Group model building to understand ‘wicked’ problems in New Zealand freshwater management.

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Abstract

Freshwater resources are coming under increasing pressure across New Zealand. High levels of water use and contaminant loss from both point and non-point sources are contributing to growing concern around both the quality of freshwater and its availability. National government regulation has provided greater guidance on the freshwater standards required in water ways, while increasingly collaborative processes are being applied to develop directions for both national and regional policy. A shift towards the inclusion of stakeholders in policy development follows global trends; however, its application in reality is difficult, due to scarce resources (especially data and time) and the high biophysical and social complexity of the issues being addressed.

This research investigates whether the use of causal-loop diagrams (CLDs), applied in a group model building (GMB) process, increases the shared understanding of a freshwater issue by a group. CLDs are a qualitative system dynamics (SD) modelling tool, which seeks to identify the interdependency between elements of a system and the direction of these relationships. They are straightforward to generate and can provide insight into the underlying causes of suboptimal behaviour in complex, dynamic environments.

The GMB process applied in this research involves the extension of an existing script-driven process, after extensive piloting. It is applied with only two supporting personnel within a limited timeframe, to explore how useful this process is within an environment involving scarce resources. The developed process is applied to two case studies, both involving freshwater management by New Zealand communities. The effectiveness of the GMB process was explored using a mixed methods approach. A post-workshop survey gathered self-reported quantitative and qualitative findings, while a qualitative analysis of data from semi-structured follow-up interviews was undertaken using thematic analysis.

The self-reported data indicated not only very high levels of individual satisfaction with the process, but also that the process had helped the group’s shared understanding of the issues and that the output (the CLD) would be useful to the group in the future. The thematic analysis identified four broad themes: that there was a desire for a different approach to decision-making; that the GMB process was a refreshing change; that the GMB process built both a group AND a group model; and that, while it was useful, it also did not provide enough detail for decision-making on its own.

The desire for a different approach was underpinned by the complexity of the decision-making process; as well as frustration from some of those involved that they either did not feel that their views were being (or had been) appreciated or from a direct sense of frustration from dealing with council (currently or in the past). It was felt that the GMB approach was a refreshing change as it was a simple and focused process, involving a small group of relevant stakeholders. More importantly, the fact that the group members were actively involved in the process, it was participant led and independently facilitated were all very positive aspects identified.

However, the process for GMB that was applied was found not to be a panacea for solving problems, with more detailed, numerical modelling required to provide insight into the relative importance of key factors.

Key words: group model building; causal-loop diagrams; system dynamics; freshwater; collaboration; stakeholders; decision-making.

Preface and acknowledgements

Returning to university full time as a ‘mature’ student to complete a thesis has been one of the best decisions I have made in recent years. It has been rewarding to grow knowledge in new and exciting areas. Yet such a journey has only been possible with the support of many wonderful people in my life. Huge thanks are extended to all my friends and professional colleagues who, sometimes knowingly and sometimes not, have helped maintain my sanity throughout. To name people individually would be to risk excluding someone, but know that you all played a part.

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My deepest thanks however, go to my family. They more than anyone have helped me stay focused, committed, and true-to-task. Only family can truly call a spade a spade, and I am grateful for it.

In life, I have tried to live by a saying whose origins have been lost in time, but which has often been attributed to Confucius around 450BC:

> *"Tell me, and I will forget. Show me, and I may remember.*
> *Involve me, and I will understand."*

Given that this research is about applying a group model building process, I think that this is useful for setting the tone of my personal interest in such an area. I hope that this work provides a useful contribution to this field and the many challenges ahead that face freshwater resources in New Zealand.

Justin Connolly

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List of abbreviations

BOPRC	Bay of Plenty Regional Council
CLD	Causal loop diagram
GMB	Group Model Building
LGA	Local Government Act, 2002
MfE	Ministry for the Environment
NOF	National Objectives Framework (part of the National Policy Statement for Freshwater Management, 2014)
NPS-FM	National Policy Statement for Freshwater Management. Issues in 2011 (*NPS-FM 2011*) and updated in 2014 (*NPS-FM 2014*)
OECD	Organisation for Economic Co-operation and Development
PCFE	Parliamentary Commissioner for the Environment
RMA	Resource Management Act, 1991
SD	System dynamics
WCRC	West Coast Regional Council
WMA	Water management area (BOP specific)
E. coli	*Escherichia coli*

1 Introduction

1.1 Background

Freshwater resources are of huge cultural, social and economic significance to New Zealand, as a people and a nation. Culturally, they are central to the identity of Maori and are the physical embodiment of their *tipuna* or ancestors. Socially, fresh water is at the core of the identity of many New Zealanders – from defining childhood memories for those who grew up here and possibly part of the attraction for those migrants who have moved here. Economically, they sustain our ability to deliver municipal water, operate industry and underscore our proud claim to generate most of our electricity needs from renewable resources.

Yet the management of fresh water is becoming a more contentious issue. Increasing population and economic growth has meant that New Zealand is starting to show its environmental limits (Organisation for Economic Co-operation and Development, 2017). Between 1996-2012, 441,600 hectares of land in New Zealand was converted to dairying (Parliamentary Commisioner for the Environment (PCFE), 2013; Parliamentary Commissioner for the Environment (PCFE), 2015) and an analysis of 10-year trends from 2004-2013 across New Zealand rivers and lakes found that while some indicators showed an improvement, there was a general decline in ecological health and increasing levels of nitrate in freshwater bodies (Gluckman, Cooper, Howard-Williams, Larned, Quinn, Bardsley, Hughey & Wratt, 2017). High levels of water use by rural and urban firms, alongside contaminant loss from both point and non-point sources, underlie continuing concern around both water availability and quality (Ministry for the Environment & Stats NZ, 2017). This ongoing pressure means that New Zealand is increasingly faced with trying to form a trade-off between economic and environmental outcomes, a core tension within the study of environmental economics (Tietenberg & Lewis, 2015).

Political awareness of these issues has grown resulting in some regulatory action having been taken with the implementation of a National Policy Statement for Freshwater Management (*NPS-FM 2011*) in 2011 (Ministry for the Environment, 2011). This outlined objectives and policies to guide local government's management of fresh water within desired limits in relation to water quantity and quality (Ministry for the Environment, 2011). This was updated in 2014 (*NPS-FM 2014*) to include a National Objectives Framework (NOF) that provided more prescriptive guidance for measuring water quality and provided 'minimum bottom lines' for several key measures of water quality for lakes and rivers (Ministry for the Environment, 2012a, 2014). Further amendments have since been proposed that seek to simplify how the swimmability of large lakes and rivers is measured and proposes a target that 90% of large rivers and lakes meet those standards by 2040 (Ministry for the Environment, 2017).

The *NPS-FM 2014* encourages integrated, collaborative approaches to developing policy (Ministry for the Environment, 2014). This follows the success of a multi-stakeholder group known as the *Land and Water Forum* that was commissioned by the government in 2009 to bring together a range of stakeholders with freshwater interests (both aligned and adversarial), and develop recommendations for national freshwater policy guidance (Land and Water Forum, 2010).

This focus on collaboration builds on a strong characteristic of various existing pieces of legislation that guide central and local government decision-making in New Zealand. This is the requirement for participation from both iwi (as partners in the Treaty of Waitangi) and members of the public (as interested and potentially impacted citizens) (Local Government Act, 2002; Resource Management Act, 1991). The *Local Government Act 2002 (LGA 2002)* sets out the powers and responsibilities of local government and a minimum expectation of public input into decision-making is outlined, subject to the scale of that decision in the eyes of the local body (Local Government Act, 2002). The *Resource Management Act 1991 (RMA 1991)* guides the management and use of natural and physical resources, it also outlines a minimum procedure to follow for public input to decision-making on issues that meet a certain *level of significance* – usually relating to developing or changing council plans and resource consents deemed to be of a certain significance (Resource Management Act, 1991).

When these pieces of legislation are combined with the highly technical multi-disciplinary knowledge associated with freshwater management, decision-making can become a complicated and time-consuming task. For example, freshwater issues usually face issues of biophysical complexity, economic complexity and are characterised by being of high interest to a wide range of stakeholders. They are multi-faceted and challenging problems to which there is no single or simple solution, which are some of the criteria outlined for 'wicked' problems (Rittel & Webber, 1973). While Rittel and Webber (1973) outline many criteria for 'wicked' problems, several are worth mentioning in more detail here.

Two of the criteria are that every wicked problem is effectively unique; and that there are no set number of describable 'solutions' (Rittel & Webber, 1973). Freshwater policy issues often meet these criteria due to the dynamic complexity of individual hydrological systems and the innumerate combinations of varying land uses and farm management practices that may be applied to achieve desired water quality or quantity targets. For example, delays between cause and effect are extensive in hydrological systems and it can take many years for nitrogen to move from the soil surface to a waterway because of groundwater lags (Anastasiadis, Kerr, Nauleau, Cox, & Rutherford, 2013).

Another criterion is that every wicked problem "can be considered to be a symptom of another problem" (Rittel & Webber, 1973, p. 165). Freshwater issues in New Zealand are, in part, a legacy of historic land use manifesting in the water issues of today (Organisation for Economic Co-operation and Development (OECD), 2017; Parliamentary Commissioner for the Environment (PCFE), 2013; Parliamentary Commissioner for the Environment (PCFE), 2015). Peter Senge put it another way when he said that, "today's problems come from yesterday's 'solutions'" (Senge, 1990, p. 57).

Another criterion for wicked problems is that they are "a "one-shot operation"; because there is no opportunity to learn by trial-and-error, every attempt counts significantly" (Rittel & Webber, 1973, p. 163). There is no opportunity to 'trial' a solution before it is implemented. As freshwater policy requires a significant investment of time and resources to develop, it is not possible to develop these by ‘trial and error’; thus, while there have been policy innovations across New Zealand, they reflect the corresponding diversity of biophysical challenges coupled with economic challenges and the political appetite for change or risk in each catchment. Examples of such innovation include: a cap-and-trade scheme for nitrogen in Lake Taupō (Young & Kaine, 2010); the use of collaborative groups of stakeholders to develop freshwater quality and quantity limits in Waikato (Waikato Regional Council, 2016a) and Canterbury (Salmon, 2012) and the use of mediated modelling using system dynamics in the Manawatu (van den Belt, Shiele & Forgie, 2013).

System dynamics (SD) is a discipline that treats problems as resulting from the *endogenous* dynamic feedback within the system of which they are a part – a system being a series of inter-related parts and the bounds of which are considered as wide as necessary for the problem being dealt with (Forrester, 1968; Sterman, 2000). Looking at the major influences of an issue holistically, within a system, help to make understanding and dealing with that issue easier.

The SD approach suits the analysis of wicked problems as an increased understanding of a system is one of its primary goals (Sterman, 2000). This is especially true where *dynamic complexity* is involved, which is often understood to include cases where inertia, feedback, time delays, non-linearity of relationships and even lack of data are a feature (Sterman, 2001). Such features are synonymous with freshwater issues and reflect the features of wicked problems (Gluckman et al., 2017; Rittel & Webber, 1973). Given the stakeholder complexity of freshwater management issues, generating a common understanding of the causes of a problem among stakeholders is highly desirable. Group model building (GMB) is one strategy used to involve clients, or those impacted by the decisions being made, *in* the SD model building process (Vennix, 1999). GMB presupposes that people think in terms of causal processes and that they are willing to question their opinions as a group, which enables them to collaborate and develop an understanding of a problem or system that is *greater* than the sum of their *individual* understanding (Vennix, 1996).

This research explores the use of GMB for increasing understanding of the linkages present between economic and environmental elements of freshwater systems. The focus of the study is on the pragmatic application of this tool during the early stages of regional policy development, where resources available for such assessment are typically highly constrained. The value proposition offered by applying SD in this context is that decision-makers, or those tasked with developing recommendations such as in a stakeholder group, can contribute more to the policy development process when they possess a better understanding of the issue that they seek to address. This is particularly pertinent from the perspective of the *NPS-FM 2014*, given how this regulation encourages the involvement of diverse stakeholders in collaborative decision-making processes.

Case study applications within this study provide insights through *action research,* which is the practical involvement of those being researched in the diagnosis of the problem and generating solutions (Bryman & Bell, 2015). This approach is taken to examine the value of GMB in the context of freshwater management in New Zealand. Action research is particularly justified here given the increasing number of applications of policy required in freshwater and the practical orientation of the research.

1.2 Objectives

Two main objectives guide this research:

1. How well does group model building using system dynamics increase a group's shared understanding of a freshwater issue?
2. How might group model building using system dynamics be successfully applied to freshwater management issues when resources available to implement the process are limited?

This research will be of interest to those involved with the development of freshwater policy, both in New Zealand and internationally. Through increasing people's understanding of the complex systems in which they are involved, it aims to improve the robustness of policy and contribute to improving the economic and environmental implications of freshwater decision making.

1.3 Thesis structure

In response to these objectives, this research is structured into the following subsequent sections:

2. A literature review outlines the gap in the literature that this research seeks to contribute to.
3. An overview of the methodology is provided, including an outline of the paradigmatic perspective of this research; the GMB methodology selected; how both quantitative and qualitative data was gathered; and the methods used to analyse these (primarily thematic analysis).
4. A description of how the methodology was piloted, found to be lacking for the context of this research and subsequently amended.
5. The results of the amended GMB process across two case study projects are described.
6. The results of the amended GMB process across two case study projects are discussed.
7. The quantitative results from post-workshop surveys and follow-up interviews are described and discussed.
8. How the thematic analysis was undertaken is described.
   Then the four main themes are discussed, beginning with:
9. Theme 1 – A desire for something different.
10. Theme 2 – A refreshing new process.
11. Theme 3 – Building a group AND a group model.
12. Theme 4 – Useful yet more detail required.
13. The final section provides a conclusion, discusses limitations of this study, provides recommendations and suggests areas for future research.

2 Literature review

There are three broad areas of research that inform this literature review:

- The decision environment from an international and New Zealand perspective;
- System dynamics modelling internationally, including some consideration of how this operates in complex decision environments; and
- The use of system dynamics modelling in freshwater policy development or in New Zealand.

As this research is specifically interested in the New Zealand context, these factors will be interpreted from a New Zealand perspective.

2.1 The evolving nature of freshwater policy development in New Zealand

Freshwater plays a crucial role in the fabric of New Zealand's identity, society, culture and economy. It is part of the identity of iwi, literally being the embodiment of their *tipuna* (ancestors) and is considered a *taonga* (treasure) by them. It is central to the predominantly rural and outdoors perception that New Zealanders have of themselves as a nation; and it is central to most major economic activities such as the production of primary products and tourism (Land and Water Forum, 2010). Primary production from agriculture accounts for more than half of New Zealand's export earnings in 2015 at $22.9 billion, with dairying accounting for 45% of that at $10.3 billion (New Zealand Treasury, 2016). Tourism accounted for $11.6 billion of earnings in the same period (New Zealand Treasury, 2016). Not only is water used for irrigation in the primary industries, but also for the watering of stock, processing and industrial use. It is also central to valuable recreational and economic fisheries, as well as being used to generate over 50% of New Zealand's electricity supply (Gluckman et al., 2017).

