Investment in 'relational resources' for developing, sharing and implementing specialist knowledge in river management'

Mould, S. A., Fryirs, K. A., & Howitt, R. (In preparation). Supporting on-ground river recovery: Investment in 'relational resources' for developing, sharing and implementing specialist knowledge in river management.

Conception: SM (80%); KF (10%); RH (10%). SM provided a majority of the intellectual contribution and oversaw conceptual development of the paper. KF and RH provided ideas and guidance in presentation of results and guided framing of the discussion.

Data collection: SM conducted all interviews.

Analysis: SM conducted all analysis of interviews.

Writing: SM (90%); KF (5%); RH (5%). SM wrote the majority of the manuscript, produced and organised figures and organised manuscript structure. KF and RH contributed to the introduction, discussion and manuscript organisation.

Chapter 6: 'Not all heroes wear capes: River Champions can facilitate effective river management'

Mould, S. A., Fryirs, K. A., & Howitt, R. (In preparation). Not all heroes wear capes: River Champions can facilitate effective river management.

Conception: SM (80%); KF (15%); RH (5%). SM provided a majority of the intellectual contribution and oversaw conceptual development of the paper. KF provided

the initial idea for the paper and helped to develop the concept of a 'River Champion'. KF and RH provided ideas and guidance in framing the argument.

Data collection: SM conducted all interviews. SM and KF provided examples of 'River Champions' in developing their characterisation.

Analysis: SM conducted all analysis of interviews.

Writing: SM (85%); KF (10%); RH (5%). SM wrote the majority of the manuscript and organised manuscript structure. KF and RH contributed to the manuscript body.

1.7 The Macdonald River case study

The case study used in this thesis is the Macdonald River, whose confluence with the Hawkesbury River is located approximately 55 km North-Northwest from the city of Sydney, New South Wales, Australia. More comprehensive regional setting information is provided in the following chapters. However, this section outlines the reasons why this river valley, its community and its broader management context were selected as the case study. Three primary factors make this case study suitable for addressing the aims of this thesis:

- The Macdonald River is showing signs of geomorphic recovery following historical land use and event-driven flood disturbance, enabling examination of geomorphic recovery processes;
- The Macdonald River has been well studied in geomorphic terms, particularly with respect to the geomorphic impacts of historical flooding (influence of social processes in its geomorphic recovery has not yet been studied); and,
- The Macdonald River community provides an example of a community of practice that has engaged with the concept of geomorphic river recovery, allowing application of this concept to be examined.

It was important that the case study site has been well studied in geomorphic terms so that this thesis could concentrate on advancing the application of sociogeomorphology in recovery-based rehabilitation, rather than allocating the majority of resources to undertaking more fundamental characterisation of the geomorphic landscape. This allowed the thesis to devote resources to the un-studied social processes that also contribute to river recovery. Additionally, it is important to note that the Macdonald River community and its activities in recovery-based river rehabilitation are not necessarily

typical of rural communities in NSW. Rather, their particularly high level of engagement in river rehabilitation provide a case study in something close to 'best practice', from which can be learned the characteristics of well-functioning community-led river rehabilitation practices. Exploration of this case study provides an unusual opportunity to investigate a river in recovery with a well-documented history and an engaged community, well supported by government-based natural resource management professionals.

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Chapter 2

The Forgotten Valley

A visual narrative of the Macdonald River

Before we dive into the academic content of this thesis, I'd like to take a moment to welcome you to the Macdonald River. This place has become very important to me over the past three years as I have taken many trips up-river (some of which were even for research purposes). The following is a visual narrative of the Macdonald River, in the style of a photo essay, through which I hope to introduce you to some of the qualities of this place that are more difficult to glean from the text, maps and figures in the following chapters. This photo essay contributes to a practice that I describe in a recent paper as 'seeing double;' that is, practicing art and science, together, as a way of recognising and negotiating social, political and place-based context, professionally and personally (Mould, 2018, provided in Appendices). 'Seeing double' means noticing the scientific as well as affective aspects of a case and reflecting on the ways that personal relationships with a place shape meaning. Rather than excluding personal relationships as points of bias, those relationships are drawn on to help with interpreting case data and connecting concepts. All of the material presented here was collected as part of my research process and some has been used as a basis for scientific interpretation. However, by recontextualising this material I hope to assert that these research objects also have significance beyond their scientific value and that reflecting on a developing sense of place is vitally important in geographical research. This is my way of situating my research in place and as an artefact of my relationship with the river, its landscape and its people.

Photographs provided by others are credited as such.

The Macdonald River is only accessible from the South by car ferry from the town of Wisemans Ferry, where the Macdonald meets the Hawkesbury River. The Macdonald has often been called 'The Forgotten Valley,' because of its history of isolation. Warren described to me the feeling he gets as he drives down from the ridge, through the switchbacks and down to the ferry:

> *"When you drop off that ferry hill you're in a totally different world, I believe."*

I have to say that I agree.

As you drive up-valley, you'll notice a few large stands of mature poplar trees taking up whole paddocks on the floodplain. One resident told me that they were planted by an enterprising landholder, who planned to sell the timber for making matchsticks. Unfortunately, the story goes that as the trees were reaching maturity, the mass-produced cigarette lighter took off and the last matchstick factory in NSW closed down.

The Settlers Arms (1836) is the focal point of the valley, apart from the river. Most people in Sydney don't seem to know where the Macdonald Valley is, but they've all heard of the Settlers Arms. The hotel hasn't changed much since this photo, which was taken around 1988. Even on busy Saturdays in Autumn, the pub dogs can be found sleeping on the road with traffic moving off the road to pass them.

Left: Photo by Percy Sternbeck, courtesy Coalfields Heritage Group, donated by the Sternbeck Family

When I think of the Settlers Arms, my first thought is always of Ninian Sternbeck. He rarely missed a weekend at the pub (although he didn't drink) and would sit by his truck, selling home-grown watermelons in summer and pumpkins in the cooler months. Ninian told me about a particular variety of corn that is only grown in the Macdonald Valley, by nobody but himself. I would always stop and chat to Ninian, often spending a few hours in the winter sun, until one day when I came by to see him and he wasn't there. He died just before Christmas, 2018 aged 83 years, and I'm sad that he won't get to see this. I dedicate this chapter to Nin.

The people of the Macdonald Valley told me the most wonderful stories about their lives, the river, the floods and some of the characters who have lived there. Heidi told me about being carried across the river in the bucket of an excavator after the crossing was wiped out in a flood, and about the people who were nearly drowned when their truck was swept away. I heard stories about horse races to settle bets, lives saved by cigarettes, rockfalls, bushfires and swimming with snakes.

Heidi's photo albums

Flooding is a big part of the Macdonald's story, and the bridges really help to tell that story. Bailey's bridge (top) was bent by floods in the 1970s and then again in the early 1980s, before it was finally replaced with concrete. The Piggyback Bridge (bottom) was buried by sand in the 1970s floods, so a second bridge was built, piggybacking on top of the first. The two levels of bridge could be seen until only a few years ago, when it too was replaced completely.

Top-left: Photo by Percy Sternbeck, courtesy Coalfields Heritage Group, donated by the Sternbeck Family
Top-right: Photo by Simon Mould, 2018
Bottom: Photo by Kirstie Fryirs, 1990s

As you drive up-river, the valley gets tighter. Steep, sandstone walls give an enclosing feeling. For me, the higher up the valley, the better.

The days of this being a 'working valley' are long gone; nobody really makes a living entirely from their land anymore. But farming is carried on by descendants of the older families and some of the newer residents keep animals, too.

Farmers tend to corn in what is now a ponded tributary lake, courtesy of Joyce Stepto of Price Morris Cottage

There's so much more that I could say about this valley, but I would like to finish by showing the recovery that's been evident in recent years. River recovery in the Macdonald is the central focus of this thesis and the specifics of that process will be elaborated on in the following chapters. However, the visual comparison between this photo from 2018 and the historical images on the previous page communicate the 'big-picture' message very clearly. The people who are working hard on rehabilitating the Macdonald are so proud of their river and care for it deeply. Their efforts, working *with* the river, are paying off.

Chapter 3

Mould, S., & Fryirs, K. (2018). Contextualising the trajectory of geomorphic river recovery with environmental history to support river management. *Applied Geography*, 94, p. 130-146.

DOI: 10.1016/j.apgeog.2018.03.00

Addendum

Following publication of this chapter in *Applied Geography*, it was deemed necessary to make the following points of clarification:

1. **Methods used in calculation of stream power**

Unit stream power calculations were undertaken using the software application, 'Geomorphic Assessor' (developed by Parfait, 1999). Manning's n (roughness) was estimated visually in the field to benchmark contemporary values for valley margin, floodplains and in-channel sections, and then estimated using interpretation of aerial and ground-level photography for historical timeslices. Unit stream power was calculated for each cross-section under each trajectory scenario (as outlined in Table 2) by manually adjusting the discharge (Q) value and re-running the model. Q was estimated using catchment area-discharge equations based on regional gauge information in the absence of continuous and reliable hydrological data available for the Macdonald River (as outlined in Methods section of Chapter 3).

2. **Comparison of channel changes (recovery) with earlier interpretations of geomorphic adjustment in the literature**

Previous authors have provided detailed analysis of the history of channel changes in the Macdonald River throughout the Holocene and in particular since historical 'catastrophic' flooding in the 20th Century. These studies are referenced in the published paper, with the exception of work by Rustomji (2008, Geographical Research). The authors were aware of Rustomji's work, and its omission from the published article is a regrettable oversight, since this work specifically addresses some of the forms of geomorphic recovery with which Chapter 3 is concerned. The present research builds on previous work by analysing changing land use and the broader human processes (including social, economic and political) which have influenced human interactions with the river over time. The integration of human processes with geomorphic processes enriches knowledge of the full range of boundary conditions (physical and social) which have constrained geomorphic adjustment in the past and now constrain the range of possible future trajectories of recovery (or degradation).

3. **Relationship between human influence and recovery trajectory**

This chapter addresses relationships between human influence and river trajectories in two primary ways: (i) examining parallel and intersecting physical and social trajectories that have influenced river morphology over time; and (ii) discussing the role that management (including use of trajectory analysis) can play in influencing possible future river trajectories. This is achieved through integrative analysis of environmental history, beyond direct human impacts on rivers and including broader social, economic and political processes. A management pathway to river recovery in this case could be simplified as "if you leave the Macdonald River alone, it will recover"; however, managing for a scenario where rivers are 'left alone' necessarily requires engagement with nuanced and complex social histories, economic and political forces and human relationships to communities and landscapes, which make up the 'social boundary conditions' that constrain future trajectories. Management of future recovery trajectories is addressed in this chapter in terms of the ways that conceptualisation, communication and dialogue concerning rivers can indirectly influence the range of possible future river trajectories. In the Macdonald River case, the River Recovery (trajectory) Diagram has since been used in outreach activities, helping landholders and practitioners to frame and prioritise their river rehabilitation efforts. Development of enhanced communication tools and effective engagement with community and professional decision-makers are major (if indirect) factors influencing river trajectories, when examined through a sociogeomorphic lens.

Chapter 4

Managing social enablers and barriers for landholder participation in river rehabilitation

Abstract

Participation by local communities is a key requirement of many environmental management policies globally. Understanding what enables or prevents landholders' participation in environmental management is a fundamental requirement for strategies aiming to utilise this often-voluntary resource base. This is particularly important where strategies have to rely on voluntary participation to achieve environmental outcomes on private land. This paper investigates landholders' motivations for participating (or not) in river rehabilitation and the outcomes of those activities from the landholders' perspectives. We draw on the concept of 'relational values' to understand landholders' motivations for (non-)participation in river rehabilitation and explore how relational enablers help to translate these motivations into actions. Identified enablers and barriers are institutional, social and personal, and are more or less relevant to individual landholders. Beyond environmental benefits, participation in river management is influenced by – and contributes to – relational values, including a sense of community, place and identity. Where bottom-up activities constitute a significant proportion of river rehabilitation work, managing the relational enablers and barriers for participation is crucial. We encourage practitioners to recognise relational values and prioritise enabling relationships in order to maximise appropriate participation in communities.

4.1 Introduction

In many countries, participation by communities has been normalised as a core component of policy in river rehabilitation and environmental management; for example, as prescribed in the European Water Framework Directive (WFD) and United Nations Commission on Europe's Aarhus Convention (Hassenforder et al., 2018; Horangic et al., 2016). However, types and levels of participation vary considerably both in policy and practice (Euler and Heldt, 2018; Maynard, 2013). For example, Arnstein's (1969) 'ladder' of participation outlines a range of levels from 'manipulation' to 'community control' of decision-making. This early work is an important reminder that community participation in environmental management is not, in itself, sufficient to deliver appropriate and sustainable management outcomes. What makes one style of participation successful in one social setting may be unavailable, inappropriate or ineffective for another (Hassenforder et al., 2018; Mehring et al., 2018; Grassini, 2017) and landholders (individuals and groups) are far from homogenous (Mehring et al., 2018; Turnhout et al., 2013; Seymour et al., 2011). Participatory frameworks need to be responsive and adaptive to both the social and physical settings in which they are developed and applied (Maynard, 2013; Pahl-Wostl, 2011; Brierley et al., 2006).

'Top-down' and 'bottom-up' structures interact in policy processes to either concentrate or distribute decision-making power among public, private and community sectors (Head, 2007). The space where these structures intersect is commonly called the 'middle ground.' In river management applications, middle-ground decision-making is often scaled at the catchment level, ideally allowing integration of values and processes from – and across – a range of scales (Gregory et al, 2011; Frissell, 1986). Whereas top-down structures and relationships can generally be described as forming 'formal' systems, bottom-up structures can generally be described as 'informal' in that they tend to emerge out of contingent and place-based social relationships (Hassenforder et al., 2018; Tadaki et al., 2017). As demonstrated by Hassenforder et al. (2018) and Gregory et al., (2011), there is no one clear or consistent approach to achieving complementary integration of top-down and bottom-up systems in the middle-ground, but rather this is a process that requires openness, negotiation, reflection and creating opportunities for social learning (Grassini, 2017; Emery et al., 2013; Pahl-Wostl et al., 2007). Such considerations go beyond policy and make up the contingent social dimensions of river management practice.

The integration of social and physical dimensions of rivers has gained increasing attention in recent research. Fields of research such as sociogeomorphology (Mould et al., 2018; Ashmore, 2015) and sociohydrology (e.g. Lane, 2014; Sivapalan et al., 2012) challenge the traditional conceptualisation of river restoration or rehabilitation as being focused on fixing problems with 'nature' (c.f. Eden and Tunstall, 2006). Instead, an integrated understanding of rivers is promoted, wherein rivers are understood to evolve and adjust due to interactions between physical and social processes, with consequences for river morphology and society as part of socio-environmental systems (Liu et al., 2007). If environmental 'problems' are the result of physical and social processes, then environmental management must recognise and work with these processes. Hence, river rehabilitation can be considered as a physical-and-social process (Mould et al., 2018).

In Australia, river rehabilitation has relied on voluntary participation by private landholders for some time (e.g. Moore et al., 2018; Curtis and Lockwood, 2000). In this participatory system, regional natural resource management agencies operating in the middle-ground plan, coordinate and incentivise on-ground works to be undertaken on private land by private landholders (Gregory, 2011; Fryirs et al., 2008; Carr, 2002). Works undertaken on private land are typically passive or low-impact in nature, applying a 'recovery-enhancement' approach. Such an approach recognises that rather than fighting river behaviour with hard engineering, in many cases, existing 'natural' recovery processes can be supported and enhanced to achieve improvements in river condition (Fryirs et al., 2018; Mould and Fryirs, 2018; Pahl-Wostl et al., 2011). The reliance on participation from private landholders in Australia makes it critical that landholders are encouraged and supported in participation. For this reason, environmental managers must understand the factors that influence how and why landholders are likely or unlikely to participate (c.f. Horangic et al., 2016; Selinske et al., 2015).

Previous studies have found that people volunteer in environmental programs for a range of reasons, including derivation of personal fulfilment and benefits from social interaction (Measham and Barnett, 2008; Ryan et al., 2001). More specifically, on the topic of participation in voluntary environmental incentive schemes, previous studies have sought to understand how and why landholders choose to participate (or not), identifying

influences from personal values, social norms, economic (and other) incentives and environmental pressures (Moore et al., 2018; Curtis and Robertson, 2003; Gooch, 2003). Curtis and Robinson (2003) undertook detailed analysis of the values that act as enablers or barriers to participation in such schemes, demonstrating diversity in motivations for (non-)participation and emphasising the need for responsiveness and choice in the design of extension schemes. In many studies examining various aspects of participation, influential values and motivations are identified and defined in instrumental or intrinsic terms (e.g. Moore et al., 2018; Urgenson et al., 2013; Seymour et al., 2011; Larson and Lach, 2008; Mendham et al., 2007). However, an emerging literature is drawing attention to a third conceptualisation of value, value as relation (Tadaki et al., 2017; Chan et al., 2016). Tadaki et al. (2017; after O'Neill et al., 2008) describe relational values as "being composed of the spiritually and historically contingent relationships and meanings that connect people to their environments and ecosystems." That is, values derived from – and in pursuit of – particular kinds of relationships between people, and between people and place. The identification of relational values offers promise for a fuller understanding of landholders' motivations for (non-)participation in river rehabilitation programs, in addition to more traditional notions of motivating values.

This research aims to understand how relationships and relational values influence landholders' participation in voluntary river rehabilitation programs. Specifically, we investigate motivations and values driving landholder participation and the outcomes of that participation – socially and personally – as expressed by landholders. Responses are used to identify 'enablers' and 'barriers' that may help to translate landholders' motivations and values into direct participation in river rehabilitation (Figure 4-1). The findings are intended to assist community organisations and practitioners in higher-level coordinating agencies to understand, develop and support the strong participation that is necessary for undertaking recovery-based geomorphic river rehabilitation in many settings. Principles to guide policy and practice in participatory river management are discussed in terms of working within a physical-and-social system (Lave, 2016; Ashmore, 2015) with greater recognition of relationships.

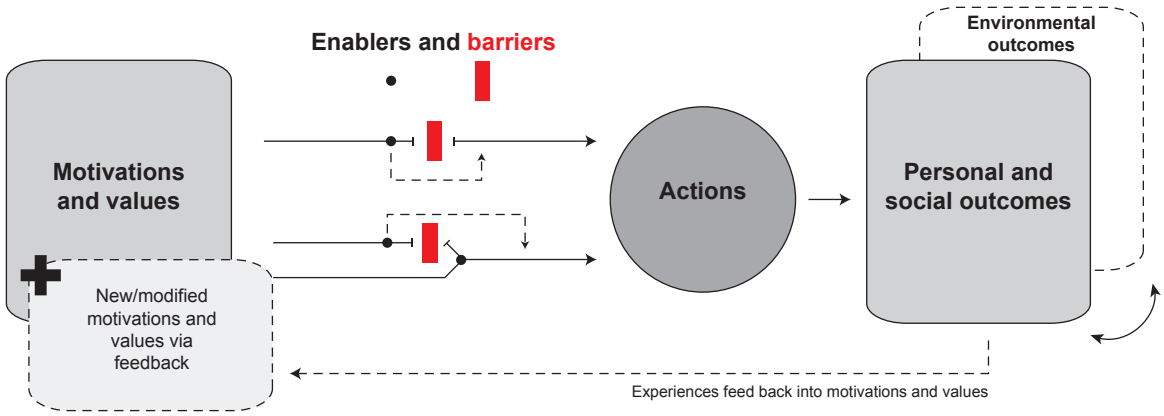

Figure 4-1: Proposed model for investigation whereby landholders' motivations and values driving participation are translated into management actions by enabling factors, or prevented from being translated by barriers. The personal and social outcomes of participation feed back into landholders' motivations and values as part of the dynamic social-and-physical system of which landholders are a part.

4.2 Methods

This research used a relational, qualitative method to explore relational values influencing participation in river rehabilitation projects in the Macdonald Valley, NSW, Australia, a well-documented river catchment near Sydney. The methodological approach recognised that data concerning personal relationships and meaning are often not accessible when more traditional 'sampling' approaches are used, and instead, focused on building relationships with landholders over time as a basis for an ongoing, inductive analysis (c.f. Brandenburg and Carroll, 1995). This process of 'doing research through relation' involved a slower process of researcher sharing trust with research participants and making themselves an informed audience for a diverse set of experiences, interpreted and understood in the particular context of emerging relationships with people and place (see Tadaki et al., 2017). Semi-structured interviews were undertaken with 15 respondents (seven female and eight male), comprising 14 resident landholders and one natural resource management practitioner responsible for the Macdonald Valley (non-resident; Table 4-1). Nine of the landholders were active and intentional participants in river rehabilitation activities and twelve owned property with river frontage at the time of writing. Interviews were usually undertaken with one respondent at a time; however, some couples preferred to be interviewed together. Interviewees were recruited initially via existing contacts, who had assisted with previous geomorphological research on the Macdonald River, and via an advertisement in a local community newsletter. Additional

interviewees were recruited by recommendation from existing interviewees until no new names were being suggested and new themes were no longer emerging. Rigour was established through purposeful selection of respondents (information-rich cases who could share relational experiences), ongoing engagement prior to and following interviews, and verification of data with respondents (Baxter and Eyles, 1997). The interviewees reflected a range of views regarding community participation in – and values about – river condition and rehabilitation. Interviewees' acceptance of the invitation to participate in the research (approved by Macquarie University Human Research Ethics Committee Ref. 5201700048; Appendix B) constructs an inherent risk of bias in the data to better represent those more closely associated with active participants (c.f. Larson and Lach, 2008; Mozingo, 2005). Ethical approval conditions very much discouraged direct approaches being made to individual potential participants. The Macdonald Valley community is small and well connected beyond river management networks, and the voluntary basis for recruitment inevitably focused the research on locals who were already interested and engaged. The recruitment methods meant that many of the key stakeholders active in river rehabilitation processes locally chose to contribute to the research.

Table 4-1: Respondents in research, assigned random numbers.

Respondent Number	Age bracket (yrs)	Gender (female/ male)	Primary land use	Time spent living in valley (yrs)	River frontage on property?
1	50-59	F	Hobby farm grazing	10-20	Yes
2	50-59	M	Hobby farm grazing	5-10	Yes
3	60-69	M	Lifestyle	30+	Yes
4	50-59	M	Hobby farm grazing	10-20	Yes
5	50-59	F	Hobby farm grazing	5-10	Yes
6	60-69	F	Lifestyle	30+	Yes
7	70-79	M	Lifestyle	30+	Yes
8	40-49	M	Grazing	30+	Yes
9	70-79	F	Lifestyle	30+	Yes
10	50-59	F	Lifestyle	5-10	No
11	50-59	M	Lifestyle	5-10	No
12	70-79	F	Lifestyle	30+	Yes
13	80-89	M	Grazing	30+	Yes
14	70-79	M	Lifestyle, weekender	10-20	Yes
15	Not specified	F	Natural resource management practitioner	N/A	Non-resident

Interviewees were asked about their connection to the valley and river (length of time living there, reasons for arriving or remaining, general experiences in community), their level and type of participation in river rehabilitation activities and their hopes for how the river might be in the future. A guide was developed to structure the interviews (Appendix C), but this guide was sufficiently flexible to explore additional themes raised in conversation. In some cases, interviews built on previous informal encounters with the respondents. Interviews typically were of one to two hours' duration and transcribed from audio recording. Transcripts were organised and coded in NVivo qualitative analysis software. *A priori* codes were developed from key themes outlined in the aims of this paper (motivations, practices, outcomes, enablers, barriers) and further interpretive codes (e.g. relationships, values) developed through an iterative process of familiarisation and reflection as an understanding of the case emerged. Qualitative analysis initially aimed to understand the experiences, activities and motivations of each individual respondent. Following this, comparisons were drawn between individuals' experiences, activities and motivations in order to build a picture of the broader social and relational factors influencing participation in this community.

4.3 Regional setting

The Macdonald River Valley in the Hawkesbury River Catchment of New South Wales (NSW; Figure 4-2) is 2730 km^2 in area, the majority of which is covered by intact native forest on Hawkesbury sandstone and shale geology (240-250 Ma), into which the Macdonald River has incised. The lower reaches of the river feature relatively small floodplain pockets, which have been farmed using European practices since the 1790s. The population of approximately 560 is concentrated in the town of St Albans and in the Lower Macdonald locality. A handful of the 'early families' who were amongst the first to be granted land by the NSW Governor are still represented in the Macdonald Valley. Following colonisation, the valley was divided into grants and allocated to free settlers and ex-convicts, whose occupation largely displaced the Darkinjung Indigenous people from their land. Early, intensive land use of cropping, grazing and dairying cleared much of the floodplains and lower hillslopes, which sensitised the landscape to erosion (Mould and Fryirs, 2018). A sequence of five floods between 1949 and 1955 caused significant channel widening via bank erosion and formation of an in-channel sand slug. Subsequent floods in the late 1970s increased in-channel sedimentation, resulting in further loss of geomorphic

complexity. For more detailed analysis of historical flood impacts see Rustomji (2008), Erskine (1986), Erskine and Melville (1983) and Henry (1977).

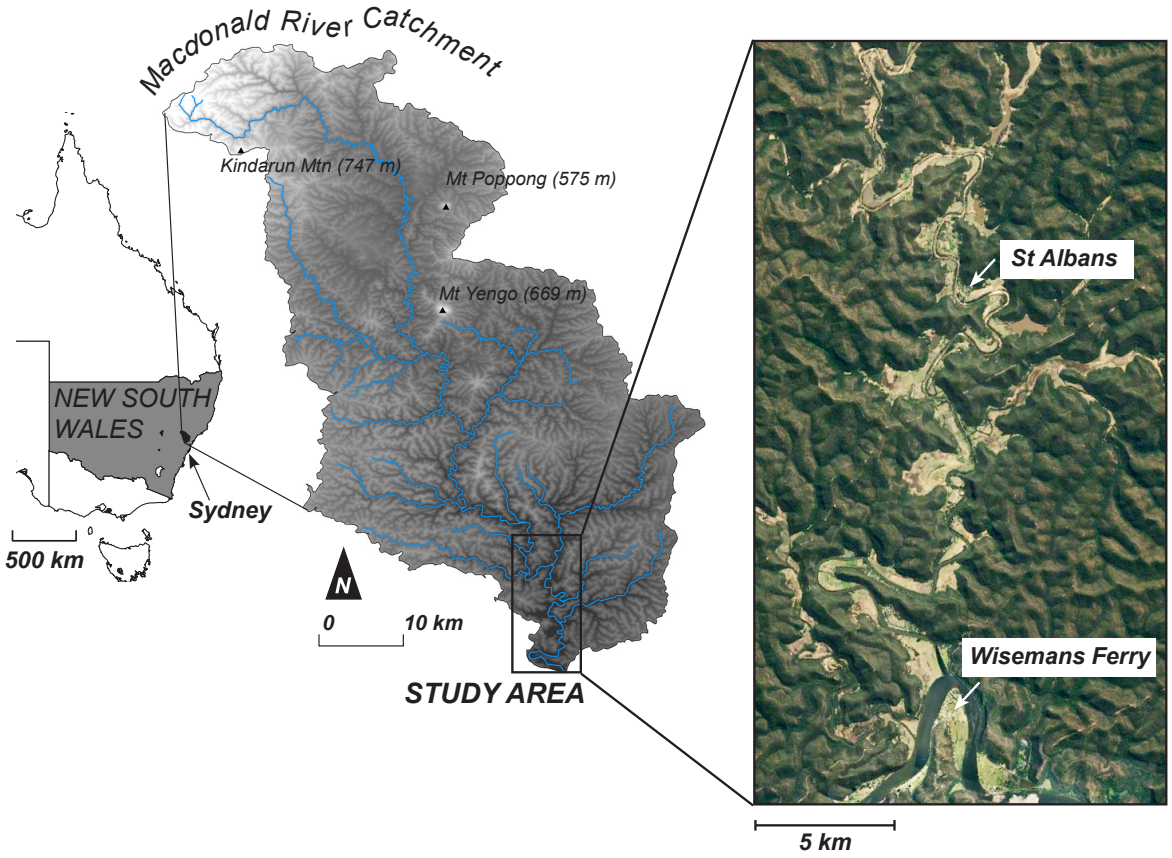

Figure 4-2: Map of the Macdonald River showing town of St Albans, where majority of residents live. Satellite imagery sourced from Google Earth.

Since these catastrophic historical floods, significant changes in demographics, land use and river condition have occurred. A general decline in agricultural intensity and increase in 'lifestyle' land uses (hobby farming, 'tree-changers' – those leaving the city for a rural lifestyle – and part-time occupancy), along with increasing interest in landscape rehabilitation, have supported geomorphic recovery in the form of channel contraction, low-flow channel re-definition and riparian re-vegetation (Mould and Fryirs, 2018). In-channel sedimentary benches, stabilised by vegetation, have confined the low-flow channel (c.f. Rustomji, 2008; Erskine and Livingstone, 1999). This allows smaller floods to produce a more well-defined low-flow channel, scour pools and form riffles, resulting in overall greater geomorphic complexity (Mould and Fryirs, 2018).

In addition to the largely undirected geomorphic recovery, community-led river rehabilitation efforts, supported by Local Government and State Government agencies operating at the regional scale, are contributing to river recovery (Figure 4-3). The Macdonald Valley has high levels of participation (approximately 60 properties) in incentive schemes provided by NSW Local Land Services (LLS; formerly Catchment Management Authority) that are intended to improve farm productivity and protect natural resources (Respondent 15 pers. comm.). Typically, these incentives are in the form of small grants to landowners for the purposes of undertaking passive rehabilitation work. These works include: controlling invasive weeds, fencing riparian zones to reduce grazing by livestock, provision of alternative stock watering points and re-planting of native vegetation. The focus is on 'recovery-enhancement' rehabilitation, which aims to support ongoing recovery processes rather than engineering change in the river. Landowners must match LLS's contribution either financially or with in-kind labour and must complete work within agreed timeframes. The specific details of each project are negotiated between LLS and landowners through development of a property management plan. While legislation protects riparian zones from certain invasive activities, participation in projects to actively improve their condition is voluntary, so strategic coordination of rehabilitation at the catchment scale, undertaken by LLS, requires understanding – and management – of relationships with landholders. This facilitation often occurs via Local Land Services Officers employed by the State Government.

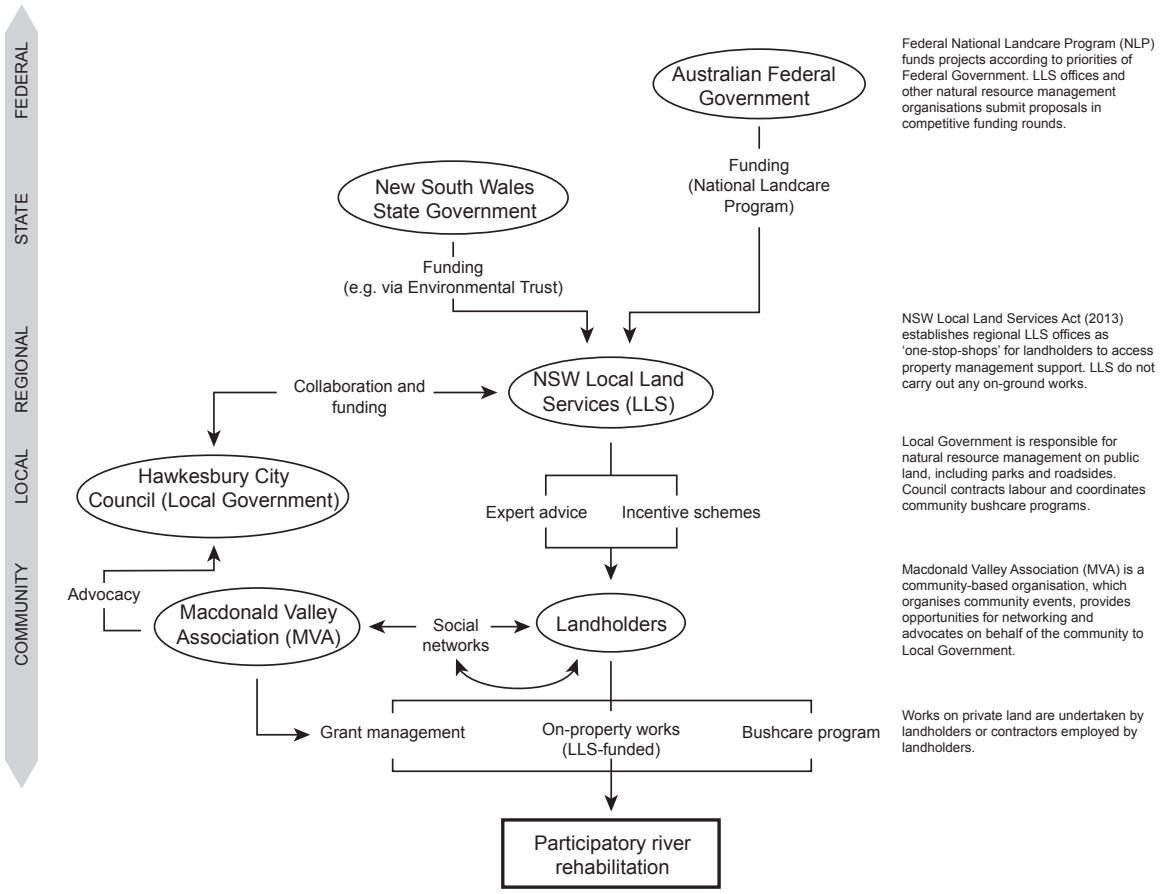

Figure 4-3: Roles of organisations and groups involved in the participatory rehabilitation of Macdonald River, where LLS exist as a middle-ground nexus for funding and coordination of works.

A local community group, the Macdonald Valley Association (MVA), has also successfully received significant funding from the NSW Environmental Trust (partnered with Local Council and LLS) to undertake valley-wide removal of particular weed species (e.g. Tree of Heaven [*Ailanthus altissima*] and False Bamboo [*Arundo donax*]). The MVA is not an environmental organisation, but as a community advocacy group (most commonly in terms of road conditions and provision of other services) the MVA has provided a platform for a small number of individual landholders to promote river rehabilitation in their community. Individual landholders have also independently applied for, and received, grants to undertake similar work on their properties. Supported by these grants, and by government collaborators, the community of the Macdonald Valley is leading a range of environmental programs from the bottom-up. Grants received by the MVA and individuals often require significant administration, which is undertaken by volunteers.

4.4 Results and interpretation

Although many landholders' primary form of participation in river management is through LLS-funded property management projects and local Bushcare groups (volunteer bush regeneration on public land, coordinated by Local Government), their motivations for participating vary, as do their pathways for becoming involved. Interviews with landholders revealed motivations and values driving participation or non-participation as well as the outcomes of participation for individuals and the community. We conceptualise the relationship between motivations/values and outcomes of participation as 'push' and 'pull' factors influencing participation. Motivations and values held by participants push them to act in accordance with their values, e.g. to fix a perceived problem. Outcomes are more like 'rewards' and pull or entice participants toward action. The personal experience of participation itself can be an outcome, which ideally encourages further participation.

4.4.1 Motivations

4.4.1.1 Motivating visions for the river

When discussing an 'ideal' vision for how the river should be, respondents revealed different personal 'baselines' against which the contemporary river was compared (Table 4-2). For non-participants, these baselines tended to correspond to how the river appeared in their earliest experiences of the river. For example, Respondent 12 arrived in the valley in the 1990s, when there was relatively little vegetation in the riparian zone (dominantly grasses and tea trees). This respondent 'fell in love with' the river at this time and would like to see it return to that state. Respondent 13 remembers the denuded riparian zone prior to – and closely following – the 1949-55 floods and continues to maintain the riparian zone in this condition, as did their father. This reflects a possible 'shifting baselines' effect, where what is 'normal' depends on the timing of your formative experiences developing a relationship with that system (c.f. Pauly, 1995). In contrast, active participants in river rehabilitation programs preferred a vision for the river that closely aligns with the goals of the recovery-based rehabilitation program. Many of the participants arrived in the valley after geomorphic recovery had already begun, so their baselines contained densely vegetated – but weed impacted – riparian zones. A cleared riparian zone does not typically factor into their range of options for how the river should be, so improvement of species mix is their most attractive management action. This raises the question of how success in

vegetation rehabilitation is to be assessed, particularly in terms of coverage and species mix. While some respondents referred simply to restoration of 'natural bushland' (i.e. pre-European colonisation) others considered that they had a responsibility to manage for a future changing climate. For these respondents, ecological functioning into the future was very important.

4.4.1.2 Motivating responsibilities

Participants in river rehabilitation saw their work as fulfilling a responsibility to the future (future of river and landscape and of future generations). In contrast, responses from non-participants could often be characterised as expressing a responsibility to the past (how the river used to be or how previous generations of farmers cared for the land). These motivating responsibilities somewhat parallel motivating visions for the river (above) and the interrelationships between care for cultural and physical dimensions of the landscape (c.f. Wilcock et al., 2013). However, it would be overly simplistic to generalise the two groups of participants and non-participants as being only future- or past-focused; the future of the valley and its community was a concern expressed by most respondents, regardless of their participation status. Concerns for the future held by non-participants tended to focus on issues such as risk of flood damage, access to the river and use of its water and riparian zones for grazing or recreation. Participants in rehabilitation were also concerned with risk of flood impacts, but they tended to frame this in terms of damage to the river and a loss of progress in river recovery, rather than risk to human safety or infrastructure. Participating respondents often stressed the importance of the river as habitat for native animals and as part of a broader vision for intact, native ecological communities throughout the valley (linking hillslopes and fluvial landscapes).

Table 4-2: Motivations and values driving participation in river rehabilitation

Theme	**Responses**	**Example from interview**
Motivating visions for the river	Channel should be shallow and river clear of vegetation other than grasses (pre-1949 flood condition) • Access to river (for humans and cattle) • Values do not align with rehabilitation agenda	"If [the channel] were deeper right down it'd be no good for me to cross in my tractor" – Respondent 13.
	River should be vegetated with soft vegetation only: tea trees, grasses, reeds (early recovery condition) • Concerns for flood impacts and erosion • Aesthetics and amenity • Values align weakly with rehabilitation agenda	"I don't believe in gum trees on the river … because they're too rigid; if something gets caught alongside them and the flood starts to gouge it out … I think reeds, tea trees, anything that bends with the water … if the river's getting deeper that's a positive, because that's how it used to be" – Respondent 8. "You just don't need all this stuff [complex vegetation]. Let it go back to grass and tea trees … it used to be beautiful when it was like that" Respondent 12.

Theme	**Responses**	**Example from interview**
	River should be well-vegetated with diverse vegetation communities (fully recovered condition) • Valuing biodiversity • Valuing 'natural' (native) bushland • Aesthetic concerns • Habitat for fauna • Values align strongly with rehabilitation agenda	"You become aware of this whole community … different tree species come into prominence at different times. And you'd be missing all that [if weeds took hold] … and we notice, the birds notice …you are actually creating, a bit more like a quilt, as opposed to just one colour, just one fabric, one texture" – Respondent 1. "We love the place and don't want it to be taken over by weeds." "We've got amazing numbers of birds here." "And we've started to have koalas come back … so we planted a whole – our tree avenues that we planted, we planted species that they eat, too." – Respondents 7 and 9. "The bird life is incredible. The native fauna is very important." – Respondent 2.
Motivating responsibilities	Identity as traditional, generational farmer • Carrying on traditional practices	"My father wouldn't let a tree grow close to the river because he used to reckon it would wash around, cause things to get washed away" – Respondent 13.

Theme	**Responses**	**Example from interview**
	Responsibility as a steward for the land • Responsibility to future generations • Earning privilege of owning land	"We can't let this [weed infestation] happen … in 50 years' time my son will be a very old man and we'll be long gone … the river will still be here … so my vision is always to 'rescue the future'" – Respondent 6. "If you own a property and let it go to wrack and ruin like that, then you shouldn't own it." "Yeah, it's like, you can't just turn your shoulders." – Respondents 4 and 1.
	Local actions seen in broader context • Being part of a greater environmental movement (e.g. catchment-scale, global scale) • Insignificance of small actions (contrary to previous)	"I think if we're going to revegetate the river, as most of us are planning to do, how is that going to change the river?" – Respondent 2. "It's our little bit; it's our little piece. And it's not too much when you break it down to that." Respondent 1. "I wouldn't get involved in [weed management] much. Although I don't like it – I don't like invasive species – but we're in the middle of a bloody invasion that affects all parts of Australia!" – Respondent 14.

4.4.2 Outcomes of participation

Respondents who participate in river rehabilitation expressed both personal outcomes (for the individual) and social outcomes (for the community) resulting from their participation. The outcomes described by respondents included building and enriching a connection to the physical landscape through work, a sense of personal satisfaction in contributing to the program and the benefits of breaking down barriers and bonding members of the community together through shared experience (Table 4-3).

Table 4-3: Personal and social outcomes of participation

Theme	**Responses**	**Example from interview**
Personal outcomes (individual)	Connection to place	"You're in the dirt on your hands and knees on different places and … you feel a sense of, I don't know, responsibility or connection, or a feeling that 'I can do something here and I can contribute'" – Respondent 10.
	Personal satisfaction drawn from work	"I get a buzz out of planting trees, I have to say" – Respondent 5. "I've always been a gardener … I love outdoor life" – Respondent 6.
Social outcomes (group)	Community building and cohesion	"There's massive social benefits … to use the cliché, it breaks down barriers; it really does. Because anyone who gets their hands dirty and doesn't mind squatting down in a huge pile of weeds … we are bonded by our physicality and our ability, and our love of what we're doing" – Respondent 6.

4.4.3 Enablers and barriers for participation

While most participating in river rehabilitation are applying very similar rehabilitation practices, the previous section indicates that there is greater diversity in their motivations for participating. This suggests some success in the design and implementation of the LLS-coordinated program, via which most landholders participate, for its ability to channel multiple motivations and values into one coherent rehabilitation agenda. To understand this relationship in more detail, Table 4-4 outlines specific enablers and barriers for participation in river rehabilitation. Enablers assist in translating motivations and values into action and may also help to overcome barriers for some potential participants. Enablers and barriers may be institutional, social or personal, and many are relational.