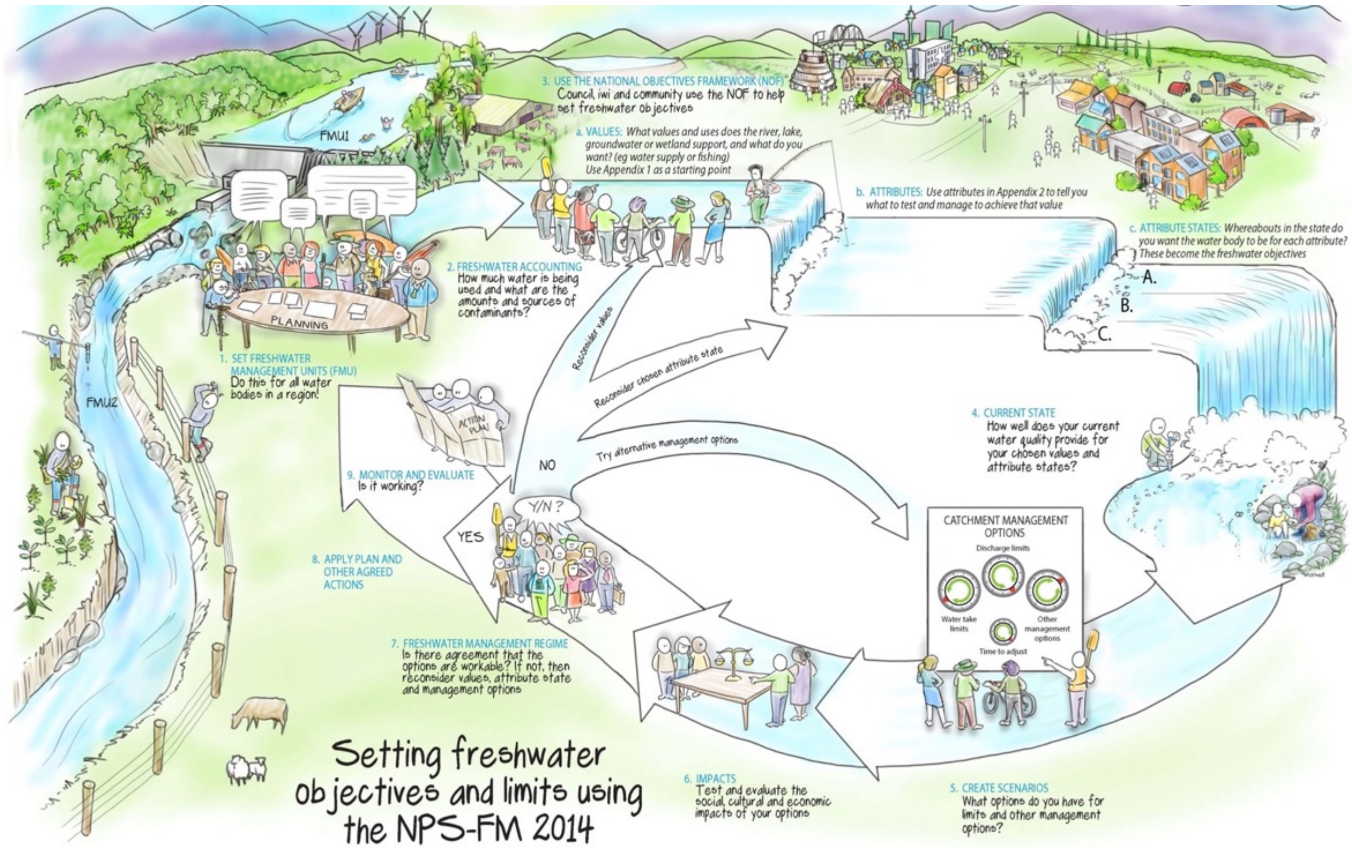
Within this context, freshwater is also under stress. Many catchments fail to meet targets that indicate appropriate levels of water quality, more than half of the monitored lakes in the country are eutrophic and, at a national level, diffuse discharges now exceed point source discharges (Land and Water

Forum, 2010). In response, freshwater policy development in New Zealand is undergoing some significant change. A range of initiatives are under way across the country to ensure that freshwater policy is developed promptly and consistently (Ministry for the Environment, 2014). Since 2009 the New Zealand government has been pursuing progressive reforms relating to how water is managed including the use of deliberative processes that involve stakeholders in the consideration of problems and the development of solutions (Ministry for the Environment, 2016). The *NPS-FM 2014* (adopted in 2011 and updated in 2014) outlines how freshwater:

- Underpins the four well beings view of society (social, cultural, environmental and economic);
- Is linked to cultural identity and is a fundamental component of the Treaty of Waitangi and the Crown-Iwi relationship;
- Is a central component of the natural environment, being linked to biodiversity and natural heritage; and
- Assists in providing the primary production, tourism and energy generation sectors a global competitive edge (Ministry for the Environment, 2014).

The *NPS-FM 2014* provides clear national direction from Central Government in relation to freshwater management, yet allows appropriate responses to be developed at a regional or catchment level. Within the *NPS-FM 2014*, a National Objectives Framework (NOF) (Ministry for the Environment, 2014) provides a framework for councils and communities to determine the *values and attributes* of freshwater and the relevant *objectives and limits* of their use. *Values* are the benefits that freshwater provides or that communities want it to provide, and *attributes* are the measurable characteristics that will be used as an indicator of this value. *Objectives* articulate the desired state of freshwater attributes in the future in relation to its existing state, while *limits* refer to the quantifiable measures of the attributes that need to be met to achieve the objectives. Two compulsory attributes are set out in the *NPS-FM 2014*, while additional ones can be either selected from a suggested list and/or developed with the local community (Ministry for the Environment, 2014). The development of such measures is conceptualised in the *NPS-FM 2014* as an iterative process, which is demonstrated in Figure 2.1.

Figure 2.1 Diagram from the *NPS-FM 2014* guidance document that shows the process for determining values, attributes, objectives, and limits under the *NPS-FM 2014*. Note the iterative nature of the process in seeking to determine these criteria.



From Ministry for the Environment (2015)

The *NPS-FM 2014* has prompted a large volume of policy development work by Regional Councils throughout NZ. Given the disputes, challenges and adversarial nature of historic approaches to developing water management policy (Land and Water Forum, 2010; Salmon, Zilliacus, Scherzer, & Bärlund, 2008), some of this work has already taken a more inclusive and deliberative approach with stakeholders than that prescribed by the *RMA 1991*, incorporating a level of stakeholder collaboration that is encouraged (but not required) in the implementation of the *NPS-FM 2014* (Ministry for the Environment, 2015). Examples include: the Canterbury Water Management Strategy, where the region is divided into discrete water management zones along catchment lines and major policy decisions are devolved to stakeholder representative zone committees (Salmon, 2012); and the Healthy Rivers Regional Plan Change in the Waikato region, where a representative Collaborative Stakeholder Group was devolved the responsibility for developing a draft plan (Waikato Regional Council, 2016b).

Any modelling or analyses used to support decision-making need to be relevant and easily understood, regardless of who is involved. Whilst a wide range of biophysical and/or economic analyses may be applied during policy development, this research is interested in the ability of SD modelling to increase awareness of the interconnectedness of freshwater systems, so that the effects of proposed policy on those systems can be considered. SD is expected to be a useful tool in normative decision-making as it will help make the impact of policy choices understood by, and responsive to, the requirements of those involved in decision-making (Senge, 1990; van den Belt, 2004). While this includes traditional groups involved with decision-making (elected representatives and staff), the trends discussed earlier also mean it can include a wide range of stakeholders.

Given the wide range of people involved, it should be expected that there is great diversity in the values surrounding freshwater and the understanding that different stakeholders possess with regards to how these systems function. Identifying if SD modelling helps to increase the collective understanding of freshwater systems within a decision-making group could improve the speed, quality and durability of decisions made in freshwater policy development in the future.

2.2 The decision environment

In this research, the *decision environment* is defined as the interpersonal and political dynamics, the technical context and the organisational (or political) structure of the decision-making environment. While this will differ on a case-by-case basis, it is generally influenced by the politics and personalities involved in the decision-making group and the structure of the decision-making organisation or process, as well the relevant mandate that has been given to the decision-making group. This is not a study of the *organisational structure* of the sponsoring organisation or any other organisation involved – that is considered organisational theory and is beyond the scope of this research. Rather, the focus is on the dynamics of the decision environment and the diverse people involved.

Decision environments internationally are becoming more complex with an increasing number and diversity of people involved; typically, this is in response to the increasing complexity of the nature of the problems being dealt with (Twyford, Waters, Hardy, & Dengate, 2012). The complexity of these contexts has led them to be termed 'wicked problems' (Rittel & Webber, 1973), 'messy' problems (Vennix, 1996) or simply 'messes' (Ackoff, 1979). Within the context of wicked problems, the dilemma being faced by policy makers may not able to be clearly defined, and there is usually no single clearly definable solution. The relationship between challenges and solutions are non-linear and many forms of normative policy response might be applied producing any number of differing results, each of varying levels of appropriateness (Rittel & Webber, 1973; Twyford et al., 2012). In short, there is usually no clear 'right or wrong' answer to modern policy challenges (Rittel & Webber, 1973). Indeed, given the diversity of values that exist within wicked problems, it is even difficult to identify 'good' or 'bad' solutions because the outcomes of a policy will vary across the different stakeholder groups involved. Many environmental problems qualify as wicked problems given their complexity, the issue of greenhouse gas emissions being an obvious example. New Zealand's freshwater problems have also been described as 'wicked' because they often involve, "complex science intertwined with a range of stakeholder values and interests that can never be fully aligned" (Gluckman et al., 2017, p. xviii). It is not a new phenomenon that social research utilised in policy development has been found to be influenced by environmental characteristics that were political, bureaucratic and personal (see, for example, Weiss, 1979).

Recent decades have seen an increase in the use of diverse approaches to decision-making, where there has been considerable evolution of the nature of structured stakeholder participation (Reed, 2008). Public participation is much more formalised in legislation within New Zealand – for example, at a minimum, the *RMA 1991* provides a process for the public to provide comments on proposed options relating to any issue that is deemed significant enough – resulting in public involvement becoming an increasing feature of local government decision-making (Reed, 2008; Twyford, Waters, Hardy, & Dengate, 2006) since the 1990's (Winz, Brierley, & Trowsdale, 2009).

Innovative practices that involve stakeholders in achieving appropriate policy outcomes are likely to continue to be developed and applied. While methods to increase stakeholder participation in decision-making are known by many different labels (Reed, 2008), it is worth noting that stakeholder influence tends to increase the higher the level of involvement they are permitted. Levels of stakeholder involvement may vary, from simply being receivers of information, through to being reviewers and active participants within set boundaries, to being highly collaborative with a high level of influence, to even being given effective control (Reed, 2008). Other approaches to including stakeholders in decision-making have also been developed, including market-based methods of incentivising stakeholders to achieve outcomes (Mäntymaa, Juutinen, Mönkkönen, & Svento, 2009) and the involvement of stakeholders in formalised collaborative governance structures, which is a growing global trend (Ansell & Gash, 2007; Salmon et al., 2008). The *Land and Water Forum* is evidence of such an approach in New Zealand which, as outlined earlier, brought a range of organisations with freshwater interests together to develop recommendations for improvements to national freshwater policy (Land and Water Forum, 2010).

Collaborative governance is becoming more common and this is where public decision-makers formally work with non-state stakeholders through a deliberative and consensus-driven process that aims to recommend or implement public policy (Ansell & Gash, 2007). Collaboration is a way of seeking out win/win solutions, rather than relying on ‘good enough’ or win/lose solutions that suit some people but not others (Doyle & Strauss, 1976), which has been a frustrating feature of freshwater policy development historically (Salmon et al., 2008). It has long been known that groups that actively work together on problem solving generate better solutions, rather than defaulting to a “majority rules” scenario (Hall, 1971), so this approach tends to minimise the risk of disagreement and increase the opportunity to implement policies that reach broader stakeholder acceptance (Ansell & Gash, 2007; Ministry for the Environment, 2012b; Twyford et al., 2012). However, problem solving is often an iterative, circular, process rather than a linear one, sometimes requiring the need to return to an earlier step to re-clarify something before moving forward again (Schein, 1988). This circular feature can be seen in the guidance diagram for the *NPS-FM 2014* shown in Figure 2.1. Therefore, any collaborative process needs to be adaptable in response to information that unfolds across time (Ministry for the Environment, 2012b) and usually involves a much higher investment of time and money, which some may view as a limitation (Ansell & Gash, 2007). Moreover, it may be a risk to successful completion of the process, if this expectation is not set at the beginning (Cradock-Henry, Greenhalgh, Brown & Sinner, 2017).

Research into collaborative governance in New Zealand has found a range of factors are required for success. These factors include: a legitimate process; establishing a desire and commitment to change; strong (preferably independent) leadership; face-to-face dialogue; a culture of learning; identifying ‘common ground’ and modelling good behaviour (Ministry for the Environment, 2012b). The people involved in a collaborative governance process are also an important variable, as is having sufficient and adequate time to make decisions (Cradock-Henry et al., 2017). While collaborative governance is not the sole interest of the decision environment perspective in this research, it is likely to continue to be widely used in freshwater policy development in New Zealand (Land and Water Forum, 2010; Ministry for the Environment, 2012b) and is an avenue that is enabled by the *NPS-FM 2014* (Ministry for the Environment, 2015).

2.3 System dynamics in general

SD is a discipline where the world is viewed as a complex system where simple linear cause and effect is not able to account for all cause and effect, as everything is connected (Sterman, 1994). SD grew out of the discipline of operations research (OR), which was using highly-abstract problem formulations to solve problems faced by the military in World War II (Forrester, 2007). Indeed, continuing dissatisfaction with the inability of mathematical-programming formulations to describe the nature of wicked problems – including a strong focus on omitting key elements of problems such that they were amenable to analysis using standard means – was a key benefit of this alternative theory. Whereas OR was mostly concerned with *analysis* of individual constituent parts, SD offered a fresh perspective by using *synthetic thinking* to better *understand* a larger system of complex causes and feedback, including qualitative factors (Ackoff, 2001).

Systems can be either closed or open (Ackoff, 1994). The behaviour of closed systems is not impacted by any external influences and only influenced by *endogenous (*internal) forces, open systems by contrast are subject to *exogenous* (external) forces. Problems affecting society in the real world are dealt with by society at large and tend to be highly complex, influenced by a multitude of factors. Many problems should therefore be considered social problems and these may occur at the level of an entire society, an organisation or an institution (Ackoff, 1994). Many such social systems are open systems and have been found to operate counterintuitively, displaying three general characteristics (Forrester, 1968):

- They draw our attention to areas where an intervention is likely to fail;
- The most influence comes from intervention in places people do not expect; and
- Policies that produce positive results in the short term normally degrade the system in the long term.

Normative policy development occurs in this social environment and we often find that the stocks of knowledge and expertise by which we define and organise ourselves only provide a narrow analytical perspective on the challenge we are trying to address (Ackoff, 1999). Further, due to the complexities of the systems being dealt with and the lack of clear understanding of the relationships between elements and their corresponding feedback links, policy development can lead to generally undesired or unexpected outcomes – this is known as *policy resistance* in the SD literature and can often undermine a policy (Ghaffarzadegan, Lyneis, & Richardson, 2011; Sterman, 2001).

The lenses through which we see and interpret the world are known as our mental models and understanding these – and how they contribute to our understanding of such complex systems to a point where we can make appropriate policy decisions relating to them – is a complex learning process itself (Sterman, 1994). This process of learning can be ably assisted by using skills, methods and tools that variously characterise SD modelling (Ghaffarzadegan et al., 2011; Sterman, 1994, 2001; Vennix, 1999; Vennix, Andersen, Richardson, & Rohrbaugh, 1992).