Table 4-4: Enablers and barriers for participation in river rehabilitation.

Barrier	Enabler	Example from interview
Expense of rehabilitation work Local Government enforces restrictions on methods for removal of vegetation in riparian zones to protect native vegetation and bank stability.	**Availability of grants** Matched funding from LLS supports landholders and encourages work to be completed within set timeframes.	"When a new person comes along and there are 50 species of weeds and natives [in their riparian zone] due to the previous owner's neglect, then they've got quite a lot of work to do. So we get grants … if you read right through [the legislation] and obey it, essentially you're maintaining your riverbank by … poisons and hand labour. That's really expensive or an unexpected expense for a new purchaser." – Respondent 3.

Barrier	Enabler	Example from interview
Onerous administration Applications for grants to manage riparian vegetation can be complicated and time-consuming for landholders to complete.	**Proactive approach from LLS officer** LLS officers have taken a proactive approach to landholder engagement, providing information to potential participants and assisting with preparation of grant applications.	"They [LLS officer] actually came and had a visit on the property … I thought I'd have to put together an application, but [LLS officer] said, 'Oh no, I do that.' … that was very positive …nearly a whole day, it took … that's really important." – Respondent 1.
Update: Although LLS officers try to remain proactive, they increasingly do this with fewer resources and in many cases can often no longer provide the level of support described by Respondent 1.		
Isolation from community and information New landholders may not know what opportunities are available to them for property management or who to approach for help.	**Proactive approach from LLS officer** (see above) **Proactive approach from local MVA members** Local MVA members contact new landholders to welcome them to the community, inform them on the functions of the MVA and introduce available property management programs.	"[The MVA] are quite active. Whenever a new person moves in, they go and see them and talk to them … we were interested in getting involved locally, and when they said there was something about weed control or nature … it was very interesting [to me]." – Respondent 2. "The MVA are very quick to pick up on new people, and they get involved, and the word spreads." – Respondent 15.

Barrier	Enabler	Example from interview
Disconnection from government Macdonald Valley has a history of being 'forgotten' by government, and some landholders would rather be 'left alone.'	**Investment in relationships** LLS officer invests time in visiting and talking with landholders, and the community has enjoyed continuity of contact with one particular officer over more than ten years, which is unusual due to staff turnover and frequent recent restructuring.	"I think that [LLS officer] would tell you that for [them] to work in the valley, it's all about the people, the connections and how you relate to people." – Respondent 10. "I think this particular relationship between us [LLS] and the Macdonald Valley is quite unique … I'm always available, and I make time to go up there." – Respondent 15.
Discordant visions Some landholders' visions for how the river could be are discordant with the aims of rehabilitation programs.	**Informal social networks** Reluctant landholders perhaps cannot be reached directly by programs but may become involved through other landholders that they trust, or by observing results for themselves.	"A lot of people say you've got to have trees and all that to hold the banks, but all of my river, I don't let any tree grow where it's going to wash [away soil in flood]." – Respondent 13. "There are some people we won't influence. But everyone else seems to be open to maybe influence by neighbours, you just don't know why someone rings up out of the blue [to ask for advice]." – Respondent 15.

Barrier	Enabler	Example from interview
Lack of knowledge in community Landholders (especially new to the area) may not have specific knowledge or experience in river rehabilitation.	**Community training events** MVA, LLS and individual landholders organise community training events, which allow landholders to learn from experts, exchange information with peers and build relationships.	"When you look at the grant we had … the incredible benefit that's come out of that grant in terms of our transformation, in terms of knowledge and what we've done with that." – Respondent 1. "In one eight-week course, you went to eight different properties so there was lots of networking … it was really good. They [landholders] talk amongst themselves. I didn't have to do anything … they're a really cohesive community and they talk to each other." – Respondent 15.
'Local politics' Some landholders were reluctant to participate because of environmental issues being attached to the MVA, which was associated with 'local politics' they did not wish to be involved with.	**A personal approach from LLS and informal social networks** Efforts by LLS officer and landholders to approach individual landholders and develop personal relationships may prevent rehabilitation agenda from being 'captured' by any particular group of local landholders.	"I don't know what's going on [with the MVA]. There's always a bit of politics in all these things." – Respondent 14. "The main area where there's room for improvement is in human relations … administration of the grant locally has been problematic with different agendas in play." – Respondent 6.

4.5 Discussion

In the Macdonald River case study, diverse personal values and motivations are being supported and channeled into a coherent set of participatory river rehabilitation activities coordinated at the middle ground. Enabling factors, which may be institutional, social or personal, drive and facilitate this process and can help to overcome barriers to participation. Whilst enablers built into middle-ground participation schemes facilitated by LLS will be enough to encourage participation for many people, others may not be reached by these enablers. Therefore, effective facilitation of participation requires development of a range of enablers, some formal and some informal, to maximise potential participation. Many of the motivating values driving participation in river rehabilitation were relational in nature, as were the enablers, which help to translate motivating values into participation toward outcomes. Whether self-organising (e.g. community connection) or deliberate (e.g. approaches made by LLS officer), prominence of relational enablers demonstrate that relational factors are important drivers of participation in addition to more tangible drivers (e.g. financial incentives and access to knowledge; c.f. Curtis and Robertson, 2003).

Figure 4-4 conceptualises the process by which institutional, social and personal enablers help to translate landholders' motivations and values into actions (participation). These enablers overcome particular barriers; however, not all barriers are relevant to all potential participants and likewise, for some potential participants, enablers may not be sufficient to overcome certain barriers. The personal and social outcomes of participation listed in Figure 4-4 are important to consider, because the personal experiences of participants have the potential to alter participants' relationships to each other and to place, which can feed back into modification of their motivations and values (which, in turn, drive further participation).

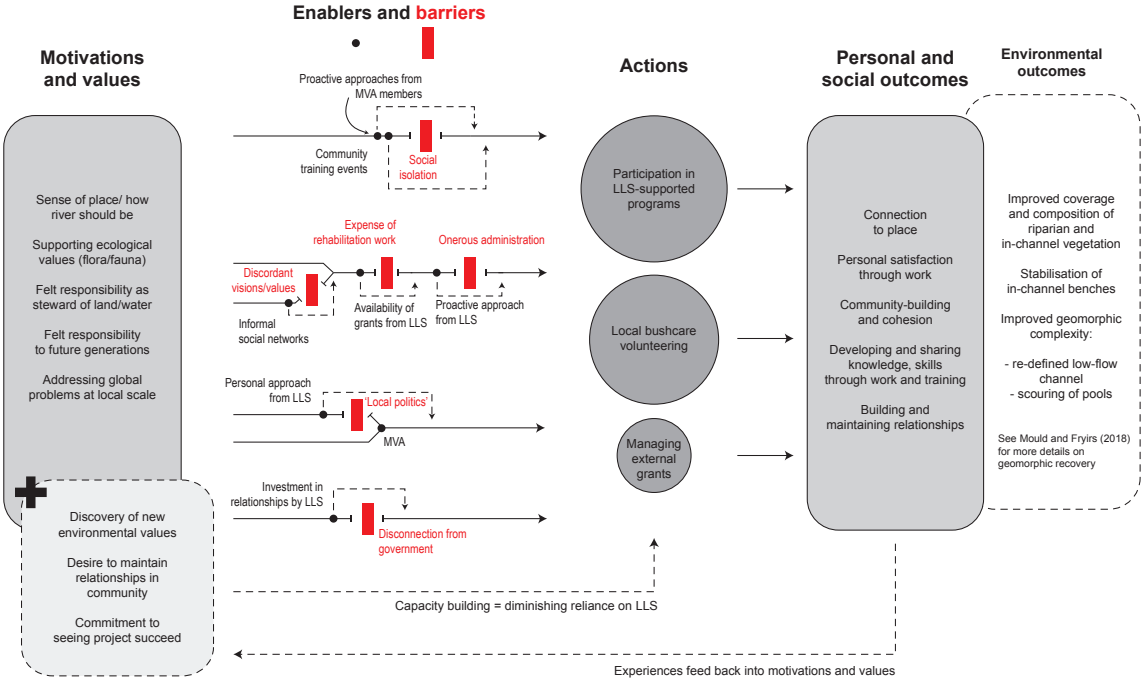

Figure 4-4: The process by which landholders' motivations and values are translated into direct participation in river rehabilitation (actions) via enablers in the middle-ground. Enablers help to overcome barriers to participation. Direct participation in rehabilitation has personal and social outcomes, which may result in evolution of motivations and values. New motivations further drive ongoing participation, and participation may rely less on support from middle-ground agencies as individual and community capacity builds. Dashed lines indicate possible pathways to participation enabled by named factors. Size of 'bubbles' in 'actions' indicates relative rate of participation in each action.

4.5.1 Managing enablers and barriers in river rehabilitation

Having identified a range of relational values that motivate participation, and relational enablers that support translation of values into participatory action, we now consider the implications of a relational understanding of participation for practitioners who coordinate and support participatory river management. We encourage practitioners to recognise relational values and prioritise enabling relationships, then consider the challenge of overcoming barriers in the context of a relational approach to participatory river management.

4.5.1.1 Recognise relational values

Relational values constitute 'softer' motivating factors, which can be somewhat difficult to account for and integrate into river management systems. Recognising relational values

means paying attention to the specific and dynamic social relationships and dynamics through which meaning is made, decision-making is negotiated (Lave, 2016; Emery et al., 2013; Rogers, 2006; Rhoads et al., 1999) and participation may be practiced. However, as found in others' analyses (e.g. Brandenburg and Carroll, 1995), potential participants may not be forthcoming with their relational values and care must be taken to build relationships of trust with individuals. Reflecting on the research methodology adopted in this study, it was necessary to spend time and establish rapport with individuals in order to gain access to their stories and experiences, as well as to gain recommendation to other potential research respondents. In practice, an approach that recognises the importance of relationships in understanding relational values is well demonstrated by the LLS officer responsible for the Macdonald River; many participants regarded the officer as a trustworthy collaborator and noted the commitment demonstrated by long-term engagement in that role (>10 years). Continuity in this role through State Government restructures and some level of organisational uncertainty points toward the potential for strong interpersonal relationships to buffer ongoing participation through change.

4.5.1.2 Prioritise enabling relationships

Incentive schemes to encourage participation in voluntary programs may come and go, and levels of financial support may change over time, resulting in loss of participation. A multi-faceted strategy to encouraging participation, including provision for appropriate levels of landholder choice (Barnes et al., 2013; Curtis and Robertson, 2003), will always be more effective than a single-focus program. Formal mechanisms for encouraging participation can be underpinned with relational approaches, by working to ensure that along with formal incentives, there are also informal, relational incentives for landholders to participate. The results from this case study demonstrate that for many landholders, relational values of community connection and interaction with the landscape were major 'pull' factors, beyond the fundamental outcome of improving environmental condition (c.f. Asah and Blahna, 2013).

The majority of enablers identified in this research were also relational in nature (e.g. personal approach from LLS officer, proactive local community members, informal social networks). Events that brought landholders together to learn from each other's experiences (social learning; Reed et al., 2010; Pahl-Wostl, 2007) were catalytic for many of the

respondents' participation. The ability to reach a 'critical mass' of participants in a location likely relies on relationships within the community, built through opportunities for social learning in a developing community of practice (Wenger, 2010). This critical mass makes up part of the feedback loop in Figure 4-4 whereby over time, participatory river rehabilitation may begin to rely less on government support and more on community-based relationships to maintain momentum (Pahl-Wostl et al., 2007). Different community networks may have different characteristics and needs (Lauber et al., 2008) so practitioners should be looking for ways to support their community networks in ways that are relevant to those communities; for example, by paying attention to the relational values that drive participation and providing support that goes beyond provision of financial incentives for work.

4.5.1.3 Overcoming barriers

For many potential participants, the benefits of participation will likely outweigh the barriers, provided that the enabling mechanisms for participation are there. However, some landholders' values and motivations act as barriers to participation because they are not closely aligned with the goals of rehabilitation (c.f. Moore et al., 2018) and landholders also may not be opposed to river rehabilitation but are initially uninterested or wary of change. These common challenges are relational in nature, and are unlikely to be adequately addressed by more traditional approaches; for example, those that adhere to the deficit model of science communication (Irwin, 2014; Eden and Tunstall, 2006; Sturgis and Allum, 2004), which assumes a deficit of landholders' knowledge is the primary barrier to participation. In these cases, a focus on relationships and dialogue are likely to be helpful for encouraging participation. Practitioners need to understand the social fabric of a community and find ways to support the kinds of relationships that will be enabling in a given setting. The power a practitioner holds due to their professional position may be less appropriate or influential than the power they can share *with* a community or landholder (see Gaventa, 2006) when they seek to engage with people as part of the physical-and-social system of relationships rather than outside of it. Attention must be paid to providing the necessary support, where possible, to the informal social networks by which non-participants may observe or hear about the benefits of participation from peers that they trust (e.g. Kuhfuss et al., 2016). Or, where particular social networks provide a barrier to participation by some (c.f. Horangic et al., 2016), individual relationship building will be

important to ensure that participation is not 'captured' by community groupings in a 'representative' model of public engagement (see Larson and Lach, 2008). In settings that rely on voluntary participation, this may be all that practitioners can do to reach landholders who are less forthcoming.

4.6 Conclusion

Regardless of the structures that dictate river management practices in specific settings (e.g. top-down, bottom-up, middle-ground), participation is an important part of achieving ongoing and effective river management. Effective participation strategies will be able to understand diverse motivations and practices making up the social context of river management, enhance enabling processes and characteristics and work with social barriers to support participation. For landholders, participation is more than an activity undertaken to improve environmental condition; it is wrapped up in relational values that situate participants within their communities and sense of place. As such, structures and systems designed to support participation must recognise relation and enact a relational approach in order to be as effective as possible. Recognising relational enablers and barriers and prioritising relationships can incentivise participation and help to overcome barriers between landholders' values and coherent river rehabilitation actions. When combined with the physical on-ground rehabilitation actions, this contributes to the practice of river rehabilitation as an integrated physical-and-social process consistent with holistic natural resource management.

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Chapter 5

Supporting on-ground river recovery: Investment in 'relational resources' for developing, sharing and implementing specialist knowledge in river management

Abstract

Integrative, science-based natural resource management requires strong systems and policies for knowledge management. Often the focus is on availability of technical information, whereas deeper knowledge development, sharing and implementation also require social networks that cross disciplinary and organisational boundaries. This research draws on a case study of the emergence and development of river rehabilitation practices based on principles of geomorphic river recovery in New South Wales, Australia, in order to understand relational dimensions of knowledge management and their implications for river management practices. Evidence from document analysis and oral testimony indicates that informal communities of practice, and the social relationships that comprise them, have been critical for developing, sharing and implementing river recovery principles through phases of organisational change. However, this research also reveals that communities of practice and the tacit knowledge they hold is insecure and may be vulnerable to loss if investments are not made in relationships and the 'relational resources' that support ongoing social learning. We see social relationships, within communities of practice, as critical to realisation of integrative, science-based river management practice and policy in the long term.

5.1 Introduction

When a river experiences a significant disturbance (e.g. floods, land use change, vegetation clearing) it will respond with various, and variable, geomorphic processes. If an improvement in geomorphic river condition is observed, these responses are termed 'recovery processes' (Fryirs et al., 2018; Fryirs and Brierley, 2016; Phillips and VanDyke, 2016; Scorpio et al., 2015). Examples of recovery processes may include the stabilisation of sediments as in-channel 'benches' when a channel has been over-widened (Mould and Fryirs, 2018; Erskine and Livingstone, 1999) or the re-development of bedforms such as pools and riffles after in-filling of a channel with excess sediment (Mould and Fryirs, 2018; Bartley and Rutherfurd, 1999). These recovery processes can be supported and enhanced by careful human intervention in order to accelerate recovery or to increase resilience and guard against further impacts from future disturbances. Recovery-based approaches to river rehabilitation have emerged in recent decades as a dominant paradigm, replacing the hard-engineered 'command and control' (Holling and Mefe, 1996) practices of the past (Wohl et al., 2015; Spink et al., 2009). With foundations in geomorphology and ecology, a recovery-based approach to river rehabilitation aims to:

- understand the behaviour of the river and what processes are occurring (Brierley and Fryirs, 2009; Brierley and Fryirs, 2005; Ward et al., 2001);
- treat the causes of problems rather than the symptoms (Fryirs and Brierley, 2016; Grabowski et al., 2014; Richards et al., 2002);
- support and enhance any recovery processes already underway in the river using as little physical intervention as possible (Fryirs et al., 2018; Groll, 2017; Kondolf, 2011; Brierley and Fryirs, 2008;
- prioritise intervention according to a catchment-based prioritisation strategy based on recovery potential and catchment position (Fryirs and Brierley, 2016; Brierley and Fryirs, 2005, 2009).

Recovery-based approaches to river rehabilitation are often low impact or 'passive' in nature, aiming to create as little disturbance as possible. Commonly, practices will include re-vegetation to stabilise sediments, protection of recovering areas from further disturbance (e.g. protection from grazing) or sometimes a decision to not intervene at all (Fryirs and Brierley, 2016; Rinaldi et al., 2015). Recovery-based approaches have advantages over heavy engineering, including lower financial cost of works and an often-higher success

rate in the long term because the approach is sensitive to – and appropriate for – the particular river type and its geomorphic behaviour (Groll, 2017; Brierley and Fryirs, 2009).

The field of river management has arrived at a point where recovery-based approaches are increasingly recognised as the best available, and there is growing evidence that on-ground river recovery is occurring in many locations (e.g. Fryirs et al., 2018; Mould and Fryirs, 2018; Scorpio et al., 2015). However, despite these encouraging signs, it is important that progress in recovery-based river rehabilitation is not taken for granted. River management practices are constrained by the social, political and policy settings in which they are applied, and these settings may not always reflect the latest science or consensus of experts in the field (Eden and Tunstall, 2006). In order to ensure that recovery-based theory continues to underpin river rehabilitation practice, it is helpful to reflect on how recovery-based practices came to be dominant and in what ways these practices are understood and enacted by practitioners.

River recovery is neither a purely 'natural' or 'human' process; rather, it occurs in the interplay between physical and human processes in a physical-and-human landscape. Geographical scholarship that recognises the inherent linking of physical and human processes in the formation and re-formation of landscapes increasingly provides a basis for re-conceptualising processes such as river recovery in terms of physical, social, political, economic and cultural emergence (e.g. Mould and Fryirs, 2018; Mould et al., 2018; Ashmore, 2015; Doyle et al., 2015; Lave et al., 2014; Urban, 2005). Approaching river recovery with such a framing invites investigation of the relationships between on-ground river recovery and the human processes that help to bring about or support that recovery. Of particular interest in a physical-and-human re-conceptualisation of river recovery is how social and political dynamics can have observable consequences for trajectories of geomorphic landscape evolution and recovery. Understandings, attitudes and positionings of scientists and practitioners can have material impacts on the physical landscape (Ashmore, 2018; 2015; Lave, 2016), which requires that these factors are understood and accounted for alongside explanations of landscape processes from the physical sciences. Critical analysis of disciplinary or cultural histories and knowledge structures can help to

avoid 'train wrecks' when different people or groups work together on river management (Benda et al., 2002).

Recognising the importance of social dimensions of river recovery, this paper investigates relationships within river management communities of practice and their importance for developing, sharing and enacting specific philosophies and practices within the public sector. We define communities of practice according to Wenger (2010), wherein they are self-organising groups of people who share a common professional interest or focus but do not necessarily belong to the same organisational units or share formal reporting relationships. Communities of practice are often associated with processes of social learning and management of tacit knowledge in natural resource management settings (e.g. Nykvist, 2017; Cundill et al., 2011; Blackmore, 2007; Pahl-Wostl et al., 2007) and with development of – and access to – relational resources more generally (e.g. Ambrosini, 2001). We draw on the example of recovery-based river rehabilitation in New South Wales (NSW), Australia to better understand relational drivers of river recovery. Whilst this case study reveals how communities of practice can emerge and build resilience against a certain degree of institutional, political and policy instability, it also raises questions as to how far this resilience can stretch and what is required to guard against loss of knowledge held within a community of practice over time. Specifically, this paper identifies the social and political processes that saw recovery-based rehabilitation approaches become dominant practice in NSW, and aims to establish the extent to which recovery theory is now embedded in formal (legislation and policy) and informal (individually- and community-held knowledge) systems of river management. This case study provides a basis for discussion on how to best develop and support the institutional and relational resources that will ensure that on-ground river recovery continues, particularly in the face of possibly-turbulent environmental, social and political futures, in a range of management settings.

5.2 Methods

This research began with analysis of documents concerning river management policy and practice in NSW to understand to what extent river recovery concepts are embedded in river management legislation and policy. This analysis focused on NSW state legislation and strategic plans developed by regional river management State Agencies, previously called Catchment Management Authorities (CMAs) and now re-structured as Local Land Services (LLS). CMAs produced 10-year 'Catchment Action Plans' (CAPs) and Local Land Services now produce equivalent 'Local Strategic Plans' (LSPs). These documents (eight most recent CAPs and eleven most recent LSPs) were analysed in NVivo software, focusing on key word analysis, to track changes in priorities and focuses in river management over time. However, whilst these documents reveal changes in institutions' official priorities and practices, they do not reveal the more nuanced effects of these changes on the experiences and practices of practitioners who work on-the-ground in river management.