If we view an integrated environmental and economic system as a complex open system (Tietenberg & Lewis, 2015), then the use of SD as outlined above could suit the development of greater understanding of such systems among stakeholders involved in their operation and management. Some of the features that characterise a complex system are the very features of small-scale SD modelling that can prove helpful in building an understanding of the overall system (Sterman, 2001). These are: feedback, time delays, stocks and flows and non-linearity. Feedback is the impact that an element(s) of a system may have on other element(s), while time delays relate to the timescale that is taken for this feedback to be realised. Stocks and flows relate to the reserves and *accumulation* of various elements within a system (physical or virtual) and the *direction* that they flow, while non-linearity reflects the complexity of the inter-relatedness of all these various elements to one another, often in a dynamic way (Sterman, 2001).

SD modelling can be either qualitative or quantitative. Qualitative models usually utilise causal loop diagrams (CLDs) and quantitative modelling seeks to deliver formalised simulation modelling of the stocks and flows identified within a system (Scott, Cavana & Cameron, 2016b; Sterman, 1994, 2000). CLDs are simple maps showing broad relationships of cause and effect and are made up of variables (the nodes of a CLD) and arrows that link them and indicate the causal influences between the various variables (Maani & Cavana, 2007; Sterman, 2000). In his influential work *The fifth discipline – the art of the learning organisation*, Peter Senge (1990) demonstrates how simple CLDs are useful in helping organisations understand complex issues without necessarily needing detailed supporting data.

Yet while CLDs can provide increased knowledge and understanding of a system (Scott et al., 2016b), use of more formalised stock and flow models of a system are often viewed as an important next step. Indeed, some view the act of simulation modelling as a necessity for SD work to be of any use (Forrester, 2007; Sterman, 2000; van den Belt, 2004). Stock and flow models are made up of three main components: stocks, which represent an *accumulation* of something (e.g. the number of people living in a city); flows, which represent the *movement* of something either from, to or between stocks (e.g. the number of people moving *into or out of* a city); and connectors, which represent the feedback between different variables even if they are not a directly-linked stock or flow (Sterman, 2000; Vennix, 1996). While stock and flow modelling can occur on a continuum from simple to complex, it has also been argued that even simple modelling can improve insight (Ghaffarzadegan et al., 2011; Sterman, 2001; Vennix, 1996, 1999; Winz et al., 2009).

The benefit of this synthetic SD approach (either qualitative or quantitative) over statistical modelling, is that it can be based on *ex ante* projections rather than *ex post* observations, it does not require rich input data, it can utilise qualitative information around interdependencies and it focuses on developing an *understanding* of the system, rather than an *analysis* of it (Winz et al., 2009). Increasing the *understanding* of a system has always been at the heart of SD, with the goal of synthesis being the identification of interventions that fundamentally change the operation of the system in such a way that enduring outcomes are achieved (Forrester, 2007). Since it seeks to *understand* a system, its use early on in a decision-making process is highly intuitive.

Within the field of SD, the involvement of stakeholders in the model building process has also increased (Ghaffarzadegan et al., 2011; Luna-Reyes, Martinez-Moyano, Pardo, Cresswell, Andersen & Richardson, 2006; Richardson & Andersen, 1995; van den Belt, 2004; Vennix, 1996, 1999). This can help in particularly complex situations where there may not be agreement that there is a problem, let alone what the problem is (Vennix, 1996, 1999) or when a high level of consensus is required to support a decision (van den Belt, 2004).

GMB is part of the SD discipline (Vennix, 1996, 1999) and has received substantial attention from previous researchers (Luna-Reyes et al., 2006; Richardson & Andersen, 1995; van den Belt, 2004; Vennix, 1996, 1999; Vennix et al., 1992). By directly involving clients or stakeholders in the model building process, GMB hopes to "enhance team learning, foster consensus and create commitment with the outcomes" (Vennix, 1996, p. 101). Communication is key to learning and while many organisations believe that they enjoy 'good' communication, this has been shown to only be shallow 'single-loop' communication that *inhibits* learning (Argyris, 1994). 'Single-loop' communication is simply the exchange of information, while true learning comes from deeper, reflective, 'double-loop' communication, which allows those involved to seek to understand and not just exchange information (Argyris, 1994). This resonates with the feature of successful groups discussed earlier – groups that *actively work together* generate better outcomes (Hall, 1971).

Achieving this type of communication and learning is an objective of GMB processes (van den Belt, 2004; Vennix, 1996). Reviews of GMB processes have found that they do greatly increase the level of *communication* that occurs within groups and an increase in the *understanding of systems* discussed; yet, there is currently little evidence to indicate that they produce better *policies* (Rouwette, Vennix & van Mullekom, 2002; Scott et al., 2016b). One of the possible reasons cited for this lack of evidence is the lack of objective measures of GMB processes that are not self-reported outcomes by participants (Scott et al., 2016b). This research hopes to apply methodology that is more objective than self-reporting from participants. In doing so, it aims to test how GMB can be applied in resource-constrained environments to improve the contribution of double-loop learning to policy development.

One thread of GMB has involved the development of set 'scripts' for running GMB processes – a 'script' being a *prescribed step* in a process for determining an outcome, using *many steps together* builds a comprehensive modelling process (Andersen & Richardson, 1997; Hovmand, Andersen, Rouwette, Richardson, Rux & Calhoun, 2012; Hovmand, Rouwette, Andersen, Richardson, & Kraus, 2013; Luna-Reyes et al., 2006). Set roles for those involved in running the process have also been outlined, to help make processes more consistent across the discipline (Richardson & Andersen, 1995). The advantages of 'scripts' are that they aid consistency in GMB processes, hopefully promoting the ability of users to replicate results and develop consistent skills (Andersen & Richardson, 1997). Nonetheless, they are unlikely to help practitioners understand or develop the skills of improvised interruption or facilitation that can be so useful to helping groups work through a problem (Andersen & Richardson, 1997), meaning this may remain a skill of personality that is more of an art than a science (Vennix, 1996).

2.4 Application of system dynamics in New Zealand

SD modelling has been used to test government policy across different departments at a national level in New Zealand, having been used to explore policies that required the collaboration of multiple government agencies with possibly conflicting goals (Cavana & Clifford, 2006). At a national government level, work has also been undertaken to explore the usefulness of perceived benefits of GMB processes across public sector clients in New Zealand, finding that increased efficiency, communication, consensus and more aligned mental models were key outcomes (Scott, Cavana, & Cameron, 2016a). Useful public policy examples from a New

Zealand context are also provided in the text by Maani and Cavana (2007), which is targeted at New Zealand SD practitioners. While there are useful examples in this text, there is little that directly relates to freshwater; the majority focused on supply-chain systems, health services, public health and inshore fishing examples.

It has been argued that SD modelling may be useful in supporting local government decision-making, to ensure improved community outcomes and long-term planning (Forgie & Richardson, 2007). However, it has received limited application in freshwater management. SD modelling was used as part of a mediated modelling process for the Horizons Manawatū-Wanganui Regional Council. Here it was used with stakeholders over a six-month period, to build an understanding of the issues and challenges within the Manawatū River catchment from an ecosystem services perspective. The objective was to develop an action plan what would improve water quality in the catchment by 2030 (van den Belt et al., 2013). This research found that SD modelling was useful, particularly at the scoping and problem definition stage, as it increased understanding of the complexity of the issues involved. It was however, not sufficient as a detailed analytical tool and participants defaulted back to a negotiation-based style of policy development part-way through the process, in part due to the dynamics of the group and in part due to difficulty for participants to understand the new (to them) concept of ecosystem services (van den Belt et al., 2013). The usefulness of SD in the earlier stages of problem definition and system synthesisation is consistent with the findings of the literature review mentioned earlier, that summarised the development of SD approaches in water resources management (Winz et al., 2009).

The qualitative tools of CLDs were used in urban stormwater issues in West Auckland to help understand the mental models of stakeholders in relation to stormwater management issues and solutions. Their use helped identify three broad perspectives: the 'traditional' linear approach that resulted in more 'hard' stormwater infrastructure but also more environmental damage in the longer-term; a low-impact design perspective that ameliorated but did not eliminate stormwater issues; and a community development perspective, that demonstrated an understanding of longer-term feedback loops relating to stormwater issues and that deal with the 'source' of the issue – more fundamental change in urban form – but which took much longer to implement (Winz, Brierley, & Trowsdale, 2011). In contrast to CLDs, simulation modelling using SD principles develops rich numerical models (often based on stock-and-flow formalisms) that provide detailed insight into issues through helping to assess the relative size of different effects present within the system.

While not research on the application of SD in New Zealand freshwater policy, Ronlyn Duncan has reviewed the Canterbury Water Management Strategy with possible implications for the use of SD (Duncan, 2013). She found that while the incorporation of local knowledge was admirable and desirable, the process of incorporating it is dominated by the linear paradigm of the scientific community and the nature of political decision-making. She argues from a constructivist perspective that the stakeholder information lost much of its contextual richness and usefulness as it was adapted into the formats appropriate for policy making and local government decision-making processes (Duncan, 2013). This identifies a challenge with the incorporation of economic thinking into the rigid structures of the decision environment of freshwater policy that SD (Sterman, 2000) using GMB (Vennix, 1996) may help to bridge.

Research in the USA has found that simple models can provide highly accurate assessments of the impacts of policy, at much lower cost and greater understanding to those involved (Ghaffarzadegan et al., 2011). Nutrient leaching and public policy modelling in the Rotorua Lakes catchment of New Zealand has shown that the benefits accruing to the use of complex models and policy mechanisms may be quite limited, given limitations associated with the marginal benefit in cost savings from such mechanisms (Anastasiadis et al., 2013). Accordingly, this thesis offers a unique opportunity to explore if simple SD modelling approaches, like that applied by Ghaffarzadegan et al. (2011), may provide similar benefits in New Zealand.

2.5 Gap in the Literature/Research Question

Freshwater management in New Zealand displays many characteristics of a wicked problem – environmental, economic, cultural and social complexity abound. There is a strong desire for change however, with strong signals and direct guidance having been provided by central government to help develop nationally coordinated freshwater policy that reflects the individual circumstances of the regions. The increasing involvement of stakeholders in decision-making through mechanisms such as collaborative processes provide an ideal opportunity to explore the suitability of GMB processes in decision-making. Not only is SD ideally suited to helping people *understand* complex systems, the 'building-block' approach that 'scripted' GMB processes provide may also assist with it being both consistently used, yet adaptable across the country. As limited resources are a constant challenge within local government, the scripted GMB approach applied in this research both extends existing theory and potentially helps to enable freshwater policy to be developed faster and more robustly, through building a greater level of shared understanding among key stakeholders.

3 Overview of the methodology

This section is divided into two main parts: the paradigmatic perspective of the researcher is outlined, then an overview of the methodology is provided.

The research methodology is divided in two broad parts: the running of GMB workshops with groups; and exploring participants' experiences of the GMB workshops through the thematic analysis of follow-up interviews.

It is important to note that during piloting of the GMB process it was discovered that the original intention outlined in this section – that of developing the architecture of a simulation model with a group in the first workshop – was too ambitious under the constrained time frames available. The methodology was therefore amended to develop a CLD instead. The methodology overview section of this section will describe the original GMB process that was selected and how its application would be measured at the end of the first workshop. Further, it outlines how follow up interviews were undertaken with the participants and thematic analysis was undertaken on the data gathered.

Subsequent sections will describe how the GMB process was piloted and adapted (Section 4); the experience of running the GMB process with two case studies (Section 5); the analysis of the quantitative data gathered from participants' surveys (Section 7); and the thematic analysis of follow-up interviews with participants (Sections 8, 9, 10, 11 and 12).

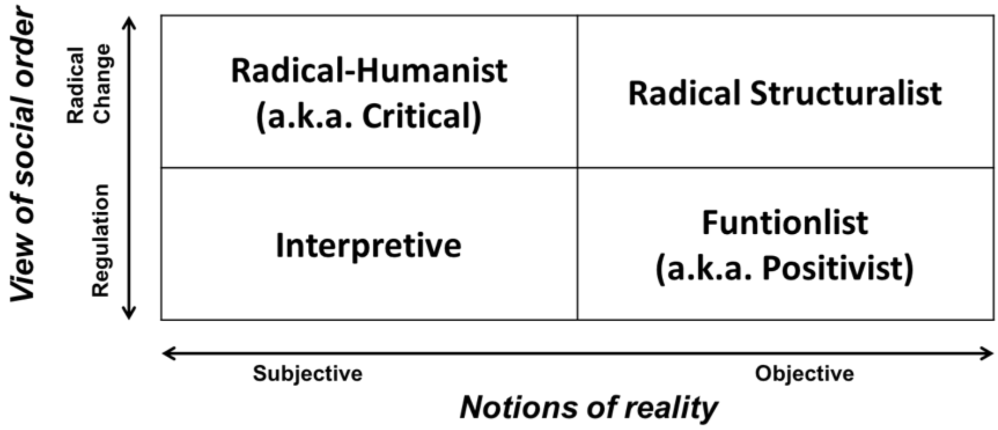
Issues of design, procedures, protocols, tools and sampling and some ethical considerations are touched upon in this section, but most data of this kind is contained in cited appendices.

3.1 Paradigmatic perspective

In social science research, paradigms are generally understood as a description of the philosophical constructs that underpin the research being undertaken. They provide insight into how the researcher views the world and how those views guide or influence their research. This section considers the paradigms outlined by Burrell and Morgan (1979) and outlines the paradigmatic perspective that guides this research.

Burrell and Morgan (1979) outline two *dimensions* that guide a researchers' perspective of the world. These are *order vs. conflict* on the one hand and *notions of reality* on the other (Burrell & Morgan, 1979). Overlaying these two dimensions creates a matrix with four paradigms that they term Functional (a.k.a. Positivist), Interpretive, Radical-Humanist (a.k.a. Critical-Interpretive) and Radical-Structuralist (see Figure 3.1).

Figure 3.1 Burrell and Morgen Paradigms.



Adapted from Burrell & Morgan (1979).

The order versus conflict dimension relates to how *social order* is achieved and which they term 'regulation' versus 'radical change'. Regulation scholarship is interested in the underlying "unity and cohesiveness of society", while radical change scholarship is interested in the conflict or dissensus that exists within society and seeks to change it through that influence (Burrell & Morgan, 1979). While binary, this dimension is not mutually exclusive and the perspective of a researcher may not sit clearly at either end.

While significant amendment of the organisational structures that are responsible for managing freshwater would be considered 'radical', most change in freshwater management in New Zealand (Ministry for the Environment, 2012a, 2012b, 2014; Salmon, 2012) has occurred within the structure of existing institutions and legislation, namely the *RMA 1991*. Guidance provided by government has been in the form of a National Policy Statement that is a tool of the *RMA 1991* (Ministry for the Environment, 2012a, 2014) and therefore appears at the regulation end of the social order dimension (Burrell & Morgan, 1979). Other change that is encouraged can occur within the regulated environment but not be required by it, such as in the use of collaborative processes for policy development (Ministry for the Environment, 2012b, 2015; Salmon, 2012; Salmon et al., 2008). While it is an approach that involves stakeholders to a higher level than traditional policy development in New Zealand (Salmon et al., 2008), it is enabled within the existing framework of environmental legislation (RMA, 1991) and seeks to enhance decision-making within existing power structures; it is therefore not radical according to the Burrell and Morgan (1979) dimension.