To understand the social processes that also contribute to changes in practice, we undertook interviews with key past and present river management practitioners who had experience with changing philosophy, practice and organisations in river management. Recruitment was purposeful and began with known contacts in NSW Local Land Services attached to the field site where current research is focused. We then 'followed the connections' of relationships to include respondents from other related organisations. Rather than taking a 'sampling' approach to recruitment, we targeted individuals who had sufficient experience with the changes in practice that are the focus of this research and who could enrich the history provided by documentary analysis with personal experience and insight into social relationships. Six respondents (Table 5-1) participated in semi-structured interviews of approximately one-to-two hours' duration. Conversations with additional individuals from Local and State Government and local interest groups also support interpretation of this research, but their responses are not quoted verbatim in this paper. The interviews followed an interview guide rather than set questions (Appendix C), as each respondent had different professional experiences and perspectives that required a more flexible approach. Themes in the interview guide included: individuals' history of involvement in river management, familiarity with river recovery concepts, experiences with changing practices over time and relationships between actors and institutions

involved in river management. This research received ethical approval from the Macquarie University Human Research Ethics Committee (ref. 5201700968; Appendix B). Analysis of interviews was qualitative and included transcribing, familiarising and an iterative process of coding using *a priori* themes (as outlined above) and emerging themes that were raised in conversation. This analysis also utilised NVivo software.

Table 5-1: Respondents participating in this research. Some generalisations have been made to roles in order to de-identify responses.

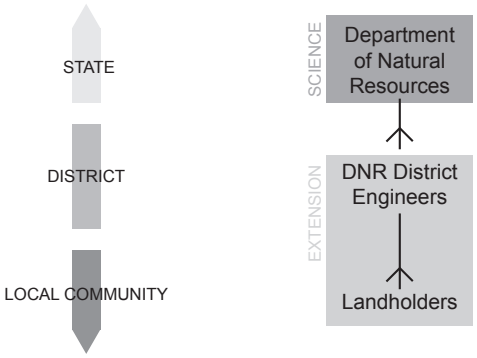
Respondent Number	**Organisation where majority of relevant work undertaken**	**Employment level or role**
1	NSW Department of Primary Industries (now Department of Industry)	Principal scientist
2	NSW Department of Industry (Water Office)	Manager (scientific focus)
3	NSW Local Land Services	Manager
4	Land and Water Australia	Program coordinator
5	NSW Local Land Services	Land Services Officer
6	NSW Department of Industry (Water Office)	Scientist

5.3 Regional setting and river management context

In Australia's federal system, river management is primarily the responsibility of the six states (territories have more Federal oversight), having been devolved since the late 1990s (Paton et al., 2004). In the eastern seaboard states of Queensland, New South Wales and Victoria, the large majority of river catchments are comprised of private land. River management in this setting is characterised by a participatory approach coordinated through a 'middle-ground' structure, where regional offices of state agencies responsible for natural resource management administer programs to support landholders in protecting and rehabilitating rivers (Fryirs et al., 2008). In NSW, this responsibility currently falls under Local Land Services (LLS). The contemporary structures and practices concerning river management in NSW have evolved through a series of legislative changes, organised here into four 'phases' (Figure 5-1). The overall arc of change is from an engineering-based, top-down approach (Phase 1) through to increasingly environmentally sensitive (recovery-based) approaches enacted in the middle-ground by regional State Agencies (Phase 2). The emergence of middle-ground agencies dedicated to extension services (providing advice to landholders) was most clear with the creation of CMAs in 2003 (Phase 3). Responsibility for science and extension functions had previously been with the Department of Primary Industries (DPI), but these functions were separated in 2003. CMAs would make decisions at the catchment scale with oversight from the state-scale Natural Resources Commission (NRC), whose responsibility was to ensure statewide priorities and policies were being enacted by all CMAs. DPI would provide scientific advice to the NRC as part of the review process for all the CMA Catchment Action Plans, as well as science-based training to extension officers in CMAs.

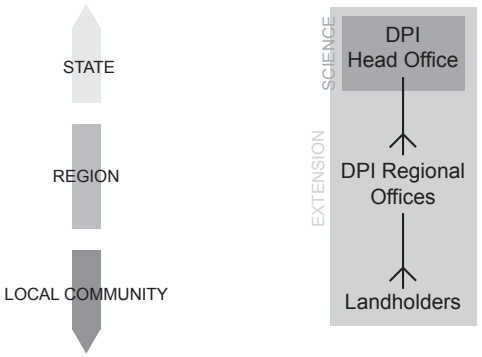
Phase 1: 'Command and control'
Top-down structure
River and Foreshores Improvement Act (1948)

Department of Natural Resources (DNR) Flood Mitigation Unit design engineered works to be built by district engineers. 'River Gangs' made up of local people undertake de-snagging.



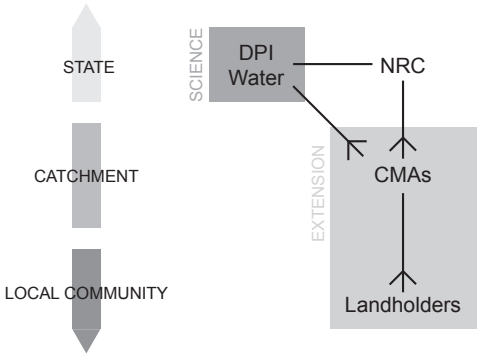
Phase 2: 'Passive rehabilitation'
Top-down structure
Catchment Management Act (1986)

Department of Primary Industries (DPI) Riverine Corridor Unit provide advice and training to regional DPI offices and develop science-based policies for river and riparian management. Management is planned with a 'whole-of-catchment' focus.



Phase 3: 'Incentivised & coordinated passive rehabilitation'
Middle-ground structure
Catchment Management Authorities Act (2003)

Catchment Management Authorities (CMAs) undertake natural resource management at catchment scale, developing Catchment Action Plans (CAPs) and providing incentives for river rehabilitation by landowners. CAPs are overseen by statewide Natural Resources Commission (NRC). DPI Water provide training and expert advice to CMAs and science-based input to NRC.



Phase 4: 'One-stop shop'
Middle-ground structure
Local Land Services Act (2013)

Local Land Services (LLS) offices provide services to landholders at regional scale (LLS areas often cross catchment boundaries). Offices develop strategic plans according to priorities of local boards and landholders. LLS provide advice on all areas of agricultural and land management. Department of Industry (DoI) Water office advise LLS offices when advice sought by LLS (no official relationship).

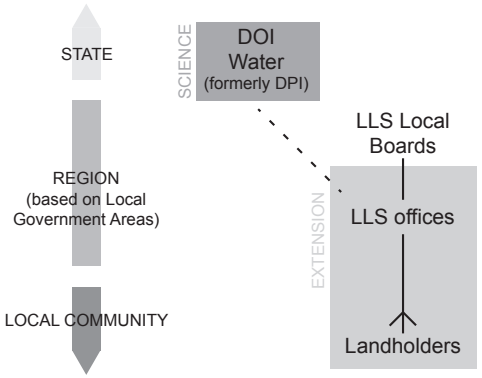


Figure 5-1: Evolution of river management structures and practices as described in legislation and from interviews. Relational diagrams on right-hard side show one-to-one or one-to-many relationships between organisations or teams. Dashed lines represent unofficial or indirect relationships.

In 2013, CMAs were abolished and replaced by regional LLS offices, which would act as a 'one-stop-shop' providing advice to landholders on agriculture, natural resource management (including river management), biosecurity and emergency management (Phase 4). The agency's focus shifted from environmental protection to customer service, with river rehabilitation making up a much smaller component relative to other the other functions of the agency (and the employees' workloads). The collapse of a number of State Government agencies into one agency coincided with election of a conservative State Government in NSW and included some AU$30 million in funding cuts and loss of more than 300 jobs in this sector (Sydney Morning Herald, 2013). LLS boundaries of responsibility were re-drawn according to Local Government Areas (LGAs), meaning that many catchments were now managed by more than one LLS office. The Natural Resources Commission (NRC) was also abolished, breaking direct links between science functions in DPI and extension in LLS. This is the current state of organisational responsibility for river rehabilitation in NSW.

5.4 Results

5.4.1 Analysis of strategic planning documents 2007-2018

Comparison of Catchment Action Plans (CAPs) produced by CMAs and the equivalent Local Strategic Plans (LSPs) produced by LLS, after CMAs were abolished, reveals a clear shift in the organisations' focus between Phases 3 and 4. Figure 5-2 summarises differences in appearance of key words related to river management as an indicator of the relative importance of those key themes before and after the latest major change in policy and organisational structure (i.e. the transition from Phase 3 to 4). The percent coverage per key word (calculated in NVivo) was averaged for the most recent eight CAPs and eleven LSPs. The most significant difference was in use of the word 'catchment.' 'Catchment' had 0.81% average coverage in CAPs compared with 0.05% in LSPs when 'Catchment Action Plan(s)' and 'Catchment Management Authorit(y/ies)' were excluded. Similarly, 'river' had 0.14% coverage in CAPs compared with 0.06% in LSPs (less than half the coverage). In context, 'Word Tree' visualisation revealed that the majority of references to 'river' in LSPs were associated with place names (e.g. the Hunter River) whereas uses in CAPs referred to rivers and riverine environments more broadly. More technical terms related to river management, particularly recovery-based rehabilitation, also revealed differences in use.

For example, 'geomorphology' had 0.02% coverage in CAPs but was not mentioned once in any LSP. 'Riparian' had 0.09% coverage in CAPs and only 0.01% in LSPs. 'River condition' had 0.06% coverage versus <0.01% and 'river health' 0.025% vs <0.01%. 'Recovery' had 0.03% coverage in CAPs and 0.01% in LSPs; however, the use of 'recovery' was very different in each, typically referring to river recovery in CAPs and to 'disaster recovery' or 'cost recovery' in LSPs. 'Rehabilitation' had 0.03% coverage in CAPs and 0.01% in LSPs. References to 'science' had similar coverage between documents, with 0.01% coverage in CAPs and 0.02% in LSPs. 'Integrated management' featured more prominently in LSPs (0.14%) than in CAPs (0.10%), likely reflecting the broader focus of LLS when compared with the CMAs' mandate. A focus on customer service to landholders was also apparent in the LSPs, with 'customer' having 0.48% coverage in LSPs vs <0.01% in CAPs and 'participation' having 0.15% coverage in LSPs vs 0.07% in CAPs.

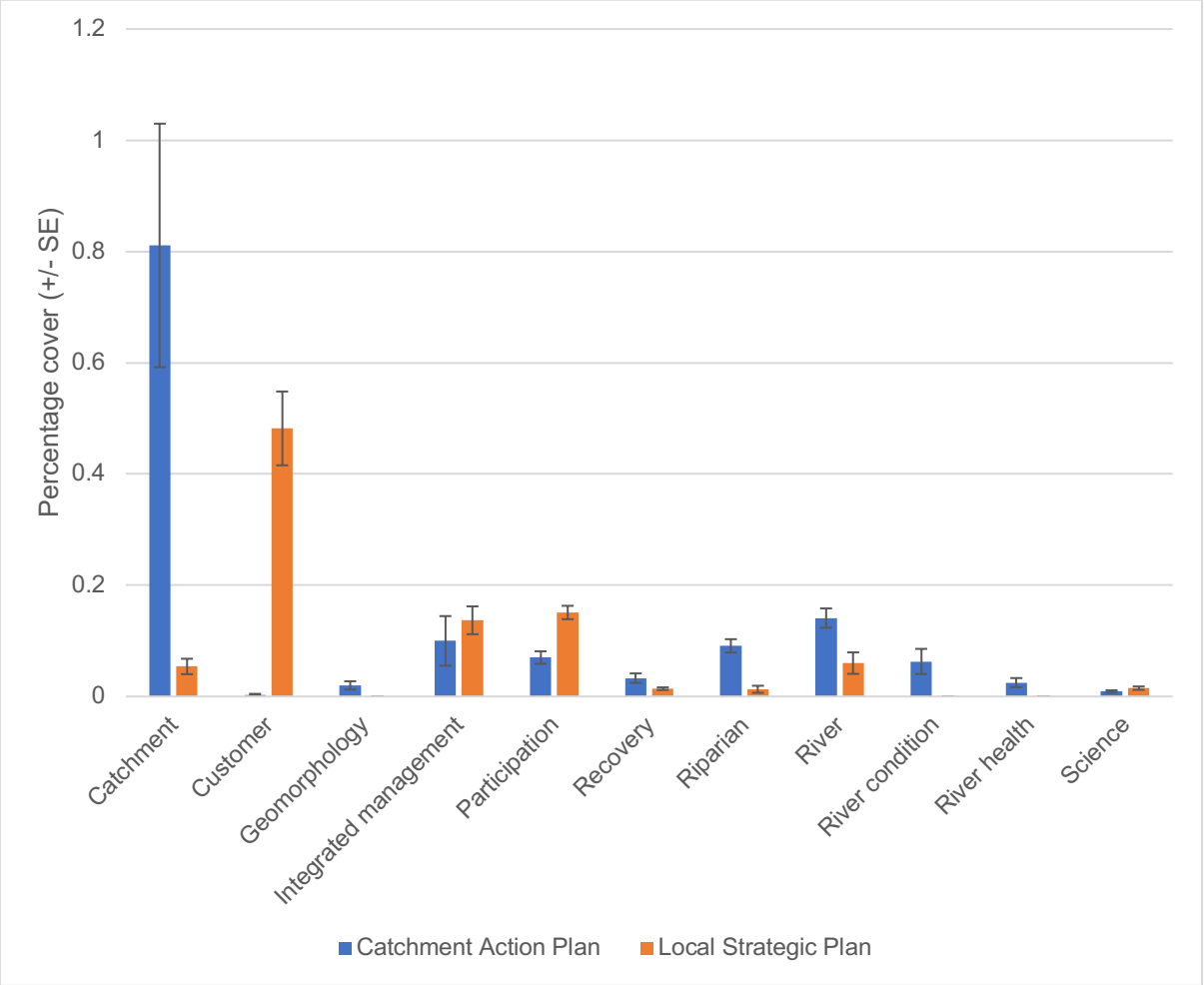


Figure 5-2: Results of NVivo keyword analysis of CAPs vs LSPs reveal a clear change in focus for the agencies responsible for on-ground river management in NSW between Phases 3 and 4 as outlined in Figure 5-1.

5.4.2 Interview analysis

Changes in the use of key terms that were related to recovery-based river rehabilitation in strategic planning documents reflect changing priorities for the agency as mandated in the Local Land Services Act (2013). However, top-down changes (e.g. in legislation) may be expressed and experienced differently depending on human/social dimensions that also make up the river management setting (see Doyle et al., 2013). Responses from interviews with practitioners covered longer-term and shorter-term changes in the river management industry, which provide context for the contemporary river management setting and help to frame potential trajectories for recovery-based rehabilitation practices in the future. Practitioners' testimony covers key changes from the initial development of recovery-based

thinking in NSW, through development of an integrated network of practitioners in recovery-based rehabilitation and finally to reflection on more recent fragmentation of the river management industry and considerations for the future.

5.4.2.1 'Phase 1' to 'Phase 2': Emergence of recovery-based thinking

Initial adoption of recovery-based approaches to river rehabilitation by NSW Government practitioners began with the gradual recognition of geomorphology as a basis for planning works (Fryirs et al., 2013). The Hunter River catchment in Central-Eastern NSW is a well-studied example demonstrating the change from hard engineering to more passive approaches (Spink et al., 2009; Erskine, 1992). In the years following catastrophic flooding and erosion in the 1950s, extensive (and expensive) engineering works were undertaken across the catchment, but particularly in the lower reaches. 'River Gangs' were employed from local communities to undertake removal of in-channel wood ('de-snagging') and modification of the channel and floodplain to reduce overbank flooding (Spink et al., 2010; Erskine and Webb, 2003). These works were planned and implemented by engineers in the Flood Mitigation Unit, who enjoyed generous funding from the Federal and State Governments. However, the Federal portion of funding for erosion control was discontinued in the early 1980s and river managers needed to find more cost-effective ways of working. In the Hunter River, this coincided with a small number of prominent engineering failures that caused rethinking of the approach to river engineering. A geomorphologist employed in the Flood Mitigation Unit at that time recalled:

> *"They put a couple of bend cut-offs in … they just dug this canal, destroyed the whole reach of the river, like 10 km; a big head cut upstream, all the sediment went downstream. It had to be dredged out of the harbor – cost millions. Big mistake." (Respondent 1).*

In order to adapt to reduced funding and avoid further expensive and damaging failures, State Government practitioners began to explore alternative approaches, including use of vegetation in passive rehabilitation (e.g. Raine and Gardiner, 1995). Engineers researched use of vegetation and the small team of geomorphologists housed with the engineers gradually became more involved in planning rehabilitation works. Respondent 1 reflected

on this gradual process of "pushing a paradigm shift", explaining that changing practice relied on the geomorphologists demonstrating effectiveness of geomorphology over time and building rapport with the engineers, one-on-one:

> *"They [engineers] were just using regime equations to find out how big a river should be and what its slope should be … we were sort of like spies or infiltrators, but after a few years in vegetation[-based rehabilitation] you have to look at river behavior, otherwise it just fails.*
>
> …
>
> *"We were going on field trips with the engineers because they were able to get cars. Driving with them, chatting with them on field trips, we persuaded them."*
>
> …
>
> *"We gradually became in charge of the river restoration and rehabilitation, just because we seemed to know what we were doing and we were fixing the problems that had occurred in the past. They gradually trusted us to do our thing." (Respondent 1).*

From 1986, river management became more regionalised with introduction of the Catchment Management Act (1986; 'Phase 2'). This meant devolution of decision-making to regional teams. At this time, three geomorphologists were based in a head office – the Riverine Corridor Unit – and tasked with training and advising regional practitioners in geomorphology and river rehabilitation:

> *"We gradually moved from designing works and supervising them to training people, and then providing specialist advice. The regional people became like the GPs [general practitioners] … we were the specialists and people would phone us, or we would go out to the region … to the problem that needed the specialist advice." (Respondent 1)*

"It was quite effective, having a central group of experts that drove technical issues and policy, and then having the people out in the region who delivered that on the ground; [it] was a good model. (Respondent 2)

There was a principal scientist for each of the major disciplines involved in river rehabilitation: terrestrial ecology, aquatic ecology, water quality, vegetation, soils and groundwater.

"We were all on the same floor; open desks, the same manager, same branch, same unit … a lot of cross-fertilisation." (Respondent 1)

When funds were available, the principal scientists collaborated on research as well as giving advice to regional practitioners; when funding was limited, they would only give advice. However, this changed in approximately 2008:

"Treasury sent down big budget cuts so the managers said, 'Okay, no more research and for giving advice, you can't have a car.' There [was] no money for cars or travel. River geomorphology is 90% fieldwork. We had to rely on whoever wanted the advice to pay for us to go there. If it was the regional government department [needing advice] then they couldn't afford it. A few times it was private landholders who paid out of their own pocket, or Local Government Council or Landcare." (Respondent 1)

This change in funding, to some degree, isolated in-house experts from on-ground practitioners and inhibited the direct line to scientific evidence that had previously underpinned river management practice.

5.4.2.2 'Phase 3': Catchment-scale passive rehabilitation

Catchment Management Authorities (CMAs) took over much of the river management activities from 2003 under the Catchment Management Authorities Act (2003). The principal scientists in what was now called 'Department of Primary Industries (Water)' continued to give expert advice and train CMA officers in geomorphology, but they were

in a separate agency from the on-ground extension officers. By now, recovery-based rehabilitation was the dominant paradigm and passive works using recovery principles were incentivised by CMAs, to be undertaken by landholders. River management became focused in the 'middle ground', with CMAs as the central agency linking landholders with catchment-scale knowledge and resources. This model relied upon voluntary participation in river rehabilitation programs by landholders, who would match the financial contribution provided by CMAs with either their own funding or with in-kind labour.

Whilst individual CMAs planned and coordinated river management for each catchment, they did so with oversight from the Natural Resources Commission (NRC), who ensured that State-level priorities were being met by each CMA. Through the NRC, scientists in the Department of Primary Industries (DPI) were able to influence river management. One former DPI (now DoI) employee reflected:

> *"There was a statewide target on improving riverine health, and we worked closely with the NRC … developing priorities across NSW. Then, they would adopt that and would work closely with CMAs and do audits on them, set guidelines for them, so that each CMA was following a standard approach." (Respondent 2)*

The result was a system where middle-ground agencies (CMAs) had freedom to develop strategies and deliver programs that were specific to the needs of their catchments, whilst also ensuring that there was top-down accountability to the State and its overarching priorities. However, this model was replaced after ten years with one that placed natural resource management, including river management, within the responsibility of an agriculture-focused agency.

5.4.2.3 'Phase 4': The 'one-stop shop' and increasing fragmentation

CMAs were replaced by Local Land Services (LLS) offices in 2013. The Local Land Services Act (2013) brought together functions from a range of organisations and authorities to create a 'one-stop shop' for landholders seeking advice about property management. The focus shifted firmly from environment to agriculture. Whereas the previous three phases

of river management reflect a progression and refinement of a science-based, catchment-focused approach, 'Phase 4' represents a clear change in trajectory.