The subjective versus objective *notions of reality* dimension is now considered, which itself reflects the two broad schools of thought within economics. On one hand, positive economics deals with observations about *how the world is*, while on the other hand, normative economics deals with subjective judgement decisions about *how the world ought to be* (Tietenberg & Lewis, 2015). Once again, although this dimension is binary, it is a 'sliding scale'. The literature review and the interest of this research in the use of SD modelling in freshwater decision-making itself reflects a real-life tension between an objective or positivist worldview and a subjective or normative[1] worldview.

The SD approach seeks to understand the elements in the freshwater system and how policy impacts them. At a more detailed level, extensive statistical and scientific research is also used in decision-making. This means that there is a wide range of objective or positive perspectives already well established. This research is interested more in the *subjective* viewpoints that exist within such systems – for those participating in decision-making, how might the *experience* of GMB help to improve their *understanding* of the relationships that exist within highly-dynamic freshwater systems? Therefore, while this research lies more towards the subjective end of this dimension, it will draw on some elements of objective research methods and lends itself towards a mixed methods approach. This acknowledges that both ends of this dimension will help to enlighten our

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1 Normative in this instance is used here in the economic sense, meaning subjective or used in judgement-based decision-making.

area of interest (Robey, 1994) and that the two are complementary (Meredith, 1995).

Having considered where this research lies on the dimensions of Burrell and Morgan (1979), the predominant paradigm that relates to this research can be defined. According to Burrell and Morgan’s (1979) dimensions, the focus of this study tends toward the subjective and regulatory. This means that the Radical-Structuralist paradigm can be ruled out.

Given interest in the use of SD in the existing and emerging processes used for freshwater policy development, the radical change or critical paradigm can be largely discarded. While it is certainly acknowledged that this research may touch on areas of critical thinking from those involved, it does not seek to *actively critique* the existing system. Rather, it seeks to identify how GMB might better achieve results through *interpreting* the *experiences* of those involved in it.

This research seeks to understand how SD modelling might contribute to the development of freshwater policy, so is approached primarily from the perspective of an *interpretive* paradigm. This sought perspectives from people exposed to GMB with the intention of generating knowledge that will contribute towards improving the efficiency and robustness of policy development, in an environment where resources are constrained.

3.2 Overview of methodology

Having defined the paradigmatic perspective of this research, this section will provide an overview of the GMB process and follow-up interview methodology that was selected.

This research is interested in how well SD GMB increases a groups’ *shared understanding* of a freshwater issue and how it might be applied with *limited resources*.

To address these objectives, a methodology for GMB was sourced from the SD literature. GMB typically involves those people impacted by or responsible for the decisions in the modelling process and became increasingly popular in the mid-1990's (e.g. Richardson & Andersen, 1995; Vennix, 1996, 1999; Vennix et al.,1992).

The methodology chosen here is a GMB process described by Luna-Reyes et al. (2006). In this article, the GMB process is referred to as 'decision-conferencing', for the purposes of simplicity and consistency, in this research the process will be referred to as 'GMB' or 'workshops'. There are several reasons why this methodology is considered appropriate for this research. First, it is considered appropriate for the New Zealand context where deliberative processes are becoming more commonplace (Land and Water Forum, 2010; Salmon et al., 2008). Second, the direct involvement of affected or responsible participants is more likely to lead to models that are understood, agreed, supported and influential in policy decisions (Ackoff, 1994; van den Belt, 2004; Vennix, 1996). Third, it provides an opportunity for multi-disciplinary involvement (Ackoff, 1999; van den Belt, 2004), which has always been an important, even fundamental, aspect of SD modelling (Forrester, 2007). Last, it is a 'script' based methodology – pre-planned parts of a GMB process (Andersen & Richardson, 1997; Hovmand et al., 2012; Luna-Reyes et al., 2006). This improves its potential for broad application, especially by people with a limited background in this area. Also, the script-based approach allows for pragmatic adaption of the process.[2] Finally, the process described is a two-workshop process (Luna-Reyes et al., 2006), which is considered appropriate given the objective of testing the process with limited resources.

3.2.1 Summary of the Luna Reyes et al. (2006) methodology

This section provides a brief outline of the GMB methodology using SD modelling described by Luna-Reyes et al. (2006).

2 While Luna-Reyes et al. (2006) describe the scripts they use in their methodology, there is also a wider collection of scripts available to draw on within the literature, particularly from an open-source collection known as 'Scriptapedia' (Hovmand et al., 2013).

3.2.1.1 The use of defined roles in decision conferencing

The methodology described by Luna-Reyes et al. (2006) utilises people running the workshops in a range of five specific roles first described by Richardson and Andersen (1995), who were also co-authors of Luna-Reyes et al. (2006). These are: Facilitator, Modeller/Reflector, Process coach, Recorder and Gatekeeper and are described in Table 3.1.

Table 3.1 Richardson and Andersen's five GMB 'roles'.

Role	Description
Facilitator	The main facilitator, responsible for the *process* and the elicitation of knowledge from participants. Will be the most visible person and have a large influence on the dynamics of the day.
Modeller/Reflector	Not involved with the *process* of the day, rather is focused on capturing a *model* that represents the discussions of the group.
Process Coach	Another champion of the *process*. No SD knowledge is required, they support the facilitator to detect and observe group behaviours and tensions. A largely invisible role to the participants.
Recorder	Records the discussion of the day and an accurate record of what happened.
Gatekeeper	A person from the sponsoring organisation, likely to be someone who has responsibility for the work, or who initiated the modelling process. An awareness of SD is useful in this person, but they do not need to be expert.

Summarised from Richardson and Andersen (1995).

To test this process with limited resources, only a limited number of roles are used in the workshops in this research. These primary roles will be that of the *Facilitator*, the *Modeller/Reflector*, and the *Gatekeeper*. As several roles can be adopted by one person (Richardson & Andersen, 1995; Rouwette, 2003) the facilitator will act as *Process Coach* if required, and the role of *Recorder* will be substituted with electronic recording devices.

Someone from the client organisation took on the role of the Gatekeeper and may or may not have been a participant in the modelling (determined on a case-by-case basis). The researcher acted as the Facilitator and worked with the Gatekeeper to prepare the workshops. Someone familiar with SD modelling supported in the Modeller/Reflector role.

3.2.1.2 The use of scripts in GMB workshops

No CLD is developed as a first step with the Luna-Reyes et al. (2006) process. Instead, participants design a simulation model structure made up of stocks and flows, which is a good way of utilising the limited time and resources available.

The below table (Table 3.2) summarises the scripts used in this two-workshop process (mostly in the first workshop). Firstly, an *introduction* to SD and 'hopes and fears' script introduces the wider group to each other and the objective of the day. Secondly, a pre-prepared *concept model* is shown to the group relating to the problem being explored, deliberate subtle mistakes are included to engage participants and build their confidence in identifying and correcting these. Thirdly, participants identify as many variables relating to the problem as possible, identifying them as stocks, flows or otherwise, and prioritising them. Fourthly, reference modes (graphs that demonstrate 'behaviour over time') are drawn for important variables. Fifthly, the group develops the model structure with the aid of: a document projector; the facilitator running the discussion and the modeller/reflector drawing the model architecture on paper and layers of clear acetate (the acetate layers allow the ability to differentiate 'sub-systems' or 'sectors' if desired or appropriate). The day ends with the sixth script where the model is reflected back to the group for endorsement before being taken away and modelled in SD software.

In between workshops, an SD simulation model is built and this is what is presented back and tested to the group in the seventh script, the only one scheduled for the second workshop. If more than one model is developed, these are discussed and a preferred one agreed to. It is possible that individual 'sectors' of the model may be discussed individually, if needed.

At the end of the second workshop, a SD simulation model has been developed and tested by the group. The final part of the script in the second workshop is to seek for the ownership of the model to be taken back by the group (and/or client) to ensure that it maintains a high level of ownership with those that will use it.

Table 3.2 Summary of scripts described in Luna-Reyes et al. (2006). Six scripts apply to the first workshop, some modelling is then undertaken, then one more script applies to the second workshop.

Script	Description
Workshop I	
1. Introduction	Introduces participants to the day, SD thinking and the project. Includes a 'Hopes and Fears' introductory exercise where participants each write down major hopes and fears for the day and share these with the group until all have been shared. This helps to identify the expectations and concerns in the room. The order that these are shared provides insight into their relative priority.
2. Concept model script	A small model with three-four stocks and two-three feedback loops that was developed before the conference is presented to the participants as a 'strawman'. This helps participants visualise the anticipated outcome of the day by introducing what an actual model looks like. Simple but obvious mistakes are included so that the participants can notice these and correct them, gaining practice and confidence in how the model and feedback loops should interact.
3. Variable elicitation script	This identifies as many variables and key stocks in the model as possible. This also helps to define the boundaries of the model. The first part uses divergent brain-storming techniques to identify and collate as many variables as possible. The second part uses convergent facilitation techniques to prioritise variables as a group. The most important/relevant variables are identified and determined if these are stocks, flows or otherwise influencing factors.
4. Reference modes elicitation	This identifies the reference modes (a graph of the behaviour of a variable over time) of identified variables.

Script	Description
	Some may be prepared beforehand with the gatekeeper but many are likely to be developed by the group, as variables may not be identified until the workshop and knowledge of their behaviour may not be known. The behaviour of variables is developed through anecdotes and descriptions with the group. This will lead to a greater understanding of the various inter-connections that may contribute to that behaviour. Participants then work as pairs or threes to graph the reference mode of variables on blank graphs (X and Y axes) and share these with the group. The script should develop draft reference modes that are likely to be more accepted by the group, as well as greater understanding of the system boundaries and maybe even some appreciation of possible policy options.
5. Model structure elicitation script	Once a range of reference modes are developed the group will determine a structure of the different variables and feedback loops in the system. The aim is to structure these to explain the relationships and stories that they shared as a group in the reference mode script. This may be initiated by the facilitator and modeller taking some of the variables that were identified in previous scripts and putting these together in a diagram and guiding the group to build it further from there. This script is supported using a data projector and document camera with the facilitator guiding the conversation and the modeller/reflector drawing the model structure on paper and layers of clear acetate.

Script	Description
6. Reflect and confirm model structure script	This begins with a reflection back to the group of the draft structure (or structures) of the model that has been developed. This is done in layers – ideally via overhead transparencies so that it is large enough for all participants to see. This may only confirm certain discrete 'sectors' of the overall system, which the researcher will potentially take away and develop further in the modelling stage. This brings workshop I to a close and provides the material for the researcher to develop a simulation model in system dynamics software.
Modelling between workshops	
Modelling	The outcome of workshop I will be the confirmation of a draft system model. The researcher will take this away and build a simulation model in the modelling software that will be made up of the variables and reference modes agreed to in the workshop.
Workshop II	
7. Transferring group ownership script	Workshop II will be based around a script that is designed to confirm the group ownership of the structure that has been developed and endorse it over from the researcher to the group. If a range of models with slight variations are developed, these various versions will be shown on different walls in the room. This will allow the group to discuss and confirm the model that best captures the system that they are considering. Simulation versions of the model(s) that have been developed by the researcher will be demonstrated to the group and various parameters will be experimented with as a way of testing the simulation model to see if it reflects the reality that the group were describing in workshop I. The focus of this script is to spend time with the parameters of the system, before any structural changes are made to the system. At the end of this script, the facilitator asks the group for their permission to confirm the structure of the model and endorse ownership of it back to them.

Summarised from Luna-Reyes et al. (2006)

Sterman (2000) notes that while CLDs are good for mapping out peoples' mental models, progressing to simulation modelling is important as it is the only way of testing these mental models and exploring the implications of different scenarios or diverse parameter sets. Simulation models are especially valuable in the complex world of environmental management, given the diversity of factors involved (van den Belt, 2004). It is for these reasons that this research originally focused on testing a GMB process focused on the development of a simulation model.

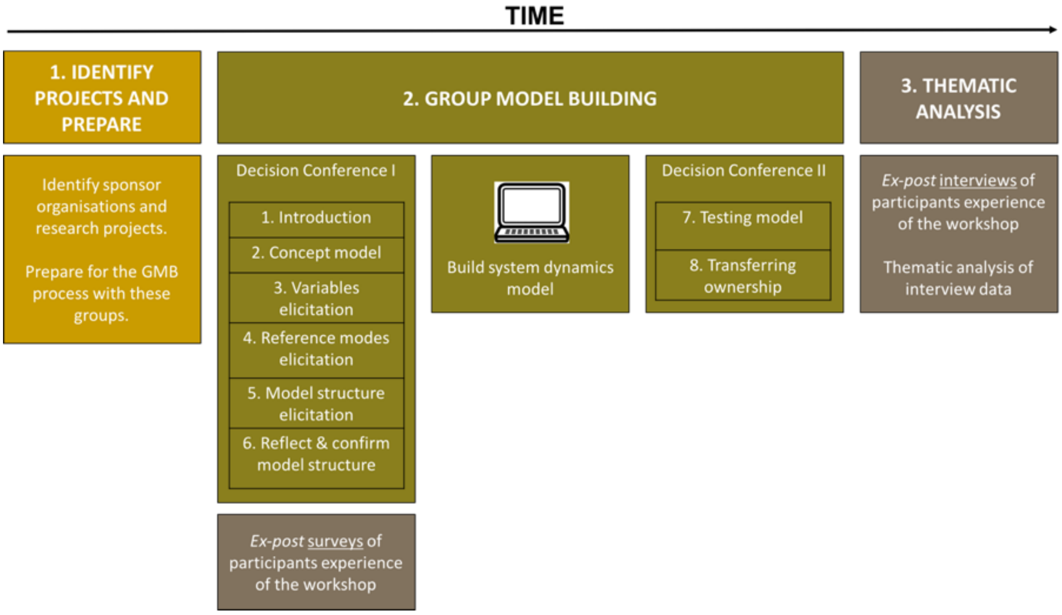
3.2.2 Putting the methodology together: preparation, GMB and follow up interviews

The methodology described in Luna-Reyes et al. (2006) will be applied in this research in the following way:

1. Sponsor council(s) and projects will be identified and the researcher will work with council staff to prepare for the GMB process. Preparation for the GMB workshops will include identifying what the GMB process will focus on, identifying participants, room layout and developing a concept model with the sponsor council(s).
2. SD models will be developed via a two-workshop process as per the scripts in Table 3.2.
3. *Ex-post* surveys of the workshop participants will be undertaken at the end of the first workshop and follow up interviews will be completed after the second workshop. Quantitative and qualitative analysis of the data gathered in these interviews will be undertaken.

A diagram outlining the methodology is provided in Figure 3.2.

Figure 3.2 Original methodology outline.



(Phase 2 based on method of Luna-Reyes et al. (2006))

3.3 Overview of data analysis

The previous section provided an overview of the methodology and how the process described by Luna-Reyes et al. (2006) would be applied. While that process will return its own outputs in the form of SD models, this section outlines how the success of that process will be measured by the researcher.

A mixed methods approach is proposed using two main methods:

1. A quantitative and qualitative survey of participants undertaken at the end of the first workshop; and
2. A qualitative semi-structured follow up interview undertaken with participants after the second workshop.

3.3.1 A summary of the types of data to be analysed and possible results

This section outlines the types of possible data to be analysed, possible results, and limitations of the data.

3.3.1.1 The types of data to be analysed

Outside of the models developed by the process there are two main types of data being collected – surveys and semi-structured interviews. Participants will fill in the surveys at the end of the first workshop (these have both *quantitative* and *qualitative* components). After the second workshop, semi-structured follow up interviews with each participant will be recorded, transcribed and *thematic analysis* undertaken on the data.

This mixed methods approach is expected to be a useful contribution to the literature and in line with the findings of a literature review by Scott et al. (2016b). These authors found that there was a need for further mixed methods assessments of GMB work, as there were issues with the accuracy of self-reported improvements in understanding and changes in mental models of participants, which some work had relied on self-reported findings to determine.

A detailed discussion of potential issues relating to sampling and validity is provided in Appendix 2. Interview protocols and questions have been included in Appendix 4 and Appendix 5.

3.3.1.2 Possible Analysis and Results

From the overview of the analysis provided previously, the workshops are expected to identify a range of varying perspectives on the nature of the systems that are mapped by the groups. It is likely that the backgrounds of each person involved will mean that they are able to contribute in greater detail in one part of the system than in others.

Some entrenched perspectives about the freshwater systems and how they relate to economic and social systems may be identified during the workshops or follow-up interviews. It is also expected that the range and depth of understanding of the systems amongst the cross section of people involved will be identified.

Overall, a broad understanding of the benefits of the use of SD modelling in freshwater management or policy development is the expected outcome from this research.

3.3.1.3 Limitations of the research

Two main limitation are identified relating to sampling and potential confusion around the understanding of SD before the research begins.

The need for purposive sampling is discussed in Appendix 2 and the sample size of projects will be two. This may create some potential limitations relating to a range of biases, however this is inherent with action research, which is generally limited in the sample sizes of projects that it can involve.

There is also a risk that people may be unwilling to take part in the research and it is hoped that a high level of individualised contact with possible participants, by sponsor organisations, will encourage a strong response.

Secondly, the results of the research may be affected by participants' confusion around what SD is – certainly at least at the early stage of the research, before the workshops have been undertaken. There may be potential reliability issues with the research sample if, based on their familiarity or not with SD modelling, the decision to be involved in the research or not is influenced by this lack of familiarity.

Some ethical considerations are provided in Appendix 8.

3.3.2 Quantitative data analysis

The quantitative data collected from the surveys will be collated and analysed at a population level for each workshop. While this is only a partial amount of the information collected, it is – importantly – the main self-reported results of participants. While self-reported results have been identified as having issues in relation to bias and the need for more objective measures of effectiveness are required (Scott et al., 2016b), this quantitative component will be useful because it will provide some (self-reported) measure against which the qualitative analysis may be compared.

The quantitative approach will be centred on the five survey questions outlined in Table 3.3 below. Each of these will be answered on a seven-point Likert scale ranging from strongly disagree to strongly agree. For a copy of the survey form, refer to Appendix 3.

Table 3.3 **Five main quantitative questions in post-workshop survey and Likert Scale**

Questions						
1. This process helped me better understand the perspectives of other people in the group relating to freshwater issues **2.** This process helped has helped me to learn more about our freshwater system **3.** I found Causal Loop Diagrams easy to understand **4.** Using Causal Loops Diagrams has increased the agreement of the group on factors that influence our freshwater system **5.** I believe the Causal Loop Diagram Model developed today will be useful for this project in the future						
Each above question will be answered on the below Likert scale						
☐ *Strongly disagree*	☐ *Moderately disagree*	☐ *Slightly disagree*	☐ *Neither agree or disagree*	☐ *Slightly agree*	☐ *Moderately agree*	☐ *Strongly agree*

No statistical analysis has been undertaken on the quantitative data. The sample sizes are relatively small due to the purposive sampling.

3.3.3 Qualitative data analysis

This section outlines how the text data gathered in the open-ended questions of the survey and the semi-structured interviews were thematically analysed. Firstly, the bias of the researcher is discussed in Section 3.3.3.1, followed by a description of the approach to thematic analysis used in this research in Section 3.3.3.2.

3.3.3.1 Acknowledging the subjective frame (bias) of the researcher

Qualitative research is interpretivist in that it seeks to understand the nature of the world by interpreting it through its participants, and constructionist in that the phenomena that it studies are the result of interactions between people, rather than being independent from them (Bryman & Bell, 2015). The focus is the phenomena that are the result of the interaction of people, thus the very nature of *qualitative* research means that it is impossible to completely remove the researcher from the process and that their inherent bias should be acknowledged and stated as part of the research (Malterud, 2001). Maltreud (2001) refers to this as the researcher's 'subjective frame' and this research subscribes to this view – that the subjective frame of the researcher should be clearly acknowledged. Therefore, it is stated here for clarity. The researcher has professional experience in a range of industries and significant experience in the local government industry where he has been involved with a range of both infrastructure and policy development projects. Consistent with the researchers' paradigmatic perspective (see section 3.1), this research comes from an *interpretivist* perspective, primarily seeking to understand participants' *experience* of the process.

3.3.3.2 Overview of thematic analysis methodology

Thematic analysis is suitable as it uses a framework through which the data is analysed, searching for and identifying repetition, metaphors, similarities and differences (Bryman & Bell, 2015). Taking the researcher's subjective frame into consideration (Malterud, 2001), text is coded and the three main things that are looked for when determining a theme are the *recurrence* of meaning, the *repetition* of key words or phrases and the *forcefulness* with which these are used (Owen, 1984). Thematic analysis is considered a pragmatic method for assessing qualitative data within the time constraints of this research.

Braun and Clarke (2006) argue that thematic analysis is widely-used, but suffers from a lack of clear agreement as to how to undertake it. They outline a straightforward framework for the analysis of data to develop themes and this is used in this research. A couple of key considerations are outlined by them, namely acknowledging the bias of the researcher; being clear on how the data will be demarcated for coding and considering whether inductive or deductive coding will be undertaken. They then outline a clear and simple framework for the analysis of data.

The subjective frame of the research has already been dealt with, so the following sub-sections will outline how the data is demarcated, discuss the use of inductive and deductive coding, and outline the framework for analysis.

3.3.3.2.1 How the data is grouped

At this point, several terms outlined by Braun and Clarke (2006) and relating to data are worth defining for clarity. Refer to Figure 3.3 for a visual representation of these terms.

A data **item** refers to any individual item of data collected. For this research, this refers to the answers to the open-ended questions in the post-workshop survey; and the *ex-post* semi-structured interviews undertaken with each participant.

The data **corpus** refers to the entire body of data collected for the research, this is collective term for all the data **items** listed above.

A data **set** refers to a sub-set of the corpus and can change depending on an area of interest. For example, one might be interested in male participants of a certain age cohort, or only responses from a certain type of data item.

The thematic analysis undertaken in **this research will only focus on the data sets** of written responses to open ended questions in the post-workshop survey and the transcriptions of the *ex-post* semi-structured interviews undertaken with participants.[3] As the semi-structured interviews provide the bulk of the data, they are usually considered as a single set unless a reason is identified to differentiate them.

A data **extract** is any individually coded ‘chunk’ of data that is extracted from any item, in part or whole. In most instances in this research, quotes will be examples of data extracts.

The data in this research was coded using NVivo software, which is software used to support qualitative and mixed methods research. It is a

3 The “word clouds” generated from the transcriptions of the interviews and the workshops are not part of the thematic analysis and are provided merely as an indicative exercise in understanding the prevalence of individual words, not any themes that might come out of them.

tool used to help organise and analyse qualitative data such as surveys and interviews[4].

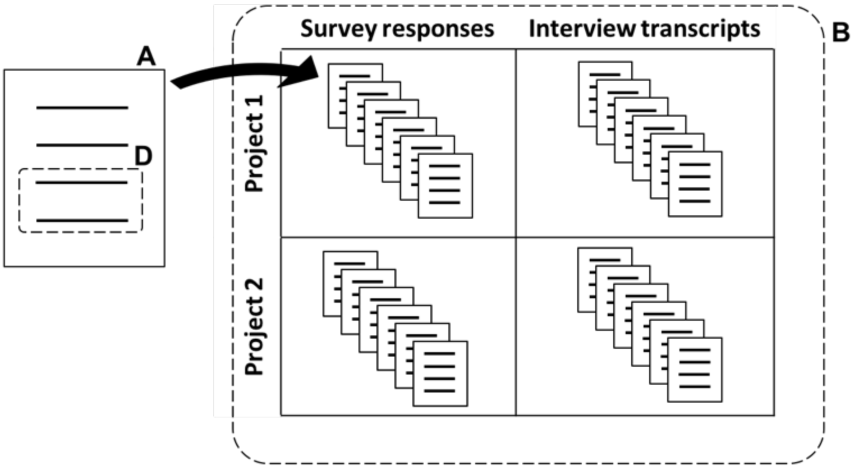
The structure of the data outlined above was replicated in NVivo as separate data items. ‘Nodes’ were then used to code and identify different extracts and these were built up into different headings and overarching themes. Nodes were also used to group the data into different data sets.

Figure 3.3 Data terms in thematic analysis – visual representation

Data terms in thematic analysis:

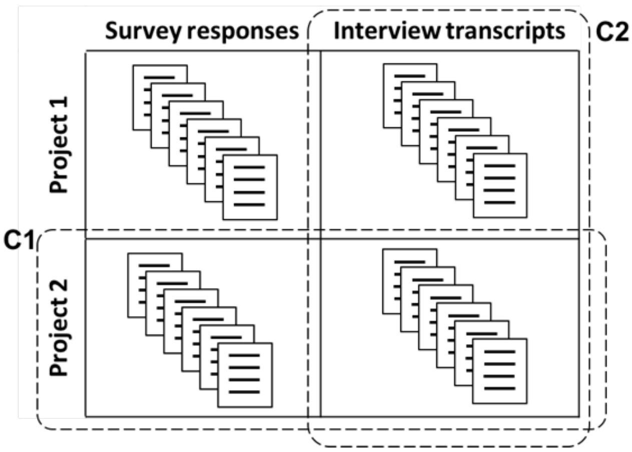
(A) *Item*: any individual item of data collected (e.g. surveys or interviews).

(B) *Corpus*: the entire body of data collected.



(C) *Set*: a sub-set of the corpus, changes depending on interest (e.g. “people in group A”).

(D) *Extract*: individually coded ‘chunk’ of data in an item (e.g. quotes).



4 NVivo is a software product of QS International and is widely used to help organise and analyse qualitative data. For more information visit http://www.qsrinternational.com/what-is-nvivo.

3.3.3.2.2 Coding - inductive & deductive

Coding is the act of highlighting any words, phrases or discussions that are deemed of interest by the researcher. These are characterised by some commonality of interest and form the building blocks of themes.

A broad distinction is made between two main ways of identifying codes: 'bottom-up' or inductive coding; and 'top down' or deductive coding (Braun and Clarke, 2006). Inductive coding generally means themes identified are linked strongly to the data themselves, while deductive coding is undertaken within a certain theoretical framework or with a given interest in mind.

Despite the best intentions of a researcher, Miller and Crabtree (1999) note that themes do not simply 'emerge' from data alone "but from the relation between empirical substance and theoretical models and notions" (Miller and Crabtree (1999), as cited in Malterud (2001, p. 486)). The theoretical framework of the researcher is referred to as the 'reading glasses' through which the researcher views the data (Braun and Clarke, 2006) and why a clear acknowledgement of it is required (see Section 3.3.3.1).

In attempting to make explicit the 'reading glasses' context through which the researcher views this research, it is important to state that this research is interested in the participant's ***experience*** of the GMB process. While the specific issues that the two case studies addressed were both related to freshwater management, they were quite specific to the problems being addressed in each project. This makes the specific content of them incomparable. The common thread that all participants did have, however, was a consistent exposure to the GMB process that guided them through the workshops.

This research is interested in specific themes relating to this common experience of the process. This is the theoretical context that the researcher is interested in regarding the data, meaning that any coding will at least in part be deductive coding. However, the absence of any specific themes or codes that are being explored outside of this experiential interest of the process, also means that while focused on the *experience* of the process (deductive coding), the researcher is *open to whatever codes, trends or themes can be identified* in the data corpus (inductive coding). It is therefore considered that this research will be a combination of deductive and inductive coding.

As such, comments and discussions that relate to the specific content of the freshwater issues have been discounted, as have participants' direct experiences of other processes that are not considered relevant. That said, comments or discussion of the participants' experience of the GMB process *in comparison* to other processes they have been involved in have been included in the coded data. While obviously different experiences, the exposure to different processes may provide insight participants experience of *this* process.

3.3.3.2.3 Braun and Clarke's phases of thematic analysis

The process outlined by Braun and Clarke (2006) has 6 main steps. These are summarised here:

1. **Data familiarisation:** Transcribing and familiarising oneself with the data
2. **Generate initial codes:** Coding initial features identified as codes across the entire data set.
3. **Searching for themes:** Collating identified codes into potential themes.
4. **Reviewing themes:** Checking if themes work in relation at the level of extracts as well as the corpus of data.
5. **Defining and naming themes:** Ongoing refinement and analysis of themes, naming of themes and applying clear definitions for each theme.
6. **Producing the report:** A collated, considered and thorough analysis and discussion of the themes. Relevant examples from data and literature drawn upon.

The first five of these steps form the structure of the section where the journey of undertaking the thematic analysis is described (Section 8), while step 6, a detailed discussion of the themes themselves, is undertaken in Sections 9, 10, 11 and 12. The thematic analysis and discussion form a major part of this thesis and are contained in these latter sections of the thesis, before the final summary and recommendations are presented.

3.4 Summary

Previous sections of this thesis have outlined the context and motivation for this research, reviewed the available literature and identified the area where this research will contribute to the literature. This section has built on this base and outlined how a 2-workshop GMB process was selected from the literature as a pragmatic methodology for testing how SD might improve policy development for freshwater in New Zealand. The approach that will be taken to analysing the results attained from the GMB process, based on the 6-step process outlined by Braun and Clarke (2006), was also outlined.

4 Piloting and revising the GMB methodology

This section describes the journey of preparing to run the GMB process with actual research groups. This is divided into the following sections: identifying sponsor organisations and projects (Section 4.1); piloting the GMB methodology (Section 4.2); and the revised GMB methodology (Section 4.3).

4.1 Identifying sponsor organisations

Several freshwater projects representing a cross section of freshwater policy development issues were identified across different regional councils.

The Bay of Plenty Regional Council (BOPRC) was working through a process with a community group in the Rangitāiki River catchment to determine values, objectives and limits for the Rangitāiki River in response to the *NPS-FM 2014* (Ministry for the Environment, 2014). BOPRC were keen to explore how an SD approach might help improve a group's understanding of the complex nature of issues related to freshwater management in this catchment; and aid in the determination of the necessary regulatory requirements. While BOPRC had already begun a process with a community group, it was agreed that a workshop would be run with a subset of this group, who would be sourced on a voluntary basis. This would support this research activity, while also allowing BOPRC to experiment with the SD approach for their own interest and possible future use.

The West Coast Regional Council (WCRC) had an issue with *Escherichia coli* (*E. coli*)[5] contamination of a major urban stream in Greymouth and they chose to use the GMB process to explore this issue. This process involved a variety of invited stakeholders.

[5] *E. coli* is faecal bacteria (emanating from humans, birds, and grazing animals) found in New Zealand waterways, and is used nationwide as an indicator of the risk that the ingestion of this and other faecal coliforms (e.g. *Campylobacter*) can lead to subsequent illness.

One other regional council was also initially interested in being involved in the research. While a case study catchment, issue and a range of representative stakeholders were identified, unfortunately, this project was not able to proceed for a variety of circumstantial and logistical reasons.

One of the key limitations identified for both case studies was that **two-days for the first workshop was not possible**. This reflected the realities of the time pressures associated with involving stakeholders in decision-making and the other pressures on the time of council staff. Any application of the Luna-Reyes et al. (2006) process would therefore have to be done with a **one-day first workshop**.

These projects are described in summary in Section 5.1 and in more detail in Appendix 13.