Although the day-to-day activities of LLS officers are similar to their CMA catchment officer equivalents (pers. comm. from respondents), structural changes have had consequences for critical relationships between organisations and the ability of practitioners to implement recovery-based rehabilitation, both of which have implications for the future of river recovery in NSW. On one hand, the transition to LLS brings together 'multi-skilled teams' of practitioners in one organisation, where previously they were housed in CMAs, Department of Agriculture, Livestock Health and Pest Authority, NSW Soil Conservation Service and others. According to one LLS employee who also previously worked for a CMA:

> *"In the CMA model we often collaborated with other agencies on projects … not only working across the agencies, but some of the actual individual people [coming into LLS] were people that we had known and worked with before. We already had a relationship with some individuals." (Respondent 3)*

However, many river managers employed in CMAs were lost in the transition, resulting in an overall decrease in available expertise on river management in NSW. As one employee of a related organisation responded:

> *"Now, for example, in LLS, I would say less than 50% of them have any expertise in fluvial geomorphology." (Respondent 2)*

Geomorphologists and people with geomorphic training are still present in regional LLS offices, but various offices will be more or less disadvantaged according to who in their branch has been trained; coordinated expert guidance, advice and training across the state's extension services has been lost (largely through abolition of the oversight body, NRC and separation of science functions from extension functions). Additionally, conversations with LLS employees indicated that in the current political climate, funding to undertake specialist training in river rehabilitation is more difficult to obtain than it has

been in the past. This places more pressure on peer-to-peer learning and the social networks that support such knowledge sharing. Together, these factors potentially leave extension bodies, like LLS offices, vulnerable to losing critical skills and knowledge as the staff from the senior generation retire or otherwise leave the organisation. This 'knowledge insecurity' was explained by a former manager of a related Federal organisation, who was asked where recovery-based rehabilitation knowledge now resides:

> *"It's mainly in their brains, I think – I do think there's going to be a whole lot of people who leave the sector, who are in their 50s or so, and I think there could be a bit of a gap there, because the next lot of people don't necessarily know where all that information is." (Respondent 4)*

The relationship between those responsible for science and those providing extension services has also changed, with implications for science-based, integrated management of rivers. Employees of the agency responsible for science no longer have official, direct mechanisms for influencing on-ground practice as they did through the NRC when CMAs were the middle-ground agencies responsible for river management. When one such employee was asked what mechanisms are in place to report on their monitoring and evaluation of changes in river condition, the reply was:

> *"At the moment, we update the River Condition Index and it goes up on our website and we just say, 'here it is, it's updated.'" (Respondent 2)*

This has resulted in science playing a much more passive role in river management. In the absence of formal mechanisms for science feeding into on-ground practices, uptake by LLS offices is uneven and relies on personal relationships between employees in each agency:

> *"There will be some LLS areas where we have a reasonable amount of influence. That is, [we say], 'here's the work we've done, here are the strategic reaches we think need addressing for river health,' and … LLS will take that on and look at funding opportunities, particularly where the landholders are also interested, and progress that … but, there's other areas where they [LLS] just don't want our expertise, and [river condition]*

is not necessarily on their radar, unless lots of landowners start jumping up and down … we're trying to influence it [practice], but, we're disconnected from the people who deliver this stuff on the ground, and [river condition] is not their focus." (Respondent 2)

Agencies in river management have not always been so disconnected. From 1990 until 2009, the Federal Government funded Land and Water Australia (LWA), who invested in networks that could sustain collaboration across regions and fields of practice. LWA produced reference guides to support river rehabilitation practice and maintained information flow via a regular and well-subscribed newsletter. Since LWA was de-funded, this function has been lost from the industry. Practitioners from a number of agencies revealed in interviews that they continue to use LWA's reference materials, despite them needing to be updated, because updated information is not available to them. On the loss of LWA, one respondent reflected:

"When you take an organisation like LWA out, you take out the hub and lose all that connection – and that has already happened in many of the other areas [in which] LWA worked, and that's an incredible waste." (Respondent 4)

More generally, on the subject of communication between scientific experts in Australia, one practitioner described a disconnected field:

"Networking in the technical geomorphic community in Australia is a hodgepodge [a jumble or mess]. It's only built up on a little bit of personal networking. So, unless you know exactly who to chase up, and who is working on what, and you've gained that knowledge just on your own, the networking is not really occurring at this time. I don't see that practitioners are properly drawing together; I still don't know who my interstate colleagues [in State Government] really are." (Respondent 6)

Similar frustrations were expressed by those producing science-based monitoring of river condition, which should ideally feed directly into on-ground practice and overarching policy. They described a structure where information is being siloed rather than integrated:

> *"That coordinated approach [to river management] that is based on sound science, has been lost. I think that's a big issue. There's a lot of single focus management now. Our agency is well and truly focused on just water management. But, when I say 'water management,' I mean 'water quantity management' and it's less integrated. So, we'll develop a water sharing plan that says 'here's how you should share water in a regulated river and here's the sorts of things you need to do to unregulated rivers to mitigate the impacts of extraction.' But as we know – as geomorphologists – or [as] any good scientist would know – there's a lot of rivers where just addressing the extraction pressure will only have a minor, if any, impact on ecological outcomes." [emphasis is respondent's]*
>
> ...
>
> *"One of the challenges for us, as scientists, is to try and shift people's paradigm away from focusing on single issue management, such as water quantity, and having a more holistic or integrated approach to improving river health." (Respondent 2)*

Document analysis and responses from practitioners reveal some clear trends of declining information sharing and collaboration, driven at least partly by decreasing funding for river management and increasing fragmentation of the river management industry. Social interactions, both formal (in training) and informal (personal networks), have carried the development and sharing of recovery-based river management practices in NSW, within self-organising communities of practice. However, it seems that these communities of practice have since been weakened or fragmented due to organisational change, making expertise in recovery-based practices vulnerable to loss. This case study demonstrates the importance of recognising and understanding social learning in communities of practice so that tacit knowledge can be secured against further organisational and political change.

5.5 Discussion

The case of recovery-based river rehabilitation in NSW highlights the importance of human relationships in both the formal and informal systems that drive river management practices. Formal systems in this case include the organisational structures as given in State and Federal legislation, and informal systems include self-organising communities of practice within – and between – organisations. Figure 5-3 describes the communities of practice that have been identified as part of this research. Communities of practice exist within organisations (e.g. in NSW DoI (Water) and various LLS offices) but also between these organisations. Although the informal relationships in communities of practice (contained in ellipses) seem somewhat chaotic when compared to the formal relationships (contained in rectangles) and in Figure 5-1, responses in this research suggest that it is largely the informal relationships, which developed under previous phases of river management policy, that have provided some level of stability in the community of practice through phases of institutional disruption. Relationships linking science (DoI) with extension (LLS) have been weakened in recent years; however, informal relationships between employees of each organisation have enabled these functions to remain linked, if unevenly.

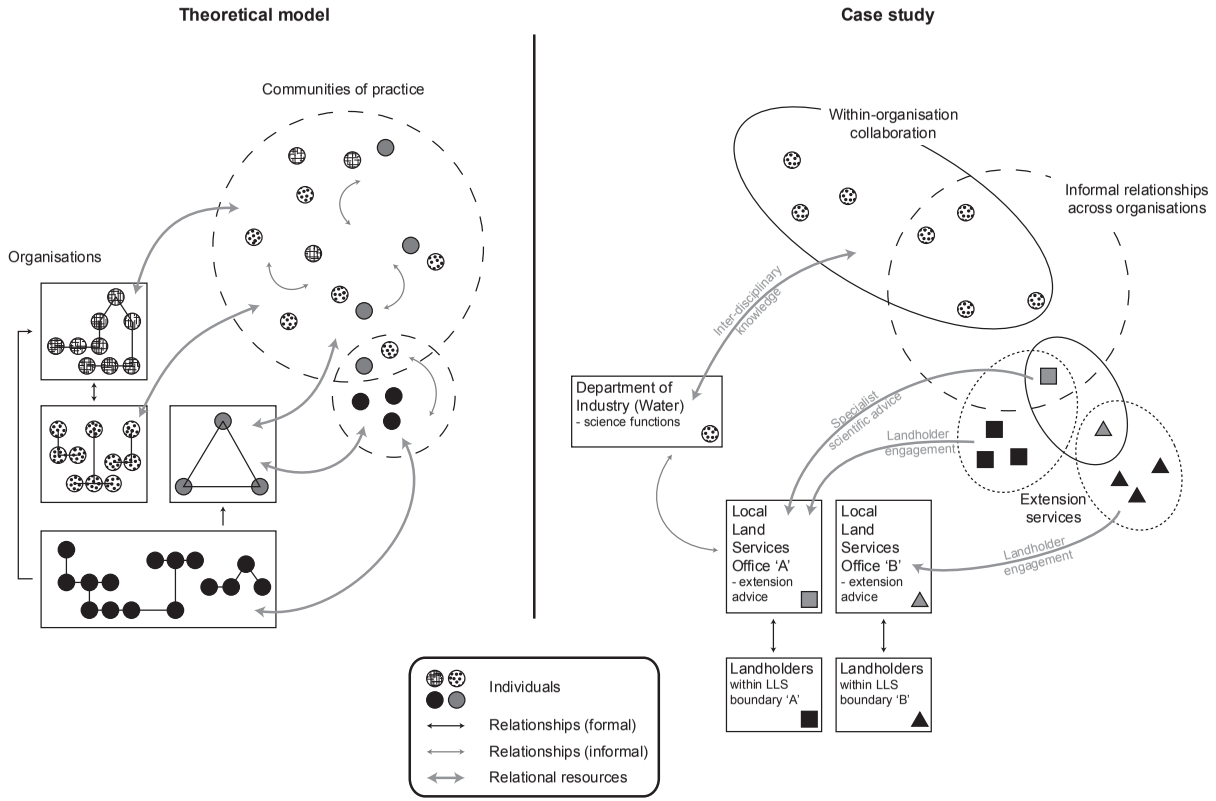


Figure 5-3: Through participation in communities of practice, individuals can share tacit knowledge and develop practices with other individuals who may fall outside of their formal organisational relationships. The informal relationships within communities of practice provide individuals and their organisations with relational resources, which are accessible only through relationships with others. These may include access to others' experiences and knowledge and new collaborations across (or within) organisational boundaries. In the case study example (on right), LLS office 'A' benefits from informal relationships with DoI Water scientists (and associated relational resources) but LLS office 'B' does not.

Documentary and oral evidence reveals that river recovery knowledge, which underpins recovery-based rehabilitation practices, is largely held tacitly by individuals and in communities of practice, and that the availability of this knowledge depends more on interpersonal relationships than might reasonably be expected. Implementation of this knowledge as practice has contributed to measurable geomorphic recovery in a number of documented locations (e.g. Mould and Fryirs, 2018; Fryirs et al., 2018) and has been retained in organisations despite significant restructuring. However, this knowledge is becoming less secure over time. It is possible that this knowledge may become 'remnant' and vulnerable to loss in the absence of ongoing maintenance and reinforcement. With this context in mind, attention must be given to the security of knowledge in organisations, what 'relational resources' can better secure this knowledge and how ongoing sharing and practice of this knowledge can be supported both informally via network re-connection, or more formally in policy.

Whilst specific practices used in river management (e.g. design of rehabilitation works) can be readily documented in technical manuals and other reference materials (e.g. Rutherfurd et al., 2000), there are elements of practice that require a deeper, internalised understanding; interpretation of geomorphic river behaviour is one such element. 'Reading' a geomorphic landscape requires the specialist expertise of observing physical forms and linking these to geomorphic processes occurring under a range of flow conditions, thinking simultaneously at the scales of geomorphic unit, reach and whole-of-catchment (Brierley et al., 2013; Fryirs and Brierley, 2013). 'Relational resources' are the 'soft' resources that are made available to practitioners through participation in social relationships within communities of practice. The term, 'relational resources,' has often been used in organisational theory (Freeney and Fellenz, 2013; Davis and Mentzer, 2008; see also Ambrosini, 2001) but has not been applied to natural resource (or river) management. Figure 5-3 illustrates how communities of practice can maintain relationships across organisational boundaries in the absence of (or complementarily to) formal relationships. In the worked example based on this case study, only extension offices that are linked in a community of practice with scientific staff have access to particular specialist knowledge (as a relational resource), whereas other offices do not have this access. For many practitioners in NSW river management, knowledge of geomorphic recovery principles and their enactment are relational resources because they are held

tacitly within social networks (the communities of practice). This internalised *knowledge*, as opposed to more tangible and explicit *information* (Roux et al., 2006), is developed through experience over time and shared through social interaction, including social learning (e.g. shared interpretation in the field). Therefore, 'securing' this knowledge in an organisation or a community of practice is more challenging than securing explicit information, e.g. in a dataset.

Roux et al. (2006) helpfully describe the 'knowledge interface' as the area of overlap between two or more spheres of knowledge; for example, between scientists and practitioners. The greater that overlap of shared understanding and experience, the greater the potential for knowledge to be shared through ongoing interaction in a professional relationship (as opposed to specific information being 'pushed' or 'pulled' across a professional or organisational divide). Within such a concept of knowledge sharing as a relational and social process, 'securing' knowledge means ensuring that relationships across and within organisations, particularly in the form of communities of practice, are kept strong. This requires a level of institutional stability, including bureaucratic succession planning, whilst still allowing the self-organising community of practice to grow and shift according to the membership composition and their requirements (Pahl-Wostl et al., 2007). This is undoubtedly a difficult balance to maintain, between flexibility in time and organisation of people, whilst also ensuring that there are more formal systems (e.g. governance structures) and policies in place to protect this flexibility (see Pahl-Wostl et al., 2007 for analysis of the European 'Harmonizing Collaborative Planning' initiative).

The above theoretical context helps with interpreting the development, maintenance and implementation of recovery-based rehabilitation knowledge in NSW, particularly with respect to the changing relationship between science and practice in the public sector. Recovery-based knowledge, which is grounded in geomorphology, was initially developed and shared by expert scientists through formal and informal social interactions as modes of social learning. We interpret social learning according to Reed et al. (2010), whereby social learning has taken place where:

- There has been a change in individuals' understandings;
- This change in understanding becomes situated or embedded in wider social units, demonstrating change beyond the individual level; and
- This change is brought about through social interaction, within social networks.

Shared field trips between scientists and practitioners, training courses with ongoing follow-up support from scientists, and independent but government-funded organisations (e.g. LWA) gradually established a cross-organisational community of practice through which recovery-based knowledge was shared. However, over time, there has been increasing fragmentation of, and disconnection between, science and practice functions (including extension services), as outlined in Figure 5-1. Organisational restructuring has eroded direct, formal relationships between science and practice whilst also disrupting some informal relationships that link science and practice through communities of practice (e.g. through loss and translocation of experienced staff). When this is combined with reduced resources and appetite in some organisations for investing in ongoing training in geomorphology, there is significant risk that experienced employees who leave an organisation may take their tacit knowledge with them. This creates a clear need to repair and reinforce relationships between science and practice to ensure that the 'knowledge interface' is maintained, that 'turbulence and trainwrecks' (Benda et al., 2002) are avoided and that practice continues to be informed by the best available science.

Although informal communities of practice have carried recovery-based rehabilitation knowledge with them despite organisational instability, this does not necessarily mean that the communities of practice can continue to perform this function into the future. In the case of recovery-based rehabilitation, communities of practice emerged out of existing official pathways for communication within and between organisations. In the present

setting, it would be difficult for cross-organisational communities of practice to become stronger without explicit commitment of increased organisational support for collaboration. The stability provided by communities of practice through organisational disruption cannot be taken for granted. As reported by respondents involved in science functions of river management, their influence on on-ground river management practices presently relies on individuals' social networks and the willingness or ability of those in their social networks to work with scientific teams on river rehabilitation. In this case, relevant knowledge is a relational resource in that it can be accessed and used only through participation in social relationships. Development, sharing and implementation of particular knowledge – as opposed to information – requires certain human resources in order to be resilient against ongoing political and organisational change (as has been the case in NSW in recent years). Specifically, the necessary resources are those that allow relationships to form and function within and between organisational units. The need to resource relationships was explained by one respondent currently working in the sector:

> *"[Those relationships] need to be resourced. And resourcing doesn't necessarily mean money, it just means time. Adequate recognition in the work schedule, [of] actually going and talking to someone and spending half the day catching up with your local researcher at [a university]."*
> *(Respondent 4)*

In addition to providing time and space for development and maintenance of relationships, relationships require a certain degree of organisational stability (c.f. Pahl-Wostl et al., 2007) so that individuals feel comfortable investing the time required to develop relationships:

> *"A big priority for NSW is just giving people stability. People don't feel safe in any of their organisations. They're constantly moved all the time, with different philosophical approaches guiding management decisions."*
> *(Respondent 4)*

However, despite making an argument for much-needed stability in the river management sector, some further disruption may be necessary to reconnect functional relationships to re-allow development of links between organisations, of the type that allowed strong relationships between science and practice to develop in the past. The informal relationships that are necessary for development, sharing and implementation of knowledge rely on 'softer' relational resources, as well as a supportive set of formal organisational structures and policies that actually *require, foster* and *recognise* cooperation and collaboration. It is difficult for passionate and committed public servants to justify investment in activities that do not fall within their mandated responsibilities, so collaborative and integrative principles must be enshrined in organisational cultures and public policy priorities.

5.6 Conclusion

Geomorphic river recovery has emerged as a foundation for recovery-based river rehabilitation in the New South Wales public sector, and river management more broadly. This emergence has occurred through the processes of social learning that occur within communities of practice that are comprised of committed and passionate scientists and practitioners. However, informal communities of practice can only continue to perform the important function of knowledge management if practitioners are supported and resourced to maintain the social relationships that sustain river management communities of practice and strengthen knowledge security. Conversations with practitioners and scientists point to a well-recognised need to invest in relational resources, allowing the development, sharing and implementation of specialist knowledge (both scientific and experiential). This includes making time and space for social learning in formal and informal settings (e.g. in ongoing training and support processes as well as less structured opportunities for collaboration across institutions). Social connectivity, facilitated through vibrant communities of practice, will be critical to realisation of truly integrative, science-based river management practice into the future.

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Chapter 6

Not all heroes wear capes: River Champions can facilitate effective river management

River management is increasingly participatory, bringing opportunities and challenges for achieving positive environmental and social outcomes. Key challenges for practitioners coordinating participatory river management include working across cultural and knowledge differences (Bracken and Oughton, 2006; Benda et al., 2002) and issues of scale (Maynard, 2013). As many practitioners will attest, river management is just as much about management of human relationships as it is about managing environments, particularly in a participatory setting (Mould et al., 2018; Natcher et al., 2005). Our experiences with river management focus primarily on the Australian setting, where project success often relies on meaningful engagement with each individual landholder in a catchment to gain their voluntary participation. Because coordination of participation can be difficult, it is critical that practitioners and scientists can identify and build upon resources already existing in a socio-environmental setting (Hassenforder et al., 2018). One important example of such a resource is individuals with particular commitment and ability to champion river management issues and projects in their communities or areas of responsibility – we call these people 'River Champions'. This paper will outline who River Champions are, how they work, and how they can best be supported to enhance the environmental and social benefits of sustainable river management.

6.1 Who are River Champions?

River Champions are people who are exceptionally motivated to contribute meaningfully to river management issues or projects and have the ability – or potential ability – to motivate and influence others in their networks to also participate. Champions may be professional river managers, scientists or local community members acting in a voluntary capacity. Because of their connection, commitment and influence, Champions are 'leverage points' (Meadows, 1999), who can help practitioners to multiply their efforts and be more targeted with reaching people in a community (Hassenforder et al., 2018). Below are some characteristics of River Champions who we have met over the course of working as applied researchers. It is in no way an exhaustive list or typology; rather, we hope that by outlining

some general characteristics, we can help you to identify and support the characteristics and activities of your own Champions in your places of work.

6.1.1 Champions are leaders (but may lead quietly)

Leadership is the most important characteristic of River Champions, but it is important to recognise that people lead in different ways. Whilst some will stand out as obvious thought leaders, others will quietly influence their peers through indirect means. Particularly in informal social networks, leaders may emerge to drive forward river management projects in small but significant ways (Wenger, 2010). In fact, many River Champions we have encountered present as being introverted, with strong social skills – not necessarily the loudest person at a meeting. One such example may be a rural landholder who gains recognition and respect from more traditional farmers by *demonstrating* benefits of streamside rehabilitation on their own property, rather than telling others how to manage theirs. They may not intend to lead, but their commitment leads for them by example. Particularly in close-knit communities, a local River Champion may be able to share their experiential river management knowledge with peers who would be inaccessible to government-employed professionals and make change in their community slowly, from the bottom-up.