4.2 Piloting the methodology

Having described how the case studies were identified, this section outlines how the methodology was piloted with two pilot groups and what was learned from that process, before applying it on the case studies. These pilot workshops proved to be a critical part of the research. Many lessons resulted from them and the Luna-Reyes et al. (2006) GMB process was subsequently significantly adapted before being applied to the case studies.

The two groups that the methodology was tested on were: a) people who were unrelated to the research, but some of whom had technical experience in the freshwater area, and b) support staff at BOPRC in preparation for using it for their project.

A summary of these pilot workshops and the lessons gained is provided in this section. Given the critical role that these pilots played in the overall research, a more detailed and expanded version of this description and discussion has been provided in (Appendix 10).

4.2.1 Pilot workshop I – Waikato

An abridged workshop (3.5 hours) was run with four participants: two senior staff from a regional council, who were familiar with freshwater issues; and two people who had no experience of freshwater issues – one was a medical professional and the other was a Masters student at the university. As a variety of participants were expected in the actual case studies, this was a good opportunity to test the GMB process on a diverse group. Only the Facilitator and Modeller/Reflector roles were used.

4.2.1.1 Structure of the process

This first pilot workshop was run strictly in accordance with the Luna-Reyes et al. (2006) process, just in less time. As the objective was to test the GMB process and not actually construct a working SD model, it was expected that all scripts would be attempted but not necessarily completed. The structure of the workshop is outlined in Table 4.1 and detailed versions of the scripts are available in (Appendix 11).

Table 4.1 Structure of pilot workshop I.

Session	Description
Introduction	Researcher introduces himself and outlines what the day hopes to achieve and how it will be structured.
Script 1 - hopes and fears (divergent)	A warm up activity is undertaken to 'break the ice' and to help introduce participants to each other.
Script 2 - SD and the concept model (instructive/convergent)	A brief presentation and explanation of what SD is and how it can be used.
Focus question	Focus question is introduced.
Script 3 - variable elicitation (divergent)	Identifying the variables ('parts').
Script 4 - reference modes elicitation (divergent/convergent)	Identifying the reference modes ('behaviours').
Script 5 - model structure elicitation (convergent)	Identifying the system structure.
Script 6 - reflect and confirm model structure (convergent)	Reflect the model back to the group and confirm it reflects what they have developed together.

4.2.1.2 Introduction

The researcher introduced himself and provided an overview of what the day hoped to achieve and how it would be structured. He welcomed everybody equally and pointed out that both those *with experience* in freshwater management, as well as those *without* were both making valuable contributions to the research.

4.2.1.3 Hopes & Fears exercise

The hopes and fears exercise was run in accordance with Luna-Reyes et al. (2006) and Scriptapedia 4.0.6[6] (Hovmand et al., 2013). Only slight procedural modifications were made:

- Different coloured paper was used for people to write their hopes (green paper) and fears (red paper) on.
- It was made more physically interactive. Participants gathered around a 'sticky wall'[7] and placed their own hopes and fears on the wall, rather than the facilitator collecting them. This was combined with participants' introducing themselves and was a good way to 'break the ice'.

4.2.1.4 What is System Dynamics? (concept model)

A brief (20 minute) presentation about SD was provided – most participants were not familiar with this approach. It introduced the concept of CLDs (see Figure 4.1 for an example) and then the characteristics of problems that suit an SD approach – namely systems that are complex, non-linear, have feedback loops, often have time delays/lags, and for which there is often a lack of detailed data (Sterman, 1994; 2000).

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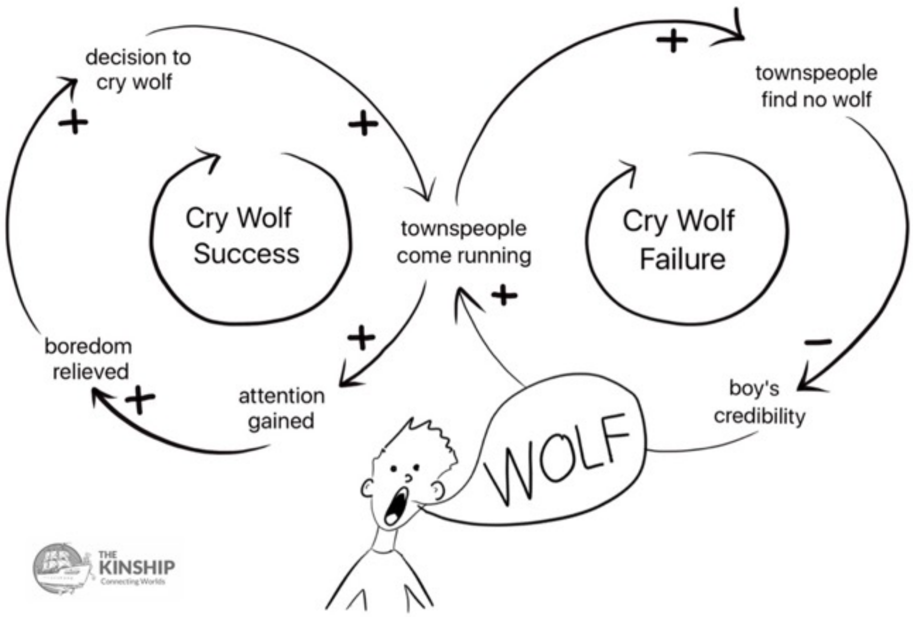
6 'Scriptapedia' is a creative commons collection of GMB 'scripts' collated by some of the founders of this approach – Hovmand et al. (2013).

7 A 'sticky' wall is a facilitation tool whereby a sheet of light material that has had a coating of spray adhesive applied is hung on a wall. Paper can then be placed on this sheet and will gently 'stick' to the surface. The paper can be repositioned without the need for tape or drawing pins and does not leave a mark. A sticky wall can be reused many times and only occasionally requires a 'top up' of spray adhesive.

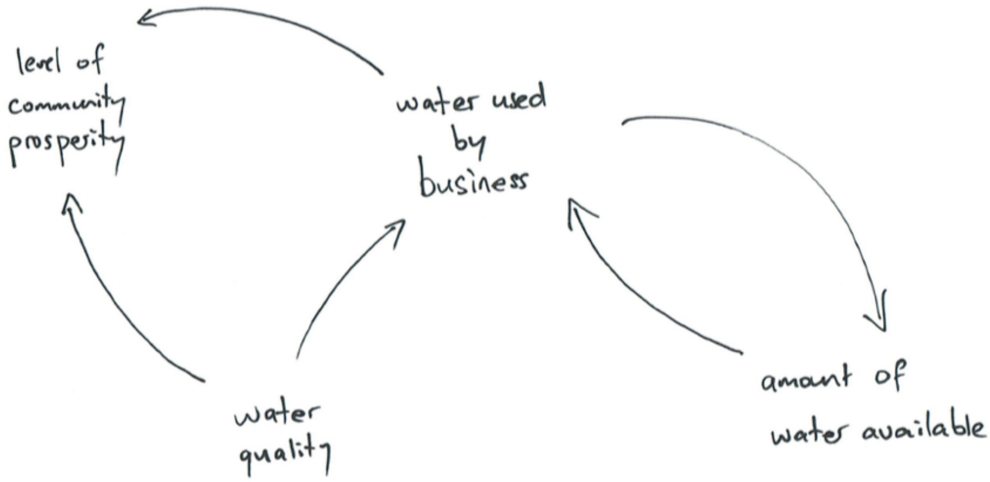
The concept of stocks and flows was explained, as this is a key concept in SD (Sterman, 1994) and the Luna-Reyes et al. (2006) framework sought to develop a quantitative stock-and-flow model.

Figure 4.1 Example CLD with annotation.



A concept model was presented to the group as a way of initiating discussion in the form of SD models (see Figure 4.2). In contrast to the recommendation of Luna-Reyes et al. (2006), this *concept model was presented in the style of a CLD*, rather than in stock and flow model architecture. The motivation for this was the desire to avoid any pre-determined variables at all in the GMB process, thus ensuring that *all* variables were purely participant generated.

Figure 4.2 Concept model for pilot workshop I.



This section took much longer to complete than expected, mostly because there were many concepts that participants were being introduced to for the first time and they needed sufficient time to absorb and understand them.

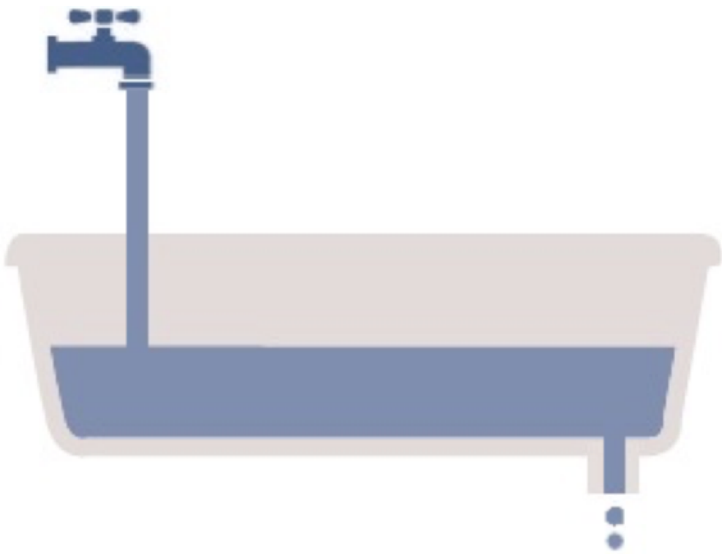
While all participants could absorb the concept of CLDs, the concept of the *polarity of the links/relationships* (being either positive or negative) took some explaining for all participants to understand. The participant who was from a technical medical background struggled because in the scientific world it appears that a positive relationship is *qualitative* in relation to the result achieved (i.e. a *positive* relationship is typically interpreted as desirable). In contrast, the mathematical context is *quantitative* and related to the trend of the *direction* of the variables – for a positive relationship, if variable A *increases* then this will mean that variable B *also increases*. This confusion for participants is consistent with the researcher's professional experience of working with groups to understand the concept of CLDs.[8]

8 The researcher was professionally involved with a government ministry in the development of a workshop for introducing people to economics and benefit-cost analysis. Part of this workshop introduced participants to the concept of CLDs. The researcher co-delivered this workshop across the country many times and at every workshop there was usually at least one person whom had challenges with understanding the polarity of relationships in a CLD. It is thought that this is because usually the audiences involved some people from a technical background, for whom

The concept of stocks and flows was then introduced and the bathtub analogy (Richardson & Pugh, 1989; Sterman, 2001) was used (

Figure 4.3) to help explain stocks and flows. During the workshop, the researcher found that all participants demonstrated an understanding of these concepts.

Figure 4.3 Images of the 'bathtub' analogy used to demonstrate the concept of stocks and flows.



Explaining CLDs first was intended as a pathway to helping participants understand stocks and flows. In practice, it was found that the subtle differences between CLDs and stock and flow models *required further explanation and discussion which was confusing for participants*. Explaining both concepts was too ambitious and confusing in the limited time available. An example stock and flow simulation model (a 'predator/prey' example) and output graph was also shown during the conference to help display key concepts (see Figure 4.4 and Figure 4.5).

Most of the workshop by now had been spent explaining CLDs and stock and flow models, leaving little time to talk about this example model. In hindsight, it was apparent that this model was too complex as an introductory model. At the end of this script participants were more familiar

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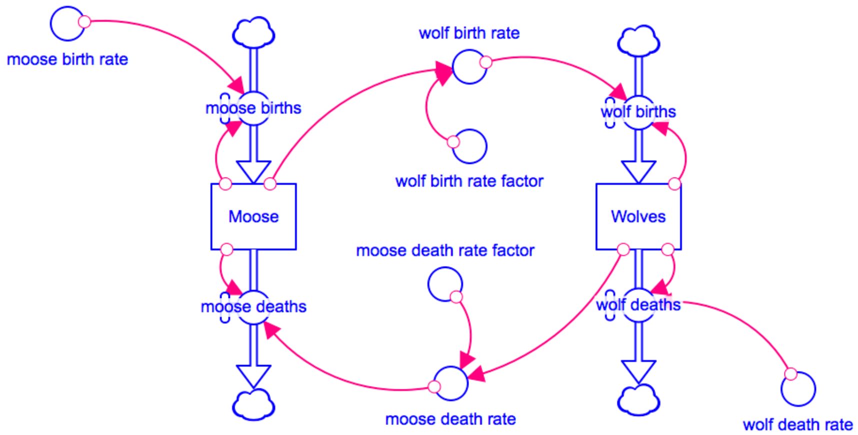
positive and negative relationships usually imply a qualitative relationship, rather than a quantitative one.

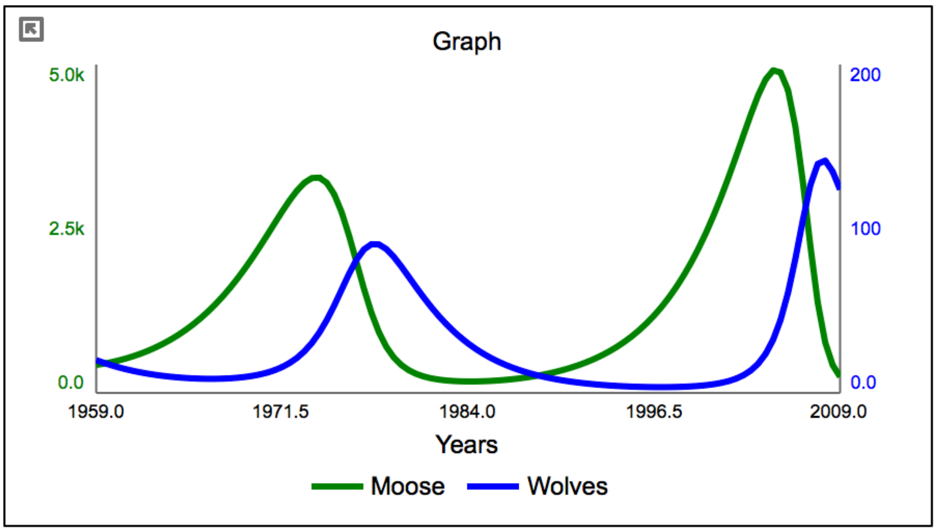
with CLDs having started with that concept, at the expense of understanding stock and flows better. This was a problem given that the explanation of CLDs was really both superfluous and time-consuming, as the goal of the workshop was to generate a stock and flow model.

Figure 4.4 Example simulation model – workshop I[9].



Predator-prey model based on Fortmann-Roe (2016)

Figure 4.5 Example simulation model output – workshop I.



Predator-prey model based on Fortmann-Roe (2016).

9 This model was constructed by the researcher in STELLA software and is based on one sourced from an example on the web. This was accessed at the following URL on 15 November 2016: https://insightmaker.com/insight/2068/Isle-Royale-Predator-Prey-Interactions

4.2.1.5 Focus question

It was time to move into the model building scripts and these would be guided by a focus question. The focus question was only introduced now to avoid confusion. This guided the elicitation of variables, behaviours and structure:

> *What is the relationship between water availability, water quality and the use of water by business across the Waikato region?*

4.2.1.6 Variable elicitation

This script was modified slightly from Luna-Reyes et al. (2006) and a *time limit* of 5 minutes imposed to list as many variables as possible. Participants then took turns sharing *three variables* that they felt were most important, these were captured by the facilitator on paper and collated on the sticky wall. Three variables were shared at once (instead of one-by-one) to save time, until all participants felt the main variables had been identified. Voting then identified the most-important variables. Each participant had 5 votes to allocate to any variables they saw fit. More sets of 5 votes would be allocated in turn until the group felt that there was a clear indication of what the most-important variables were. Two sets of 5 votes were allocated before the group judged felt the most important variables were listed. The results are tabulated in Table 4.2.