6.1.2 Champions use social capital effectively

'Social capital' is the sum of our relationships with others in our social networks and the resources (tangible and intangible) that those relationships allow access to (Grix, 2001). Champions tend to be socially skilled and capable of bringing people together. For this reason, they can often be considered as 'nodes,' or points of dense interconnection in a social network. These individuals add value by connecting social networks and their associated social resources. For example, a particularly effective catchment management officer working in a participatory setting will have well-developed relationships with local community members. The officer can also draw in relevant expertise from their professional peer network to incubate new emerging relationships between those peers and community members, expanding and/or diversifying the network. A river management professional explained to us in the course of previous research the importance of social capital as a resource in river management, as well as the need to invest time and effort in connecting people between social networks:

"We make sure [to give landholders] a genuine referral [to the right person]; a warm one, rather than flicking them an email … not a 'fob off,' you need to introduce them properly."

Social capital consists of personal relationships, which rely on trust. Many of the Champions we have encountered are effective because they have developed relationships of trust with their peers and with others in their networks. Building trust with Champions over time may allow them to 'lend' others their trust, providing the others with access to people and social resources that would otherwise be unavailable (of course, providing that this is done with sensitivity, respect and the spirit of reciprocity).

6.1.3 Champions can be found within – and across – a range of management scales

Scale is a vital consideration in river management and indeed many challenges associated with rivers concern the conceptualisation of issues, problems and processes as being scaled in particular ways, in social and biophysical terms (Maynard, 2013; Brierley and Fryirs, 2009; Howitt, 1998). Champions can be found working at a range of scales (e.g. local community, regional organisation, catchment, state or nation) but it is their ability to recognise and interact with people and landscapes *across* and *between* scaled framings of environmental problems that helps them to be effective. Examples of effective cross-scalar work in river management can be found in 'middle-ground' organisations, wherein river management coordinators are positioned between 'bottom-up' and 'top-down' management processes to act as a nexus for exchange of resources such as knowledge, materials and funding (Hassenforder et al., 2018; Gregory et al., 2011; Jennings and Moore, 2000). River Champions that we have observed working in this capacity are skilled in understanding the needs and motivations of individual landholders whilst also understanding the catchment context in terms of project connectivity, geomorphic process and recovery potential (see Fryirs and Brierley, 2009). These individuals spend time and effort working with landholders to support river rehabilitation on their properties whilst also using catchment-framed knowledge to connect projects on properties and encourage landholders to see property-scale river management efforts within a catchment- and community-scale context, building a sense of shared purpose.

6.2 Supporting River Champions in communities of practice

River Champions are a diverse group of people who will each have different experiences and values motivating their participation (Chapter 4) and different social connections and skills (Lauber et al., 2008). This makes it difficult to suggest specific strategies for fostering, nurturing and supporting River Champions in different settings. However, there are general principles that will help with this. All Champions will be, in some way, part of a community of practice. Communities of practice are informal, self-organising social networks of people who share a common interest; for example, in caring for a particular river or catchment. Communities of practice exist between and outside of more formal organisational structures and can extend beyond disciplinary boundaries (Wenger, 2010). For example, a community of practice may emerge from relationships between landholders working on river management, and this community may be linked to a more professional community of practice via relationships between individuals (e.g. catchment management officers) who are members of both communities. Communities of practice are ideal environments for peer-to-peer information sharing and for social learning (Reed, 2010; Pahl-Wostl et al., 2007). However, communities of practice can also provide 'softer' benefits such as social support systems and a sense of social connection.

Perhaps the most critical resource upon which river management relies is the time that people give to the cause. Everybody's time is valuable, but this is particularly true for volunteers, for whom time volunteered must be traded from other important areas of life (e.g. paid work or family); this can come at significant personal cost. Thus, it is important that communities of practice are nurturing spaces that reward people's contributions. Different people will be motivated by different values (Chapter 4) and will respond to rewards in different ways. Some may actively avoid the limelight of accolades or grand gestures, so understanding Champions' motivations for participating, and the trade-offs they are making, will help to find ways of appropriately supporting and rewarding their work. For practitioners and scientists, too, time is a scarce resource (for example, see Castleden et al., 2012). Many workplaces reward performance, but relationship building and supporting social networks may be overlooked in the Key Performance Indicators (KPIs) created to measure rewardable performance. As one highly experienced respondent told us in research we have undertaken:

"We say that knowledge is important and we say that it's to be shared, but we never adequately fund it; the transaction costs of relationships are seen to be too high. So, going and having a cup of coffee with someone, to me that's essential, [but the attitude is] 'What's the point of doing that?' That [investing time in relationships] is how you actually find out what's going on."

We have spoken to professional river management officers who have been discouraged (through withdrawal of funding) from undertaking fieldwork to engage with communities, and who now feel that they are isolated from the people who would directly benefit from their expertise. On the other hand, we have seen professional river managers in other organisations who have developed close relationships with their local communities and whose superiors support and encourage continuity of engagement because they see the benefits. These are the river managers who have been able to achieve strong community participation in river management, taken up by passionate local people who are happy to give up their time to the cause.

6.3 Concluding thoughts

None of the above will be of much surprise for people who work in the river management sector and many of the points made will apply to a range of environmental management settings. However, we hope that by giving explicit attention to River Champions and their important work, we will encourage professional practitioners, scientists and local community members to think carefully about who their Champions might be, and how best to help enable them to be effective. River Champions are influential because of their connectedness in social networks, and it is these networks that also support and enable them to be effective leaders. The most important take-home message from this discussion is that development of well-connected communities of practice and careful investment in social relationships is likely to be the best way to nurture and support the emergence and success of current and future River Champions.

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Chapter 7

Discussion: Advancing relational practices in recovery-based river management

The preceding chapters explore the concept of geomorphic river recovery from a relational perspective. This analysis reveals geomorphic river recovery to be deeply embedded in relationships between physical and social processes, and that physical-and-social processes are embedded in the geomorphic landscape (c.f. Ashmore, 2018). Although this embeddedness in itself is unlikely to be surprising to those familiar with river management, the case study material presented in this thesis does highlight some particular challenges associated with addressing physical-and-social dimensions of river recovery in management. These challenges include: understanding and communicating complex physical-and-social interactions (Chapter 3), working with relational values and divergent motivations in communities (Chapter 4), dealing with fragmentation and disruption in river management policies and systems (Chapter 5) and developing ways to support communities of practice and the individuals and relationships that constitute them (Chapters 5 and 6). Figure 7-1 summarises the major themes emerging in this thesis and demonstrates how geomorphology, critical geographies and river management practice contribute to analysis of geomorphic river recovery as a relational, physical-and-social process. Table 7-1 outlines the contributions of each chapter to the thesis aims, as introduced in Chapter 1. In response to the findings of Chapters 3 to 6 and the key challenges outlined above, this chapter will explore opportunities and challenges for improving river management at the intersection of science, practice and society. It begins by briefly outlining the ways in which this thesis contributes to a relational understanding of geomorphic river recovery. Ultimately, this understanding forms a basis from which to advance an agenda for managing rivers, relationally, as physical-and-social systems.

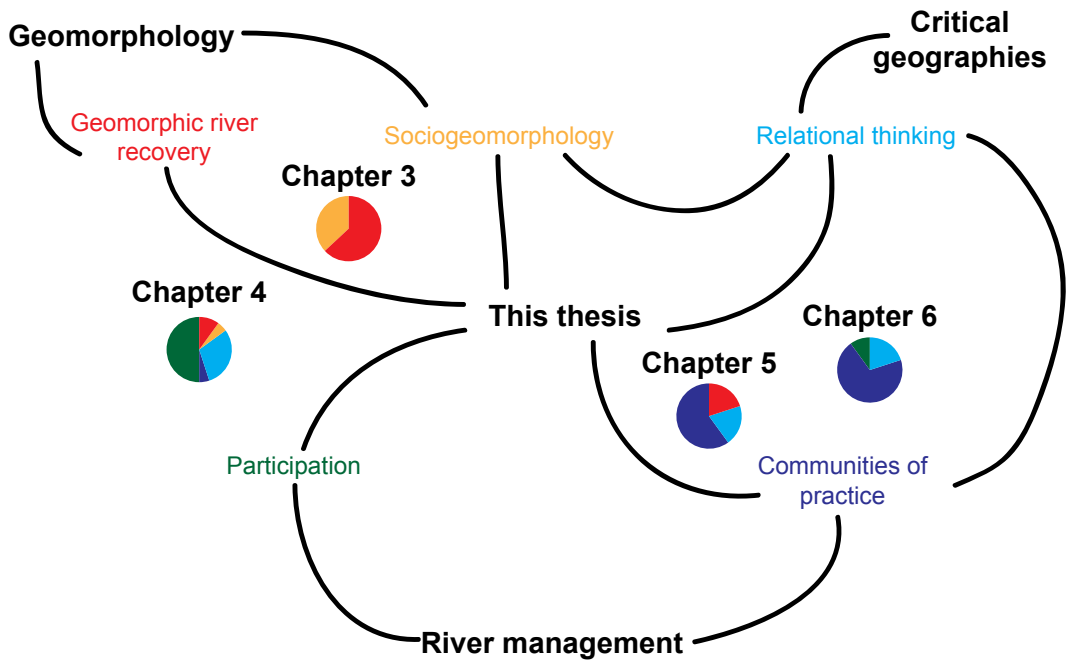

Figure 7-1: The major themes in this thesis (coloured text) connect related fields of research and practice: geomorphology, critical geographies and river management. This figure has been modified from the Introduction (Chapter 1) to visually represent how the thesis' themes contribute to each paper (Chapters 3-6, where colours in pie charts correspond to text colours). This thesis applies a sociogeomorphic framing to the concept of geomorphic river recovery. Sociogeomorphology bridges between the fields of geomorphology and critical geographies in consideration of the relationships that enable or limit river recovery. Relational thinking guides analysis of geomorphic river recovery along with the river management processes that aim to support recovery, namely participation and communities of practice. This discussion chapter focuses on the coming together of these themes for the advancement of relational practices in recovery-based river rehabilitation.

Table 7-1: Research questions and aims as outlined in Chapter 1 and the contribution each chapter has made to those aims.

Research questions	Research objectives	Chapter 3	Chapter 4	Chapter 5	Chapter 6	Chapter 7
In what ways is geomorphic river recovery a physical-and-social process?	Using a case study, demonstrate application of a sociogeomorphic framing, investigating river recovery in terms of emergence through interactions between physical and social processes	Integrated physical-and-social environmental history as basis for trajectory analysis				
How do relationships between people, and between people and place, contribute to geomorphic river recovery?	Explore relational dimensions of participation in river rehabilitation by local landholders to understand motivations and values influencing local participation		Mapping of 'enablers' and 'barriers' influencing conversion of values and motivations into actions			
	Investigate development, sharing and application of recovery-based river rehabilitation practices in order to understand how social relationships shape practices in the professional river management sector			Analysis of communities of practice for developing and maintaining science-based management practices		
	Draw on case studies to characterise and highlight effective uses of relational approaches to leadership by individuals working in river management				Characterising 'River Champions' and how they can best be supported in communities of practice	
What are the implications of the relational nature of geomorphic river recovery for river management practice and the relationship between geomorphic research and practice?	Advance a relational approach to recovery-based river rehabilitation through exploration of its implications for river management at the intersection of science, practice and society	Understanding and responding to physical and social relationships in river recovery requires integrative scientific knowledge combined with effective communication	Understanding enablers and barriers to participation will help practitioners to be more effective in supporting voluntary participation in river management	Communities of practice require institutional support if they are to be effective in driving and supporting river management practice in the long term	Management systems must support 'River Champions,' and communities of practice are the ideal environment for nurturing and enabling their contributions	Call to advance relational practices in recovery-based river rehabilitation means understanding and supporting enablers of recovery in physical-and-social systems

7.1 Physical and social processes in geomorphic river recovery

Geomorphic river recovery is now well developed as a scientific concept, but is typically framed in terms of 'natural' geomorphic processes operating with modification by human influence or impacts (e.g. Piegay et al., 2018; Fryirs and Brierley, 2016; Scorpio et al., 2015; Brierley et al., 2013; Kondolf, 2011; Dufour and Piégay, 2009). The sociogeomorphic framing adopted in this thesis reconceptualises geomorphic landscapes as socio-natures (Ashmore, 2015; Eden et al., 2000), implicating physical and social processes as inseparable in understanding and explaining recovery. This thesis further develops the concept of sociogeomorphology by demonstrating how boundary conditions can serve as an integrative concept to recognise and communicate the significance of physical and social process relationships in river recovery. Social boundary conditions such as economic forces, social networks and landholder identities limit and enable geomorphic recovery in conjunction with physical 'imposed' and 'flux' boundary conditions, such as valley confinement, flow regime and sediment load (Poeppl et al., 2017; Brierley and Fryirs, 2005; Liébault and Piégay, 2002). River management planning processes can build on a sociogeomorphic environmental history in order to develop possible trajectories of future recovery and/or degradation, constrained by physical and social boundary conditions (Chapter 3). This research contributes a fuller understanding of the range of mechanisms by which river recovery can be enhanced using river rehabilitation activities that target physical and social drivers of recovery (Grabowski et al., 2014) and work with specific, place-based conditions (Brierley and Fryirs, 2009).

7.2 Relational dimensions of participation in river management

One major social boundary condition limiting possibilities for geomorphic river recovery is the willingness and capacity of local people to participate in river management (Eden and Tunstall, 2006). This is particularly true in settings like Australia, where the majority of river rehabilitation relies on voluntary participation by landholders (Moore et al., 2018; Fryirs et al., 2008; Lockwood, 2000). For this reason, it is vital that researchers and river managers understand how and why people choose to participate (or not) and where efforts may be expended to achieve appropriate quantity and quality of participation (recognising that different levels and styles of participation will be appropriate for different settings; Hassenforder et al., 2018; Grassini, 2017). Chapter 4 contributes to this field of research by

presenting a tool for mapping the social dynamics of participation in a particular setting. These dynamics include the social processes by which landholders' motivations and values may be translated into participatory actions, as well as feedbacks from participatory experiences into modification of those initial motivations and values. Mapping out the social dynamics of participation is a useful process for practitioners seeking to identify 'leverage points' (Meadows, 1999) as elements in a system where targeted efforts may produce particularly effective results (e.g. for overcoming barriers or enhancing enablers).

An important outcome of this research is that it draws attention to the relational dimensions of participation. This thesis demonstrated that people are drawn into participation – or not – in part by their relationships with each other and with the river as a physical-and-social landscape. These findings suggest a practical alternative to the 'deficit model' of community engagement (Irwin, 2014; Eden and Tunstall, 2006; Sturgis and Allum, 2004) whereby participation can be reframed in relational terms. A relational reframing of participation emphasises that willingness and capacity to participate is a dynamic attribute, which will change according to individual experiences and social relationships. Although education is undoubtedly an important component of river management that can influence participation patterns and practices (Curtis and Robertson, 2003), additional benefits can be gained from focusing on dialogue that enables knowledge exchange in multiple directions and the ongoing development of personal relationships. Relationships can make up the capacity to weather and adapt in response to organisational or systemic disruption (as in Chapters 4 and 5).

The social relationships that make up communities of practice can be particularly effective in supporting and driving participatory efforts in river management, and in particular, the efforts of River Champions as leaders (Chapter 6). Leadership in self-organising networks, such as communities of practice, is different from leadership in formal structures. In formal, top-down structures, authority is sourced from position in a hierarchy, whereas in informal structures, authority is negotiated and earned through relationships with others. This aspect of relational power – or power *with* others (as opposed to power *over* others) – is dealt with by Gaventa (2006). In his analysis of 'spaces' for power, Gaventa (2006) differentiates between 'closed', 'invited' and 'created/claimed' spaces for sharing power with others. In a river management context, 'closed' spaces imply little-to-no input into

decision-making from outside of formal structures and 'invited' spaces may include consultative processes. Self-organising communities of practice offer opportunities for 'created' spaces, where people may become powerful, together, because of their relationships with each other. By supporting establishment of strong and well-connected communities of practice, we can help to create the kinds of social environments in which new and/or modified relationships with others and with rivers may emerge, and actors may be empowered through those relationships.

7.3 Communities of practice and recovery-based river management

Communities of practice play a significant role in developing and sharing knowledge used in river management, contributing to the process of river recovery. The relevant communities of practice are self-organising, and develop and change over timescales independent of (but influenced by) political and organisational dynamics (Wenger, 2010). The management of tacit and explicit knowledges in communities of practice is a critical river management activity (Bodin et al., 2006; Bouwen and Taillieu, 2004), and yet the interpersonal relationships that make up communities of practice are often largely invisible to formal management structures. Analyses of dynamics within communities of practice at the local scale (Chapter 4) and state scale (Chapter 5) identify a range of relational resources that are only available to river managers through social relationships in communities of practice. This research highlights that social relationships are critically important for knowledge management and the development of river management practices (Rogers, 2006; Roux et al., 2006).

The relative independence of communities of practice from formal river management systems, as demonstrated in the thesis case study, allows knowledge sharing relationships to remain intact in some cases despite organisational disruption (Chapter 5). However, a lack of official status also makes communities of practice and their associated relational resources vulnerable to attrition through employment turnover and associated cultural change, if networks are not supported by elements of formal systems (Pahl-Wostl et al., 2007). Investment in these relationships should be prioritised in river management systems. For institutions, this means developing a professional culture that recognises and supports the value of time spent building and maintaining relationships. Although relationship development is time-consuming and can be socially or professionally

challenging, the longer-term benefits of spending time "drinking tea" (Castleden et al., 2013) are not only desirable, but may also be critical.

7.4 Toward relational practices in recovery-based river management

Having outlined the ways that this thesis contributes to our understanding of river recovery as a relational, physical-and-social process, I now turn to considering what it might mean to *practice* a relational approach to recovery-based river management, for scientists and practitioners. The intent is to propose principles that can guide development of specific practices tailored to the physical-and-social setting in each case. In a nutshell, taking a relational approach to recovery-based river management means identifying and supporting the relationships (both existing and emerging) that enable river recovery. These relationships are physical and social in nature, contingent, dynamic and variable in space and time – clearly no easy task! In choosing to work with relationships, one must accept inherent 'messiness' (c.f. Lane et al., 2011) and learn to become comfortable in a messy, relational space. For example, a key characteristic of a relational approach to river rehabilitation is the choice not to compartmentalise elements of a river system, but rather to look for, understand and manage the connections between elements (Poeppl et al., 2017). Understanding and managing these connections relies on scientific knowledge of the kind that recognises these connections. Such scientific knowledge will often cross disciplinary boundaries, requiring researchers and practitioners who are capable of working and communicating across those boundaries (Lave et al., 2018; Fryirs et al., 2013; Bracken and Oughten, 2006).

Sociogeomorphology was adopted as an integrative framework in this thesis to help with constructing an understanding of the studied river system that includes relationships between physical and social processes. A sociogeomorphic framing begins with the premise that the connections between physical and social processes in river recovery are deeper than interaction between adjacent, but separate, spheres of process. Rather, broader and indirect social processes, direct human activities and geomorphic processes are all related and interwoven in emergence of river morphology and behaviour; and, river morphology and behaviour are part of the emergence of a physical-and-social system (Ashmore, 2018; 2015). Interpreting sociogeomorphic relationships requires thinking from critical social geographies in dialogue with geomorphology, in line with the growing field of Critical

Physical Geographies (Lave et al., 2014; Lane, 2016). People do not only have relationships with rivers, but rivers also draw people into those relationships and each is changed through their relationship with the other (c.f. Eden et al., 2000; Crowley, 1999; see also Chapter 2 and Appendix A). This process describes a kind of 'co-becoming,' whereby actors (human or otherwise) exist through their relationships with others, which are constantly regenerating (Bawaka Country et al., 2013; 2015; Eden et al., 2000). In a sociogeomorphic landscape, people and social systems (including researchers, academic knowledge systems, cultural norms and river managers) are implicated in that landscape. In conjunction with geomorphic boundary conditions, these social boundary conditions of relation enable and limit possibilities for trajectories of river recovery and/or degradation, and so must be investigated in the development of integrative research aimed at supporting relational river management (c.f. Ashmore, 2018; Poeppl et al., 2017).

Recognising inherent relationships within physical-and-social landscapes (as in sociogeomorphology) not only supports more integrative explanations of phenomena such as river recovery, but can also provide a framework for *acting* in river management and attempting to contribute positively to the place and community in which one is working (Lave et al., 2014; Castleden et al., 2013; Fryirs and Brierley, 2009; Harvey, 1984). A relational approach recognises that change can be effected through relationships with others, rather than by 'manipulating' elements of a system from a perceived position 'outside' of that system, as euphemisms of 'management' often imply (Howitt and Suchet-Pearson, 2006; Natcher et al., 2005). This shift in positionality of the researcher and practitioner as working within the physical-and-social system being managed strongly challenges conventional practice in river management, but is essential for realising relational river management practices. By taking a position within a relational system, the researcher or practitioner also enters into a relationship of responsibility with the river and with other actors, rejecting the positivist worldview that isolates the researcher from their objects of research (Lane, 2016; Wilcock et al., 2013). Repositioning the researcher or practitioner constitutes a practiced recognition of the unavoidably political nature of research and management (Lave, 2016), including the consequences of that work for relationships within physical-and-social systems (Tadaki et al., 2012).

Making change, relationally, from within a system, relies on well-connected social networks such as those found in functioning communities of practice. Within communities of practice, development of relationships can come to replace the 'stakes' that typically define people's involvement in river management (Mould et al., 2018). The 'stakeholder' paradigm, which underpins participation and engagement in most river management settings, can be particularly problematic for its ability to introduce or reinforce existing unequal power relationships by compartmentalising interests and excluding relevant voices from decision-making (Jackson, 2006; Hillman, 2005). Replacing stakes with relationships allows shared (if contested) knowledge (as in Wilcock et al., 2013) to be developed through dialogue, forming a basis for decision-making (Tadaki et al., 2012).

Developing shared knowledge through dialogue and relationships requires some reorganisation of the people and systems involved in that process. Lane (2016) provides some insight on such a reorganisation in his interpretation of Stengers' (2013) advocation of a 'slower science.' This includes repositioning the scientist so that they will encounter "those who ask different questions or bring other kinds of understanding, normally excluded from scientific understanding" and "engage with the subjects of our research [in ways that give] them the power to make us think differently about them" (Lane, 2016, p.11). The 'us' here can apply not only to researchers but also to river management practices, and the research objects could include both human and non-human agents. Lane's argument supports practices that turn toward dialogue as part of a relational research practice, allowing others to 'speak' for themselves (and challenging 'us' to listen; Howitt, 2019). An emphasis on listening as part of developing relationships is fundamentally important for creating spaces for sharing power (as in Gaventa, 2006). Whilst scientists and practitioners may be accustomed to their particular authorities derived from professional position and the status of their knowledges, entering into a relational system for river management requires recognition of relational sources of power and the need to earn your share in that power (see Lane et al., 2011). It is through dialogue that these relationships can be developed and maintained (Mould et al., 2018; Wilcock et al., 2013) and it is through relationships that decision-making frameworks can be reconfigured to recognise and respond to rivers as physical-and-social systems.

7.5 Conclusions

This thesis explores the concept of geomorphic river recovery as a relational, physical-and-social process and considers the implications of this framing for river management practice. Using the Macdonald River and broader NSW river management context as a case study, this thesis analyses some of the ways that the physical-and-social nature of river recovery manifests and influences the range of possible future trajectories that a river may take. Building upon this analysis, this thesis insists on a shift in positionality from external observation of a contained system to relational engagement as part of a porous, messy and complicated physical-and-social system. It contributes key principles toward developing a relational approach to the practice of recovery-based river management. These principles can be applied to other river management settings in order to develop specific, tailored practices, and include:

- Adoption of an integrative framework (e.g. sociogeomorphology) for recognising and understanding physical-and-social process relationships;
- Practiced application of critical geographical theory to effect a repositioning of researcher and practitioner as working *within* a physical-and-social system, emphasising relationships over 'stakes' as a basis for participation in river management;
- Building and nurturing relationships between researchers, practitioners and community volunteers through development of well-supported, and supportive, communities of practice as created spaces of shared power; and
- Ensuring that dialogue, including both speaking and listening, is prioritised as a means for developing and maintaining the types of physical-and-social relationships that enable river recovery to occur.

Beyond the principles proposed in this thesis, the development of relational practices in recovery-based river rehabilitation will require further research that investigates the application of relational principles in a range of settings. We need to understand how these principles can be applied in different spatial, social and management contexts. However, it is one thing for a researcher to put forward the above agenda, and quite another to put it into practice. For many practitioners in the river management sector, this may sound like yet another 'wish list' of academic idealism. On the other hand, these characteristics of relational practices are almost all based on practices observed whilst conducting this

research, whether or not the practitioners applying them were cognizant of the fact. The difference is that the observed practices tended to be applied intuitively and unevenly, because the present paradigm of river management does not explicitly recognise or encourage such practices. Committed and capable practitioners will continue to enact relational practices, with or without support from their superiors and institutions, because they know the importance of relationships for achieving positive outcomes in river management. However, realisation of truly relational practices as an integral framework for river management will require some rethinking of the systems and assumptions that presently underpin policy and practice; for example, the compartmentalisation of elements in river systems and the thinking that defines relationships according to 'stakes'. In addressing this challenge, there is a need for stronger advocacy for what experienced practitioners and researchers know to be true – that in addition to having the best available science, positive river management outcomes rely on engaged and connected communities of practice that are capable of learning together in advancement of river management knowledge and practice. Advancing a relational approach to recovery-based river rehabilitation should be a priority for those who seek to ensure that the rivers we live with will continue to live with us.

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Appendices

Appendix A

JOURNAL OF MAPS
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Seeing double in art and geoscience: 3D aerial portraits of 'lost' Anthropocene landscapes

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ABSTRACT

Relationships between humans and environments are deeply challenged by recognition of the Anthropocene, which implicates humans as major drivers of planetary-scale environmental changes. Responding to these challenges requires technical expertise, but also creativity in dealing with complex social, cultural and political relationships of place. This paper introduces *Relief* as an art project that repurposes historical aerial photographs for the creation of affective, low-tech 3D experiences of landscapes and their histories. The creation of these works, and the experience of viewing them, offer a process for witnessing change in the Anthropocene. Content and aesthetics bring viewers into different ways of seeing landscapes, with implications for outreach and communication, as well as approaches to situating science and scientist in relation to society, politics and place. This art project leads into discussion of human agents and non-human agents as co-producers of landscapes, and the opportunities for art and science to respond to environmental concerns.

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Critical physical geography; environmental change; geomorphology; Snowy Mountains; visualisation; witnessing

1. Introduction

Recognition of the Anthropocene brings deep challenges to human-environment relationships and our place in the world by asserting that our re-shaping of the planet's surface is a force of geological scale (Crutzen, 2002; Maslin & Lewis, 2015; Steffen, Crutzen, & McNeill, 2007). Activities such as mining, dam building, manufacturing and urban development have altered geologic, geomorphic, hydrologic and atmospheric systems and processes in significant ways, unsettling our relationships with natural systems. This upheaval of our sense of place in the world has been likened to the destabilising effect brought by the discovery of plate tectonics (Clark, 2011) and even Galileo's radical insistence that the Earth does indeed move (and now is trembling in response to our significant environmental impacts; Serres, quoted in Latour, 2014). So deep are the Anthropocene's challenges to society and a sense of place that writers are developing new vocabulary specifically to describe them (Macfarlane, 2016) and even proposing 'psychoterratic disorders' that stem from socio-environmental change (Albrecht et al., 2007). As a fluvial geomorphologist, it is easy to reach for instances that confirm the Anthropocene, if not necessarily as a formal geological epoch, then as an expression of the deep, complex and compounding ways that humans have changed the surface of the Earth in the 'critical zone' (Brown et al., 2017; Lewin & Macklin, 2014; Meybeck, 2003; Wohl, 2013).

Geomorphology and related geoscientific disciplines are recognising and responding to these complex human-environment relationships by investigating the co-production of social and physical systems (e.g. Ashmore, 2015; Linton & Budds, 2014; Mould, Fryirs, & Howitt, 2018; Urban, 2002). Recognition of geomorphic landscapes as co-produced by social and physical processes goes further than investigation of 'human impacts' (Head, 2008). It suggests that humans are acting *with* environments from within socio-natural systems, echoing longer-standing arguments from the social sciences and environmental philosophy (e.g. Latour, 2005; Muecke, 2006). Co-production and the Anthropocene are opening up discourse within sciences – including in physical geography – about the roles of science and scientists as social, political and environmental agents who not only investigate landscapes but also re-make landscapes through their positions, intentions, interventions and analytical frameworks (Ashmore, 2015; Mould et al., 2018; Tadaki, Brierley, & Cullum, 2014). A proposed 'critical physical geography' (i.e. reflection and critique from within physical geography) aims to explore these concerns (Lave et al., 2014; Tadaki, Brierley, Dickson, Le Heron, & Salmond, 2015).

My own research interests in fluvial geomorphology relate to river rehabilitation and recovery, and how

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physical and social processes combine to make and remake rivers. Stemming from this research is recognition of the politics of being a scientist – and a citizen – embedded in relationships between people and places. Particularly in river rehabilitation, we must engage with others, who see, feel and know differently to ourselves, and yet to a large degree, our scientific training does not prepare us for this challenge. I feel tension between my scientific culture, which values objectivity, and my felt responsibility to engage with the socio-political context of connection in which I live and work. Rather than attempting to suppress this tension, I make use of it through an art practice that allows me to explore both divergence and convergence between my science, my self and my sense of place. This paper will present a selection of images from the art project, *Relief*, in which historical aerial survey photographs are repurposed to tell stories about geomorphic landscapes and challenging human-environment interactions. This project is innovative in that it transforms aerial photographs from inert snapshots into an impetus for critically exploring time and agency in environmental change. The images are three-dimensional (3D) 'portraits' that draw attention to human and non-human agency and an aesthetic of place. This processes takes on particular relevance in the context of the Anthropocene, wherein we must question where it is that we fit in relation to our environments. This paper will then briefly discuss 'seeing double' (through scientific and artistic lenses) as a practice that simultaneously cross-pollinates and critiques between art and science, helping to resituate the scientist in relation to society, politics and place.

2. Methods for production of maps

The *Relief* project consists of a series of composite images created using historical aerial survey photographs from locations across New South Wales (NSW), Australia. Stereo pairs of photographs (adjacent photographs from an aerial survey with overlapping coverage) were digitally scanned from sets of aerial photographs held in my home institution archives and at the National Library of Australia. Selected pairs were modified in Adobe Photoshop software to produce anaglyphs. Anaglyphs are stereo images overlayed and filtered into red and cyan channels so as to appear in 3D when viewed with red/cyan 3D glasses (Figure 1). An anaglyph uses filters to allow each eye to see only one of the two images in the composite image, substituting normal 3D binocular vision for the left and right vision fields of successive aerial photographs, so viewing common objects from two different angles. Some photographs were further modified by superimposing dark shadowy shapes on the landscape, marking areas where significant environmental changes have taken place. These shadows were added by tracing features from topographic maps and satellite photography available form NSW Spatial Information Exchange (http://maps.six.nsw.gov.au).

3. 'Relief': background and introduction to works

Relief emerged from a point of inspiration in teaching second-year undergraduate geomorphology students to use stereoscopic images for geomorphic mapping,

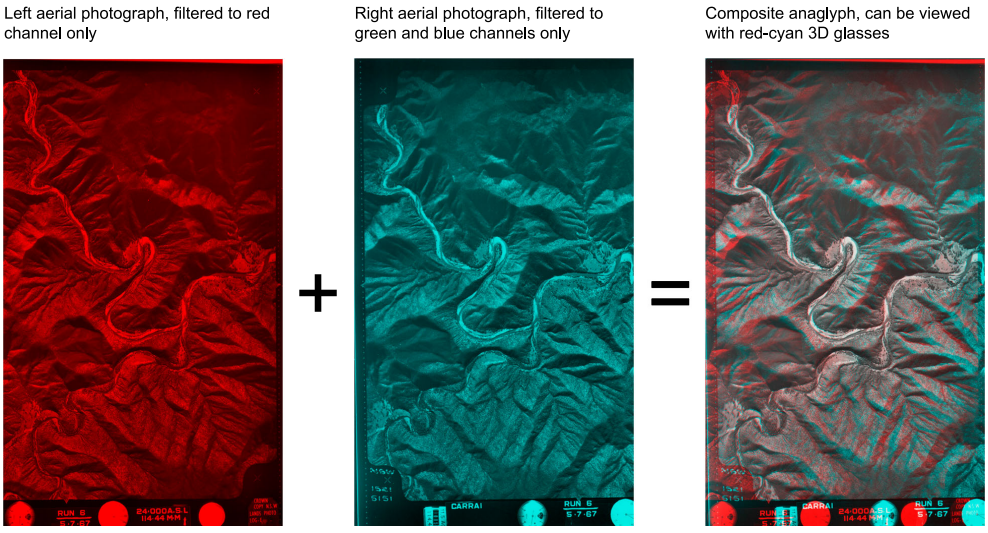

Figure 1. Red-cyan anaglyphs are created by overlaying adjacent aerial photographs from a survey flight. Images are digitally filtered using the RGB (Red-Green-Blue) channels.

and the sense of wonder and excitement that some students expressed when two flat images came together to 'leap out' in 3D. I routinely use historical aerial imagery in my research that reconstructs river evolution (e.g. Mould & Fryirs, 2017, 2018), and have become fascinated by the medium. In contrast with more modern sources of spatial data, such as Google Earth (which has transformed virtual spatial experiences; e.g. Tooth, 2006), aerial photographs offer a view restricted by the framing of the photograph. This limitation is significant for creating a particular experience, one that is more like viewing a portrait than interpreting data. The viewer is denied distraction, which makes for a slower experience of place with more careful engagement. The affective quality of the aerial images is made more potent with the knowledge that many photographs depict aspects of landscapes that no longer exist, in the sense that they have been irreversibly transformed. In beginning the project, I wanted to share that uneasy feeling that arises from the viewer experiencing a relic.

Images in the series were first released in the form of an experimental self-published magazine (a 'zine'), presented at the 2016 Zine Fair, Australian Museum of Contemporary Art, Sydney. Since release of the short zine, *Relief* has been developing to engage more deeply with concepts of agency, responsibility and environmental change. Initially, the images were presented with little background information or context. However, works produced subsequently tend to be more critical, some using shadows to indicate specific changes that have occurred in these landscapes since the photographs were taken, thus incorporating a temporal dimension. This is an important development for the project in that it makes a shift away from novelty, retaining the exciting experience of 3D vision but using that experience to communicate my deeper sense of unease with the loss and change that has occurred.

This paper presents images from the Snowy Mountains region of southeast Australia, Australia (Figure 2). The works presented in this paper, examples from *Relief* (Figures 3 and 4), are not maps in the traditional sense, as in a reference text with clear delineations, numerical scale or utility (e.g. navigation). As a collection, they form something closer to a 'narrative atlas' (c.f. Wood, 2013) that is deliberately ambiguous; the images are small vignettes of specific locations with particular histories, but speak to a broader narrative of impermanence, agency and responsibility (http://www.simonmould.com/relief/). They are best viewed with widely available red/cyan 3D glasses, so appear in 3D, but 3D vision is not critical for understanding the work.

3.1. Tumut River (1944)

'Tumut River' (Figure 3) shows an active river whose meander cutoffs and abandoned channels demonstrate its freedom to adjust its form and move across the floodplain in response to flowing water. However, in 1968, the Blowering Dam was built as part of the Snowy Mountains Hydroelectric Scheme, impounding the river and forming a reservoir (lake). As a result, the Tumut River's capacity to adjust was constrained by the stillness of its water. In Figure 3, a dark shadow indicates the contemporary footprint of the reservoir, the dam wall being the straight line at the top of the shadowy shape. All that is under this shadow – river, hills, trees, roads – has since been made invisible beneath the water.

3.2. Old Adaminaby (1944)

'Old Adaminaby' (Figure 4) also depicts an area now partially filled by a reservoir, Lake Eucembene. The farming town of Old Adaminaby (pictured) was relocated to make way for the reservoir and people were still living in the town at the time the photographs were taken (see Raymond, 1958). The dark shadowy area in this image represents the contemporary inundation extent of the lake, which slowly crept up over the town following impoundment in 1958. From time to time, in periods of low rainfall, the waters of Lake Eucembene recede and the ruins of Old Adaminaby re-emerge (Morris, 2006), neither wholly human or natural, but a kind of halfway place where physical and social agencies intersect.

4. Discussion

4.1. Interpreting 'Relief'

Relief presents 3D portraits of landscapes that invite viewers to see those places in a particular way. This experience of place is influenced by the subject matter (landscapes with particular characteristics and histories) and the aesthetic qualities of the medium (anaglyph). In terms of subject matter, each image presents a story of landscape evolution involving interactions between geological, geomorphic and anthropogenic/social processes. 'Tumut River' (Figure 3) and 'Old Adaminaby' (Figure 4) both deal with the circumstances and consequences of damming as part of the Snowy Mountains Hydroelectric Scheme. The Scheme was an enormous project undertaken from 1949 to 1974. Construction consisted of 'seven power stations, 16 major dams, 145 km of interconnected tunnels and 80 km of aqueducts' (Snowy Hydro, 2017) to divert water from the Murrumbidgee, Snowy and Tumut Rivers for agricultural use and the generation of hydroelectricity. Approximately 100,000 people contributed to the construction, one-third of whom were Australian, and with many of the others coming from Europe after World War II. Thus, the Scheme produced significant changes in both the

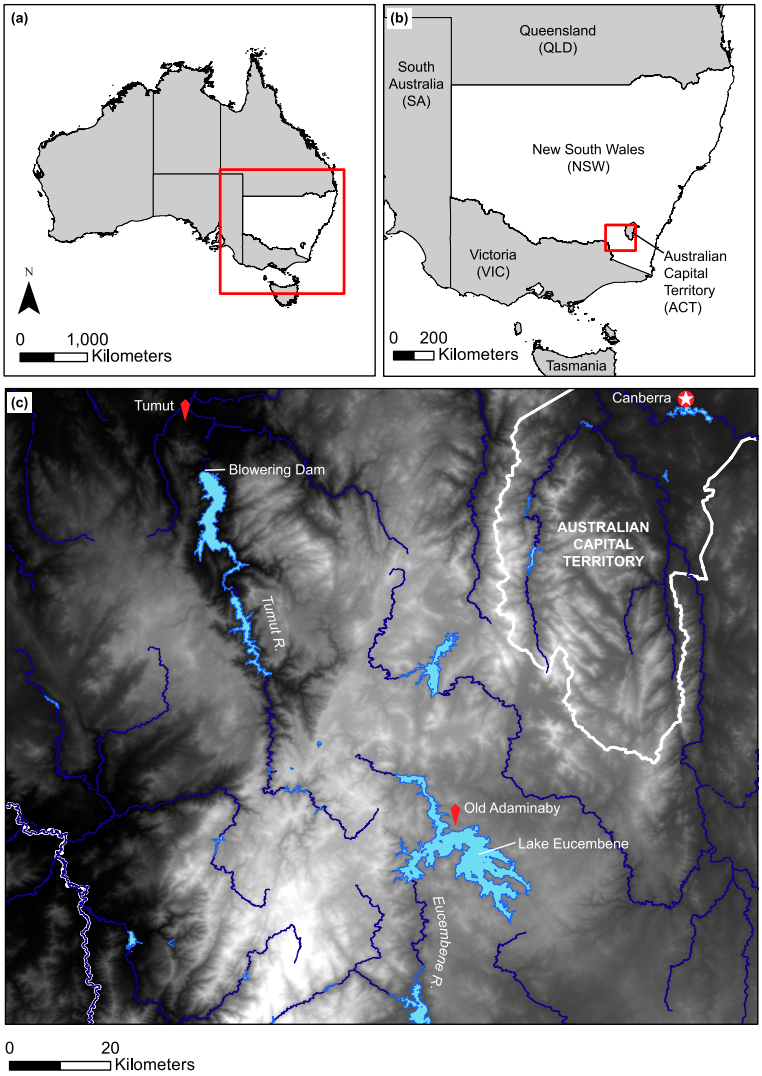

Figure 2. Location map, showing the Snowy Mountain region, southeast Australia, and the approximate area covered by Figures 3 and 4.

physical environment and the make-up of communities as new landforms were created and 'new Australians' were inducted through labour and the creation of myths that would shape Australian identity (Ashton, 2009; Griffin, 2009).