Table 4.2 Most important variables elicited for the Waikato pilot workshop (table).

# votes	'part' or variable(s)	
5	Water quality	Water quantity
4	Climate change	
3	Physical profile Community prosperity	Ecological profile
2	Iwi rights & interests Consumptive use Water policy Non-consumptive use	Human population Water inflow Discharges
1	Historic land use Business influences	Permeability/impermeability (recharge)
0	Municipal take Passive use Extractive access	Extractive use Navigation

The top two variables were water quality and quantity – the main variables in the focus question. One lesson is that *variables present within a focus question should be assumed as the first variables in a model*. Attention would then go to other variables that would *explain the behaviours* seen in these primary variables.

The variables were also very high level and could be their own 'sectors' within a model. A sector is a more detailed sub-model within a model and while not part of the Luna-Reyes et al. (2006) approach, their inclusion has been advocated by Marjan van den Belt (2004).

The second most important variable was Climate Change, which also potentially lends itself to being a 'sector' of its own and may include variables like temperature and rainfall.

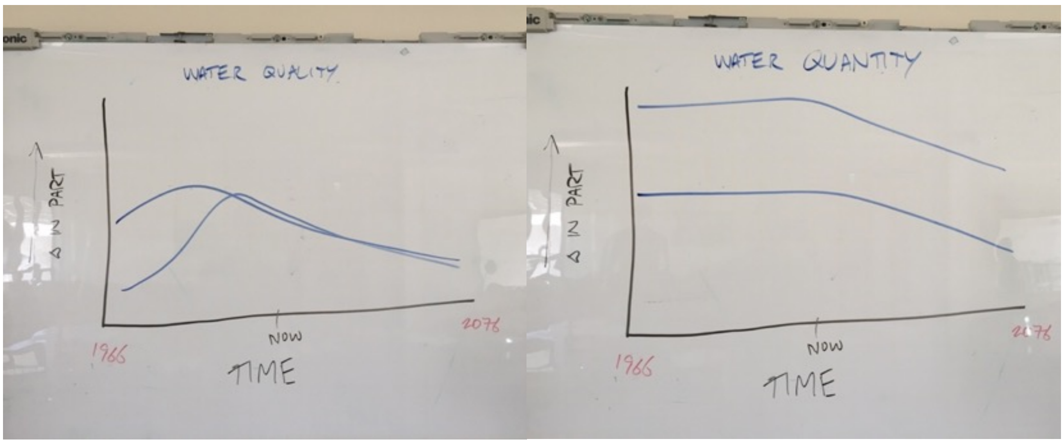
Ex-post analysis of the workshop found that better definitions of the variables could have been captured. While the listed variables were clearly understood in the workshop, recording clearer definitions would help reduce confusion in the future.

4.2.1.7 Reference mode/'behaviour' elicitation

This script sought to identify a reference mode (or behaviour-over-time graph) for each major variable. Rather than doing this as individuals (Luna-Reyes et al., 2006), this was done in *pairs*. This allowed members of the group to *learn from each other*, continuing to develop familiarity as a pathway to developing appreciation and trust of other participants' views (van den Belt, 2004).

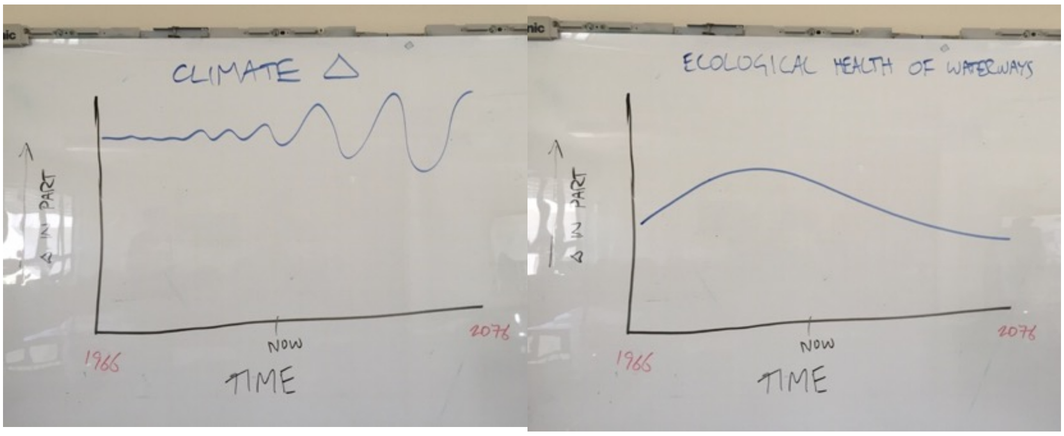
Working on a graph template with variable change on the y-axis and time (1966-2066) on the x-axis, participants sketched the relationships that they thought had and might occur given current practices. Reference modes were only identified for 3-4 variables and provided insight into how well participants responded to this script.

Figure 4.6 Example successful reference modes – note the similarity between groups.



A positive result was that the groups produced similar reference modes for some of the variables (Figure 4.6), and a negative result was that some variables proved very difficult to graph behaviour for (Figure 4.7). This was likely due to them being highly aggregated and spatially diverse within the system being investigated (the region), indicating greater disaggregation may be required if a sharper definition of reference modes was desired. This however seems to be incongruent with building a shared, high-level understanding of a complex system.

Figure 4.7 Example challenging reference modes.



4.2.1.8 System structure elicitation

Up until this script, the workshop had been run by the *facilitator* only, now the *modeller* also became a prominent role (Luna-Reyes et al., 2006). The modeller drew the model using a document projector[10], and the graphic was projected onto the screen from where the facilitator coordinated the discussion. Starting with the most-important variables, the group:

1. Added each variable to the model.
2. Identified each as a stock, flow, or other influencing variable.
3. Drew connections between it and other variables.

An image of the model in progress is shown in

Figure 4.8 and the final model is shown in Figure 4.9.

10 A document project is the modern equivalent of an overhead projector, which is what was used by Luna-Reyes et al. (2006).

Figure 4.8 Using the document projector to draw the system.

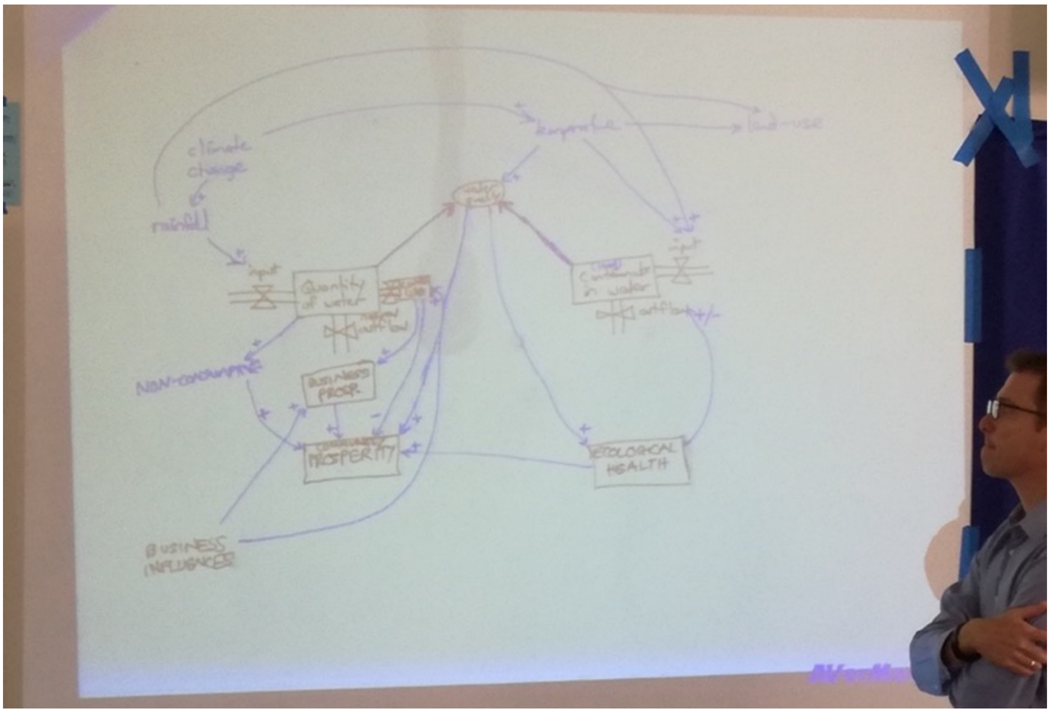
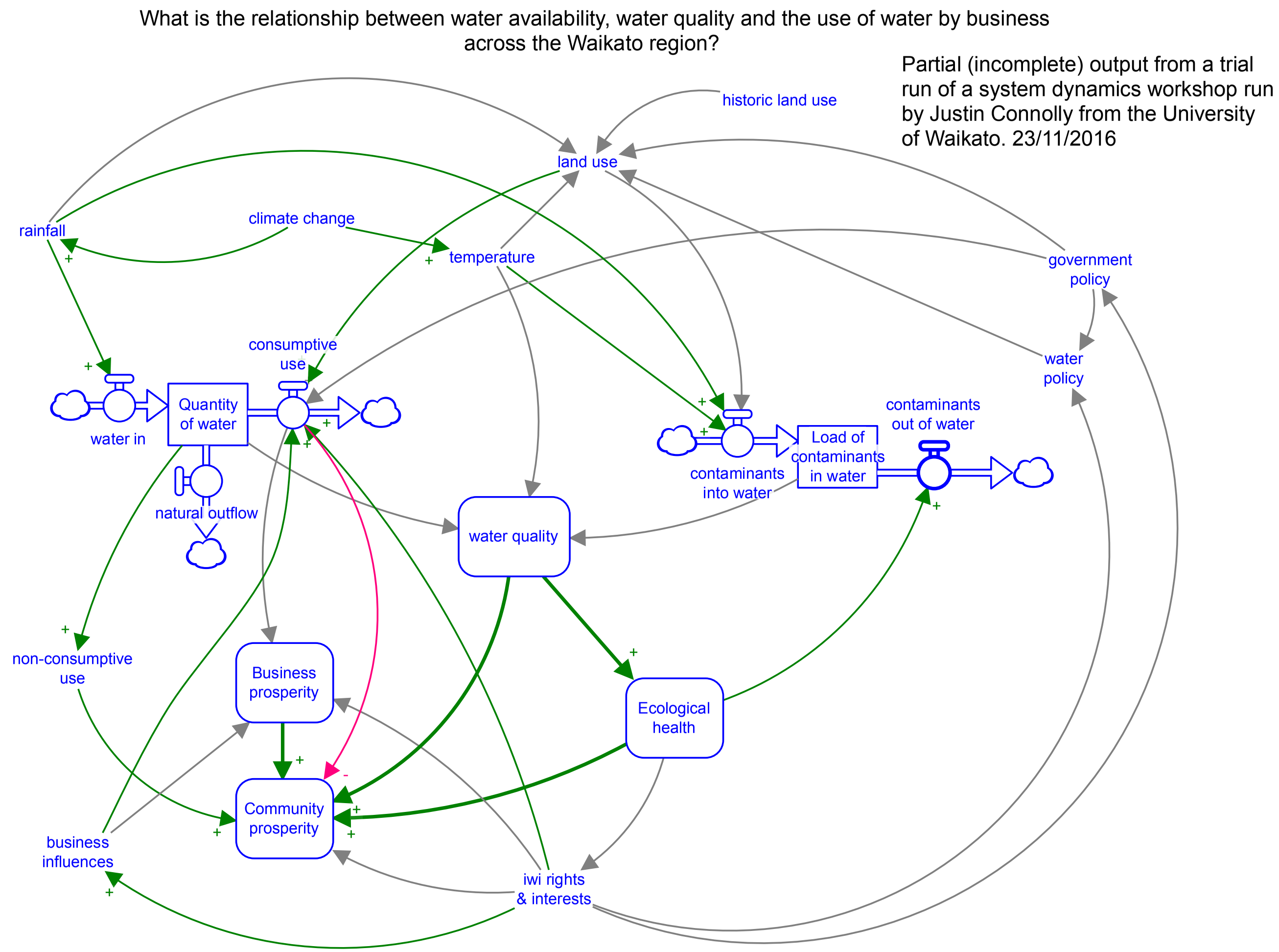


Figure 4.9 Test workshop I – output model.



Overall this script was successful and there were two important parts to it. The modeller produced a tangible result of the discussion in the model diagram; and the diagram generated discussion about the interdependency of elements within the system.

This second part was highly valuable in terms of promoting group learning, given that people from a range of backgrounds were involved, and it was much more difficult to document. This would only have been possible if it was recorded electronically or someone was present to transcribe – highlighting the importance of the 'recorder' role (Richardson & Andersen, 1995).

The communication between both technical and non-technical participants was good and all views were appreciated. All people seemed to learn something, which appeared to be consistent with the high-quality group communication that is intended in GMB (van den Belt, 2004) and has been reported in previous GMB processes (Scott et al., 2016b). This is likely to be a result of the type of double-loop communication described by Argyris (1994) that the process enabled, which allowed a dialogue around issues and increased participants' understanding (Doyle & Strauss, 1976).

The use of clear acetate layers for drawing the model (Luna-Reyes et al., 2006) was found to be cumbersome. As the model was not based on 'sectors' (van den Belt, 2004), it was difficult to know when new layers should be added. Wet ink tended to run when acetate layers were added and sometimes a connection drawn earlier needed modification and so layers of acetate would have to be removed to access it. Their use generally made drawing the model more difficult.

4.2.1.9 Summary of lessons from pilot workshop I

The lessons from the first pilot workshop were:

- **Time was a challenge**. Only one day was available to apply the first workshop from Luna-Reyes et al. (2006), this would be difficult.
- **Both technical and non-technical participants** demonstrated an ability to **grasp the concepts of SD (**CLDs and stocks & flows).

- **Understanding the polarity of relationships in CLDs was difficult**. The alternate use of ***'same'*** (positive) and ***'opposite'*** (negative) terminology may be less confusing (Sterman, 2000).
- The **key variables** defined in the focus question **should be assumed** as variables in the model.
- The use of the **document projector was a success**, while the use of **acetate layers for drawing the model in layers was unsuccessful.**
- Participants struggled to determine **reference modes/behaviour**. Not all variables necessarily HAD a reference mode (aggregation issues) or geographic diversity was a problem (spatial issues).
- **When eliciting variables**, it was necessary to ensure people **focus at as high a level of aggregation** as possible and generate a limited number of variables.
- **Too many concepts were introduced to the participants** in the introduction session for them to understand (e.g. CLDs AND stocks and flows).
- **The region-wide approach was problematic** for this example.

4.2.2 Pilot workshop II – Bay of Plenty

Once the BOPRC confirmed their involvement in the research, an initial meeting was required as part of the preparation (Luna-Reyes et al., 2006). This meeting with staff – some of whom had a basic understanding of CLDs – was used to run a second pilot workshop. This would also familiarise support staff with the research.

Learning from the first pilot-workshop and responding to the research objectives, the following amendments were made:

- **The workshop was run by one person** acting within both the facilitator and modeller roles (Richardson & Andersen, 1995).
- **A sticky wall and paper was used to build the model**, instead of a document camera.
- **A whiteboard was used to collate the variables** instead of a sticky wall (this was as per Luna-Reyes et al. (2006)).

- **No explanation of a CLD was provided**. Familiarisation with the concepts of stocks and flows would be the focus.