Elsewhere, both in Australia and farther afield, there is a long history of significant social and cultural change resulting from damming; for example, the flooding of Lake Pedder in Tasmania, Australia and the Tryweryn valley in north Wales. In the Tasmanian example, loss of 'wilderness' in part sparked the rise of the Green political movement in Australia in the 1970s, which contributed to protection of the iconic Franklin River shortly thereafter (see Crowley, 1999). In Wales, the Tryweryn scheme continues as a symbol for the Welsh nationalist movement, having had significant hydropolitical consequences in the region (Griffiths, 2014). In the Snowy Mountains Hydroelectric Scheme, much public discussion, understandably, focuses on the significant engineering feat and its economic and social implications. There is typically far less consideration afforded to the landscapes that were lost, or irreversibly changed, in the process. Damming typically induces significant changes in the behaviour and functioning of rivers and the impacts are in many cases irreversible; for this reason, dams are particularly evocative of the Anthropocene. *Relief* draws attention to places that

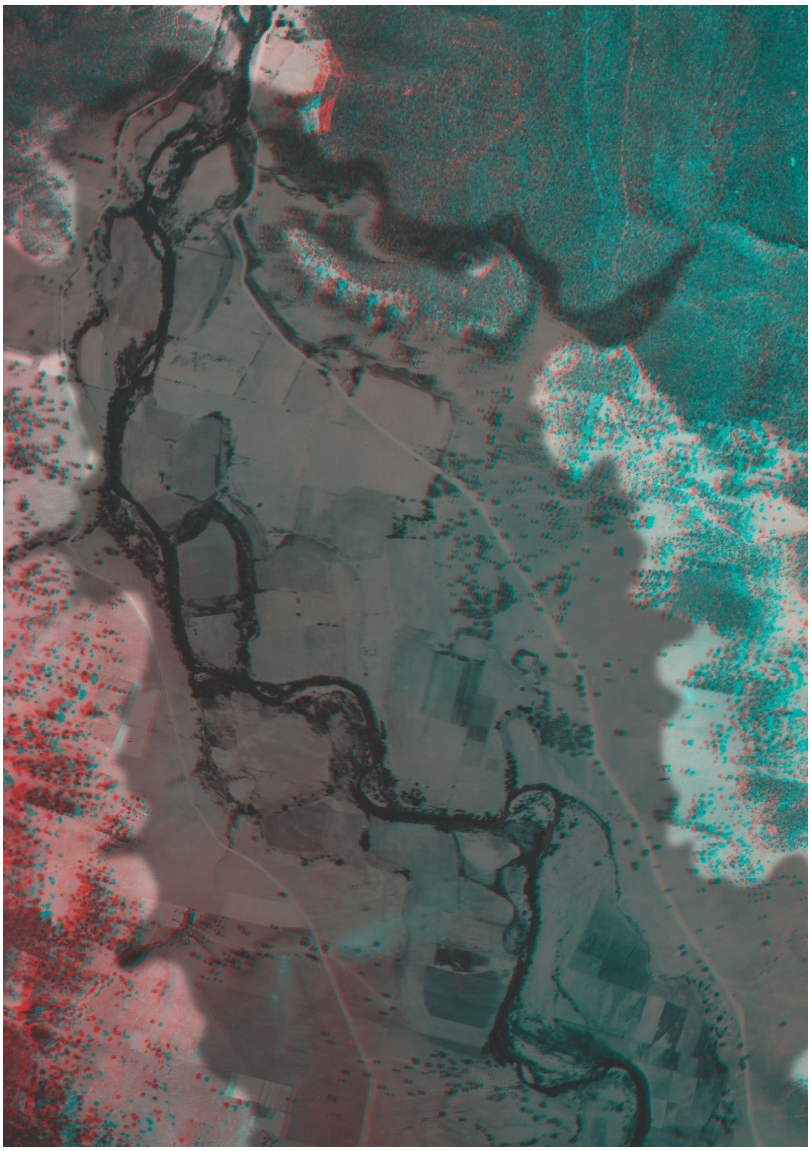

Figure 3. 'Tumut River (1944)', showing an active river with meander cutoffs and abandoned channels, and a shadow indicating the footprint of the reservoir that would later be impounded behind the Blowering Dam wall.

were drowned when rivers turned into reservoirs, taking those 'lost' places out of the abstract by revealing their forms. This encourages the viewer to consider what has been lost in each case and to engage with these places by witnessing their histories.

In 'Tumut River' (Figure 3), viewers are invited to experience a section of river that can no longer be seen or visited. The section of river underneath the shadowy outline of the lake is a complex environment with a long history of geomorphic evolution, reflected in the many meander cutoffs and abandoned channels that reveal how the river has changed course over time. This complexity in character and behaviour has been lost through damming, which has simplified the environment with the introduction of a homogenous, dark water surface. Complex interactions between water and landforms have been reduced to a simple function of topography: anything below the particular elevation of the dam wall will be inundated. The brutal simplicity of this new engineered environment, constrained by the straight line of the dam wall, is juxtaposed against the elegance of a dynamic geomorphic system. The dark shape of the lake, which

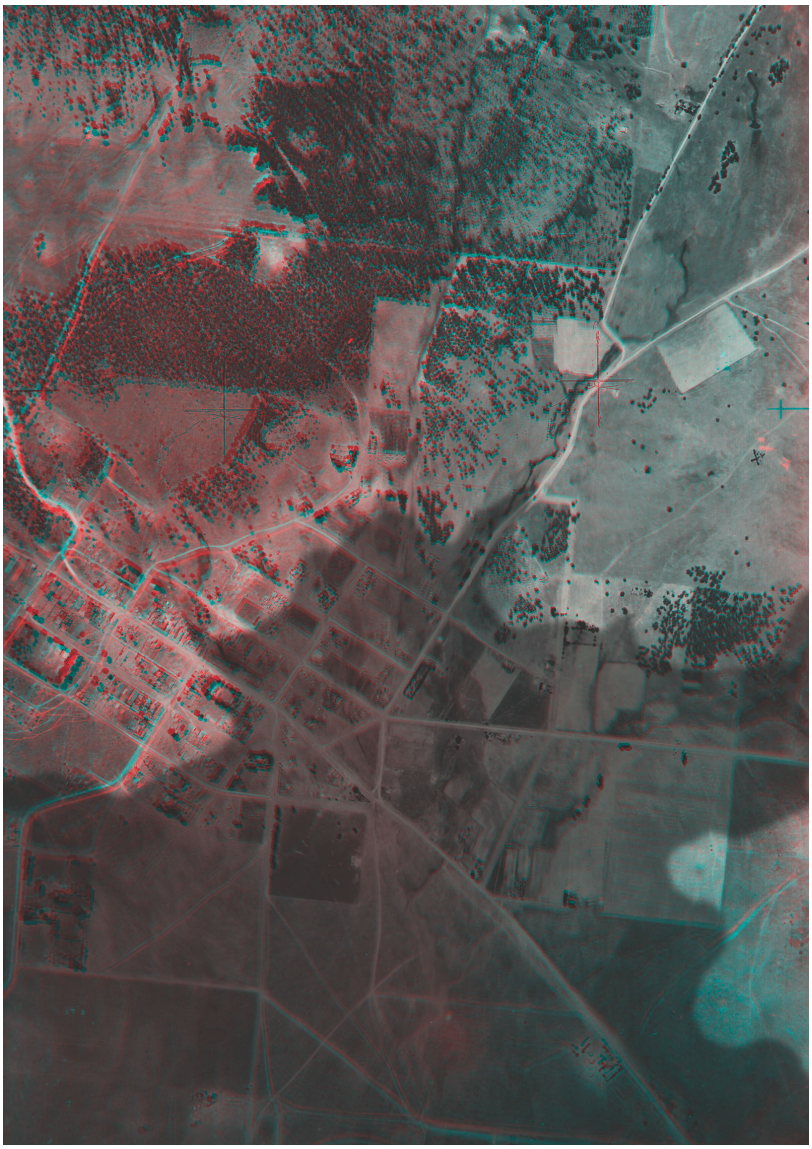

Figure 4. 'Old Adaminaby (1944)', showing the town of Old Adaminaby, a shadow indicating the footprint of the future Lake Eucembene.

hovers over the landscape, allows one static image to represent a process of transformation by superimposing the present on the past.

'Old Adaminaby' (Figure 4) shows a small section of Lake Eucembene, where the shadowy shape of the reservoir is encroaching on a small town. Although this represents a similar inundation process as in 'Tumut River' (Figure 3), the framing of this image suggests a different kind of agency for the waters of the former Eucembene River. The dam wall is not visible in this image, and the water appears to be creeping up over the town, seeking out the low-lying areas (Figure 4). In contrast with 'Tumut River', the creeping waters in this image appear indifferent to the hard edges of anthropogenic development, instead responding only to the contours of the bedrock valley. What remains of the human settlement after relocation will be swallowed up and then revealed by the receding water only in periods of low rainfall and out of human control. The superimposition of contemporary water levels on this historical image of Old Adaminaby, taken when it was still inhabited, points to the loss of

human relationships with place. Although the town was relocated only a short distance away, the upheaval of a community is a significant task. It would likely have been an unsettling experience for many residents to watch the streets of their town – and its familiar landmarks – disappearing under the rising water. Similarly, the recurrent surfacing of artefacts and ruins as the waters recede likely also brings to the surface difficult memories, entwining human experience of place with the hydrological variability of the reservoir (c.f. Griffiths, 2014).

Others have responded to the physical and relational transformation of rivers by damming in ways that dialogue constructively with *Relief*. For example, Hywel Griffiths's poetry on the dammed Elan Valley in Wales conveys a similar melancholic feeling for the loss of natural character and behaviour, a parallel with the dark and eerie shapes that foreshadow the loss of place in *Relief*:

> 'There are no currents weaving, ribbon-like,
> it's quiet where the waterfall once roared,
> the sources and the sink are now divorced'
> (Griffiths et al., 2017, p. 6).

However, Griffiths et al. (2017) also articulate an interpretation of the 'Anthropo(s)cenic' (Matless, 2017), which recognises the opportunities for new and positive relationships with place, brought about by transformation at Anthropocenic scale (see also Tooth, 2016). This tension in human-environment relationships, created by transformation, is captured effectively by Australian artist, Bryden Williams, who has produced works in response to damming in Australia and China (http://brydenwilliams.com). Williams's photographic works in the 'Hydro-Wilderness' series examine containment of 'natural' forces by anthropogenic materials and the [blurry] distinctions between public (wild) and private (urban) space. 'On The Yangtze' is a video work also produced by Williams, on which he reflects: 'Together we sat in awe of the sheer size and sense of sublime that resided within both the natural and the man made features of the environment.' This sense that heavily transformed landscapes may simultaneously be characterised as emblematic of extreme human modification, but also beautiful and revered by people (as in Griffiths et al., 2017), is a thought-provoking proposition for the Anthropocene and how we can foster a sense of place in these landscapes. In the *Relief* project, coming to terms with transformation of human-environment relationships is explored through a process of witnessing as a practice for recognising and processing the consequences – both positive and negative – of change.

Witnessing geomorphic and geological landscapes that have been made invisible is a primary concern for the series of works in *Relief*. It is inspired by the practice of becoming-witness, which involves 'drawing people into others' (including non-humans') lives' and both 'standing *as* witness' (sharing/communicating) and '*bearing* witness' (opening oneself to others; Rose & van Dooren, 2017, p. 125). By witnessing 'lost' landscapes, it is my intent that a viewer is invited to not only see, but also to care, as they seek to learn about an 'other' (in this case, a landscape) and become more receptive – and empathetic – to its past, present and future. Such attentiveness is seen as being critical at a time when we are recognising, more and more, our implication in the causes, consequences and necessary responses to some of our most significant environmental challenges. Viewers of *Relief* are invited to witness landscapes as an exercise in empathy that might lead to new ways of thinking and acting in relation to landscapes. This is to guard against the 'social death' that befalls non-humans when they are seen as dispensable or inconsequential, a process that enables the ecocide associated with the Anthropocene (Rigby, 2009; Rose & van Dooren, 2017), but in this case applied to the geosphere – perhaps 'geo-cide'.

Particular aesthetic qualities of the medium used in *Relief* contribute to an experience conducive to bearing witness. The subject matter and aesthetic in *Relief*, together make for an uneasy experience of landscapes that have been lost. This experience invites the viewer to reflect on environmental change with the weight of responsibility that comes with recognising the role of humans in that change. Rather than being 'just images', *Relief* is an attempt to create virtual experiences of places that offer more to the viewer than the raw data (aerial photographs) are capable of. The 3D effect is the most prominent element of the visual aesthetic because it transforms a flat image into something more dynamic. Not only do the landforms take on height, but in the printed medium, they also shift and bend as the viewer makes small movements with their hands. This makes for a surprisingly tactile experience of holding and peering into a place. The red/cyan 3D glasses also introduce a particular effect. First, they are somewhat isolating and encourage the viewer to focus on the anaglyphic material, since it can be difficult to focus on the non-anaglyphic world when wearing the glasses. Second, they give a shadowy quality to the viewer's vision, since images with variable relief require that the viewer readjust their eyes to focus on particular points. Together, these effects make for an immersive experience that some viewers have described as dream-like and hazy, similar to a distant memory. Although the memory is not the viewer's own, it is a sort of 'second-hand,' shared memory, accessible only through documents and artefacts (c.f. Griffiths, 2014). Accessing these memories in order to witness can trigger an emotional response that is similar to – albeit much milder than – the 'solastalgia' described by Albrecht et al. (2007). One of a range of proposed 'psychoterratic disorders', solastalgia

describes a sense of loss one feels when the environment changes around a person to the point that one can no longer find solace in their surroundings – a kind of homesickness for a place that has been transformed (Albrecht et al., 2007; Macfarlane, 2016).

4.2. 'Seeing double' as a practice

'Seeing double' – that is, through art and science – is a practice that can help to recognise and negotiate social, political and place-based context, personally and professionally. I consider this to be consistent with notions of being critical in physical geography (Lave et al., 2014; Tadaki et al., 2015). The art practice described in this paper is not academic research in its own right, but it has implications for research practice. I seek out places and situations that will allow me to explore intersections of human and non-human agencies. It is at first driven by curiosity, but leads to the compulsion to communicate. This is the responsibility of bearing witness: by witnessing, the researcher is bound to a place through a relationship of morality, or an ethic, that requires them to stand *as* witness (Rose & van Dooren, 2017).

One way that this practice contributes to research is by guiding reflection on the role of researcher in relation to the landscape under study. For example, while *Relief* celebrates the aerial photograph, it also performs critique on the neutrality of such a data source and the particular context in which these place-based data are interpreted. Although aerial photographs are objective in their rendering of a particular view of a landscape, their production and use are unavoidably political. All aerial photographs are taken for a reason and do not exist as neutral artefacts. For example, the 1944 set of aerial photographs from which 'Tumut River' (Figure 3) and 'Old Adaminaby' (Figure 4) were sourced were taken specifically for the purpose of scoping and planning the Snowy Mountains Hydroelectric Scheme; i.e. for understanding the landscape so to be able to transform it. It is likely that not all members of the national-level committee responsible for this project were familiar with the region concerned and would have relied on these aerial photographs – along with maps and other resources – to make important decisions concerning this landscape's future. Hence, it is significant that these photographs represent the landscape in a particular way. The scale of the photographs is important, keeping in mind that scale can variously make objects and patterns visible or invisible, pronounced or diminished (Wood & Fels, 1992). Temporality is also a concern here: because aerial photographs represent a scene as it was for only a fraction of a second, they make invisible certain variabilities and tend to present the landscape as inert. The particular view of these landscapes provided by aerial survey creates particular possibilities for interpretation, making the photographs powerful beyond their face value.

The fact that these particular photographs would have been used in the design of systems and processes that would so significantly transform their subjects makes their repurposing in *Relief* all the more powerful. By modifying these photographs and mobilising them as tools for witnessing, *Relief* 'reclaims' their political power for an alternative, critical purpose. The implication for scientific practice is that all spatial data, and their interpretation, are the product of particular, contingent framings – some subtle, some not so subtle – that are deserving of critique when making interpretations that aim to describe the world (c.f. Harley, 1989; Harvey & Chrisman, 1998; Kitchin & Dodge, 2007). These framings are produced by inescapable social, political and place-based contexts. The influence of context on data collection and interpretation does not suggest that objectivity in science is impossible. Rather, it supports an argument for critical engagement with that context as part of a process of reflection and situated practice in science (c.f. Suchet, 2002) rather than practicing objectivity by insisting on value neutrality. Art-science practices, like in *Relief*, can help to draw attention to the social and political context in which technical interpretations and decisions are made, encouraging critical reflection within the sciences that is consistent with analysis of the co-production of physical and social landscapes (Ashmore, 2015; Linton & Budds, 2014).

Recognising our social, political and place setting is all the more important in the context of the Anthropocene as we realise just how closely (and complexly) linked are the futures of humans and non-humans. As a matter of inherent moral concern (as opposed to a neutral issue become politicised; Latour, 2005; Stengers, forthcoming), the Anthropocene requires thinking that traverses fact and feeling and extends beyond disciplines to answer the question 'how should we live?' (Castree, 2014). Scientists are active in remaking the world, materially and conceptually, so our institutional, intellectual and cultural settings, which influence our work, can have real implications for the material world and surrounding discourse (Tadaki et al., 2014). Hard engineering and 'techno-fixes' cannot be the primary response to the challenges of the Anthropocene as these are the very kinds of responses that have created many of our present problems (Chakrabarty, 2009). Critical reflection on the place of the geoscientist can contribute meaningfully to reframing public understandings of landscapes and environmental systems in ways that recognise relationships and agencies and, particularly, do not diminish the agencies of the geosphere (Clark, 2011). Respect for environmental agencies and natural systems is at the heart of 'softer' modes of human intervention, which characterise contemporary best practice environmental management (e.g. Biron et al., 2014; Fryirs & Brierley, 2009).

Geosciences and art (particularly visual arts) can work together to both support and critique in constructive ways. Rather than either being consumed or appropriated by the other, perhaps the most interesting science-art projects could be described as 'more than art, more than science' – hybridisation rather than homogenisation (Marston & De Leeuw, 2013). *Relief* demonstrates one model of scientist-as-artist, but collaborations of scientists *with* artists can also form productive relationships capable of opening up new and creative ways of practicing science and art (e.g. Dixon, Hawkins, & Straughan, 2012; Gibbs, 2014; Griffiths et al., 2017; Hawkins, 2011; Marston & De Leeuw, 2013; Tooth et al., 2016). As argued by Dixon et al. (2012, p. 242), 'collaborations can produce novel narratives that no longer "fit" in the established spaces of the journal and the gallery, the field site [or laboratory] and the studio.' Such possibilities for transdisciplinary work hold promise for finding ways to address significant social, political and environmental concerns that also reach across and outside of traditional intellectual and cultural boundaries. By choosing to 'see double', researchers may renegotiate their position in relation to the subjects of their research and the people who also relate to those places in different ways.

5. Conclusion

The *Relief* project highlights two primary opportunities for crossover between art and geosciences. First, that repurposing scientific materials and methods can bring viewers into different ways of seeing and appreciating landscapes and their histories. Second, that art practice can support a process of situating the researcher by providing an opportunity to explore and reflect on personal and professional relationships with society, politics and place. Both of these 'outcomes' are embedded in a practice of witnessing, as clarified in this paper, which positions the witness in relation – and moral engagement – with others. Repositioning humans in relation with society, politics and place is necessary for the task of responding to significant environmental concerns in the Anthropocene, which inherently cross technical, social and cultural terrain.

Software

Maps were created using Adobe Photoshop CS6 and Adobe InDesign CS6.

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Appendix B of this thesis has been removed as it may contain sensitive/confidential content

Appendix C

Interview guide: Landholders

1. Background and relationship to place

    1.1. How did you come to live in the Macdonald Valley?

    1.2. Do you live and work here full-time?

    1.3. What was your earliest/first impression of the valley and the river?

    1.4. When you picture the valley in your head, what do you see/ what do you think of?

    1.5. Is it important to you to be close to the river?

2. Changes in environment and community

    2.1. Have you noticed any changes in the valley in your time here? (Prompt: changes in community, changes in physical landscape, e.g. vegetation or river)

        2.1.1. How do you feel about those changes?

        2.1.2. Do those changes make you feel differently about your environment/community?

    2.2. What do you remember about flooding in the valley?

        2.2.1. Which floods do you remember?

        2.2.2. How have floods impacted your life?

        2.2.3. How do you think flooding impacts on the community? (Prompt: day-to-day and longer-term)

        2.2.4. Do you worry about flooding?

        2.2.5. Has a flood ever made you feel differently about your environment and community?

3. River health and recovery

3.1. Do you think the river is healthier, less healthy or the same as when you first arrived?

3.2. In your opinion, what might a healthier version of this river look like?

3.3. Have you heard people talking about the river 'recovering'?

3.3.1. What does that word mean to you in the context of this river?

3.3.2. Do you think the river is recovering?

3.3.2.1. How do you see/not see recovery occurring?

3.3.3. How do you feel about seeing / not seeing recovery?

3.4. Have you participated in river rehabilitation activities?

4. Future directions and aspirations

4.1. How do you think the river might look in 5, 10, 20 or 100 years?

4.1.1. How do you feel about your prediction – does that sit well with you?

4.2. Do you think there are any challenges in the way of the river becoming healthier?

5. Closing

5.1. Is there anything we haven't covered that you think might be interesting for this research?

5.2. Do you have any questions about this research or how your responses will be handled?

5.3. How would you like to be kept informed about how this research progresses?

Interview guide: River management practitioners

1. Opening

    1.1. How long have you worked in the river management industry?

    1.2. How long have you worked with your current institution?

    1.3. How would you describe your role in your institution?

2. Institution

    2.1. How would you describe your institution's role in river management? [Prompt: responsibilities, key activities? Note: How does participant describe role – e.g. in policy, action or relationally?]

    2.2. Which other groups/institutions do you and your organisation have contact with in river management?

        2.2.1. In what capacity, when and how?

    2.3. How would you describe your institution's approach to river management?

        2.3.1. What kind of thinking/principles underpin your practice?

        2.3.2. What are the priorities and common key goals/KPIs?

        2.3.3. Where does your practice get direction from? [Prompt: e.g. policy, higher management?]

        2.3.4. Who decides where and what management approaches and activities take place, and how do they make that decision?

3. River recovery

    3.1. Are you familiar with the terms, 'river recovery' or 'recovery enhancement'?

        3.1.1. What do you understand those terms to mean?

        3.1.2. How did you become acquainted with these concepts?

        3.1.3. (How) do you apply these concepts in river management?

4. Relationships

4.1. Are relationships (people-people; people-place) important for you in your management practice?

4.1.1. What kinds of relationships, and how are relationships important?

4.2. What do you do to build and maintain relationships?

4.3. Are you encouraged or supported (by employer/organisation) to focus on relationships in your work?

5. Closing

5.1. Do you have any questions about this research or how your responses will be used?

5.2. How would you like to be kept informed about the progress of this research? [E.g. by email/post/phone]