This process was run with a group of eight staff members in November 2016 (for 3.5 hours again). All had experience of freshwater issues including policy, science, stakeholder engagement and communications.

4.2.2.1 Structure of the process

The process was again run according to Luna-Reyes et al. (2006) within a constrained time frame. The objective was to test all the scripts, not necessarily complete them. Table 4.3 shows the workshop structure.

Table 4.3 Structure of pilot workshop II.

Session	Description
Introduction	Researcher introduces himself and outlines what the day hopes to achieve and how it will be structured.
Script 1 - hopes and fears (divergent)	A warm-up activity is undertaken to ‘break the ice’ and to help introduce participants to each other.
Script 2 - SD and the concept model (instructive/convergent)	A brief presentation and explanation of what SD is and how it can be used.
Focus question	Focus question is introduced.
Script 3 - variable elicitation (divergent)	Identifying the variables (‘parts’).
Script 4 - reference modes elicitation (divergent)	Identifying the reference modes (‘behaviours’).
Script 5 - model structure elicitation (convergent)	Identifying the system structure.
Script 6 - reflect and confirm model structure (convergent)	Reflect the model back to the group and confirm it reflects what they have developed together.

4.2.2.2 Introduction

A simple introduction again began the workshop and the objectives for the research were outlined. The focus question was outlined and reiterated later (section 4.2.2.5).

4.2.2.3 Hopes & Fears exercise

This script was run the same as in the first pilot workshop and was again quite successful, providing an interactive way to begin and introduce everyone.

4.2.2.4 What is System Dynamics? (concept model)

This presentation was amended to focus on introducing the group to the conditions that lend themselves to SD models (complexity, feedback, dynamic behaviour etc.) and the main components of SD simulation models (stocks and flows as per Sterman (1994)). No explanation or example of a CLD was given, in contrast to the first pilot.

The analogy of a bathtub to describe stocks and flows was again used (Richardson & Pugh, 1989; Sterman, 1994) and was perceived to be well understood.

A simple example of a SD model was explained – a bank account with a regular deposit being made into it with no withdrawals. The model architecture was described and explained (Figure 4.10), then an example of model output was provided and explained (Figure 4.11).

Figure 4.10 Example model structure – bank account

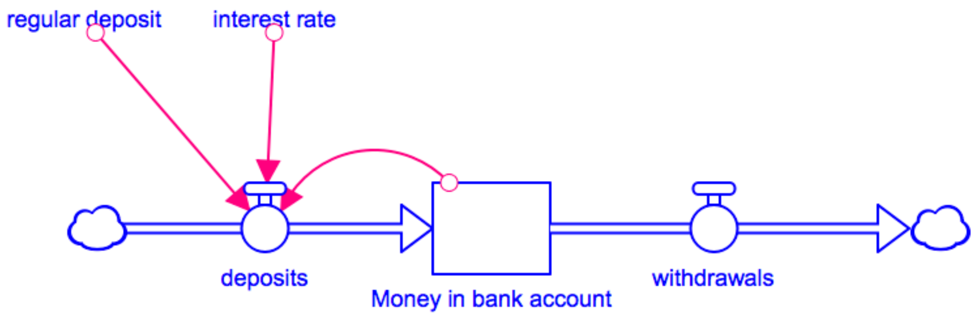
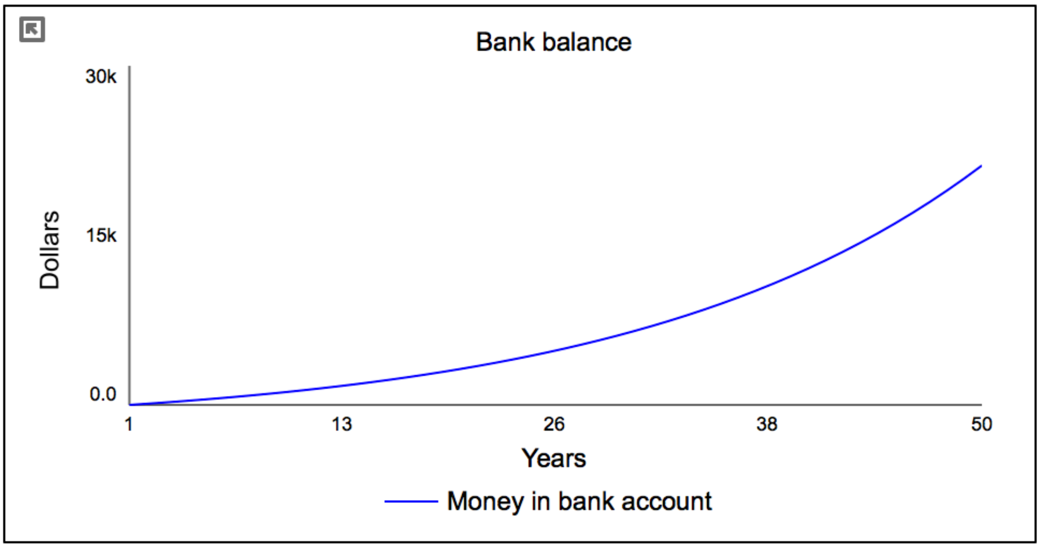


Figure 4.11 Example model output – bank account



This was simple, accessible and well received, presumably as everybody has a bank account. It avoided the subject matter of freshwater and any potential controversy with this. The predator-prey model was then described (as in the first pilot workshop – see Figure 4.4 and Figure 4.5). This took more effort to explain, as it was more complex than the bank account example and again added time pressure.

Unlike the first workshop, participants found the concept and structures of stock and flow models accessible and understood them after some discussion. However, like the first pilot workshop, participants struggled to absorb and understand two different examples, leading to confusion.

4.2.2.5 Focus question

The focus question was developed with the gatekeeper, who was keen to explore participants' views of how they saw different parts of a system being connected. The focus question was:

> *What variables and relationships influence and are influenced by freshwater in the Rangitāiki catchment?*

4.2.2.6 Variable elicitation

This script was run as in the first pilot workshop and in accordance with the Luna-Reyes et al. (2006) process. Participants brainstormed as many factors as they could and then shared them with the group three at a time, gradually building up a total list. In contrast with the first pilot workshop these were collated on a whiteboard, providing an opportunity to explore if either approach was preferred.

A larger number of variables were elicited relative to the first pilot – 35 in total – with some being obviously aggregated. Discussion identified those agreed as stocks (seven) and voting identified those that participants thought had the greatest impact. These would form the basis of the model (see Table 4.4).

Table 4.4 Variables with stocks identified and ranked (table). The number of ticks next to each item indicates their relative importance, as voted by the group.

	Variable or 'part'		
Stocks	**Biodiversity**	✓	**Level of employment**
	Population	✓	**Business profitability**
	Quantity of land		**Freshwater**
	Food		
Other 'parts'/variables	Land use	✓✓✓✓	Recreation
	Local government policy	✓✓✓	Cultural relationships
	Rainfall	✓✓✓	Temperature
	Central government policy	✓✓	Tangata whenua prosperity
	Farm system	✓✓	Biosecurity
	Consumptive water demand	✓✓	Wants/needs/desires
	Non-consumptive water demand	✓✓	Certainty
	Population health	✓✓	National electricity demand
	Flood management	✓	National food demand
	Hydro dams/lakes	✓	Topography
	Soil characteristics		Climate change
	Discharges (commercial and municipal)		Geomorphology
	Legal responsibilities		Access to information & data
	Land ownership structure		Kaitiakitanga

Those voted most important are underlined, the number of votes they received with is indicated by the number of ticks (✓)

The level of detail that these variables were identified at was much finer than those in the first pilot. For example, national electricity and food demand; legal responsibilities in relation to land; and land ownership structures. This likely reflects the larger group size and the fact that all participants were council staff. Some variables were still unclear and required further discussion that the time frame did not allow.

While useful, this process appeared to overwhelm the participants with the complexity of the situation. It became obvious that it would be difficult to achieve a workable SD model from the variables generated within the time frame.

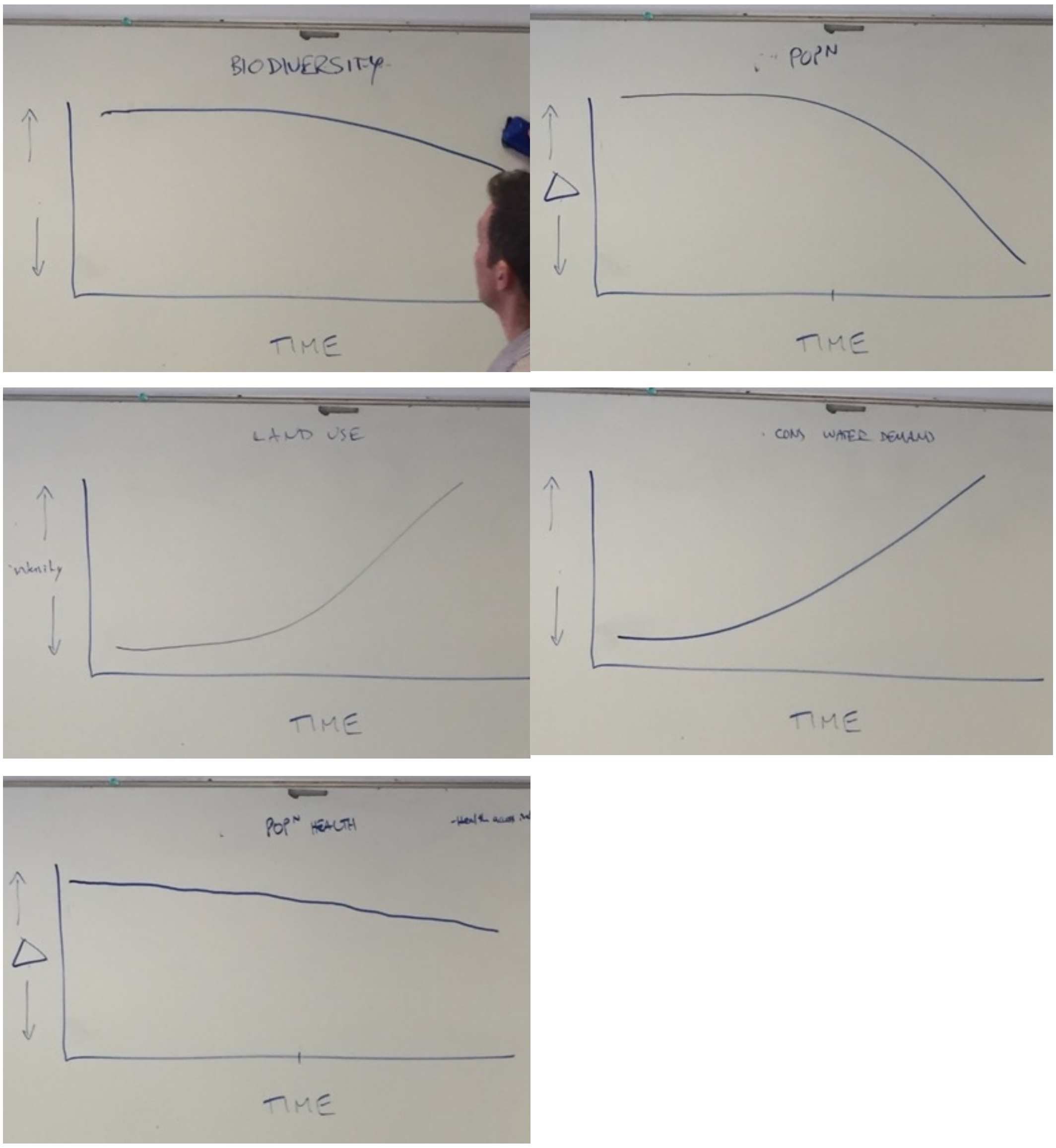
Ex-post feedback from the group also indicated that the facilitator tried to *reinterpret and change the words* of the suggested variables, rather than *capture the words as they were provided*. While the facilitator was trying to evolve those suggestions into variables that would work well in a stock and flow model, this had the *unintended consequence* of disengaging some participants who felt that their suggestions were *not being heard* and captured correctly, or that they were somehow 'incorrect'. This was a valuable lesson from this pilot workshop. The need for independence when facilitating has been highlighted and the role of the facilitator is to guide the *process*, while the role of the participants is the *content* (Doyle & Strauss, 1976; Hunter, 1994). The perceived need to modify and interpret these variables was partly due to having only one person filling the roles of both facilitator and modeller. Interrogating participant suggestions where they were unclear was also *a priori* seen as a strategy to help provide clarity to other group members.

Attempting to limit the number of variables, at least to begin with, was also an insight from this workshop. This was necessary to achieve a model within the time frame and would focus the attention of participants on the variables that they saw as most relevant and perhaps help deliver a consistent level of aggregation.

4.2.2.7 Reference mode/'behaviour' elicitation

In the first pilot workshop participants worked in pairs to develop reference modes and then discussed these as a group. Given time constraints and seeking to test an alternative group approach, this session sought to develop reference modes through group discussion. This behaviour over time was recorded on a whiteboard, while the group discussed how they perceived certain variables had and would continue to 'behave'. This process continued until there was a high level of agreement amongst the group. This was attempted for two of the identified stocks and three of the other variables (Figure 4.12).

Figure 4.12 Example reference modes elicited. Clockwise from top left: biodiversity; population; consumptive water demand; population health; land use.



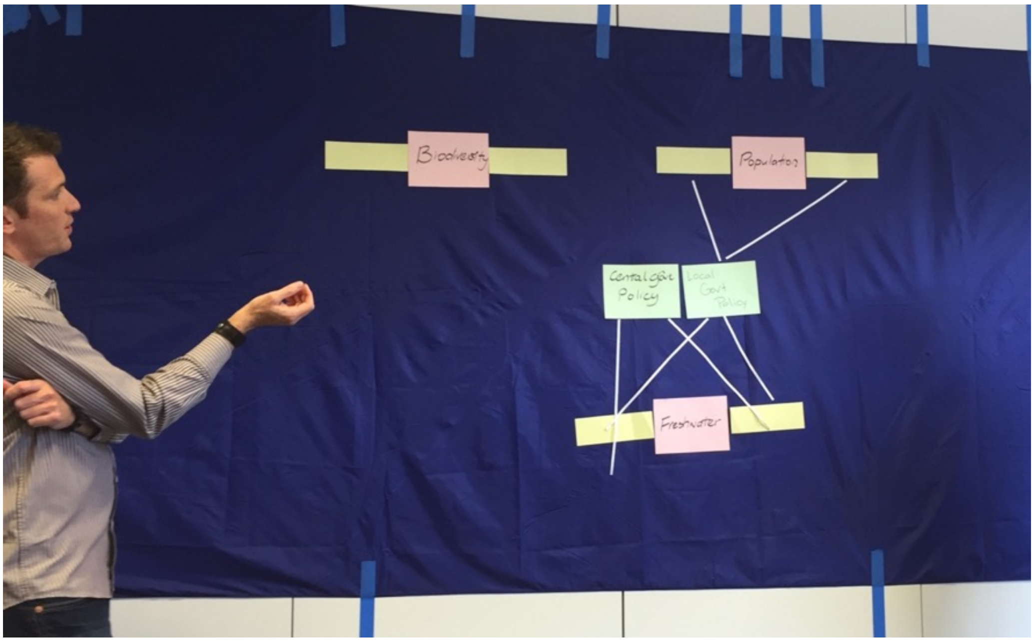
Like the first pilot, some variables were highly aggregated which proved challenging to describe behaviours for. For example, "land use", where it was not possible to describe how the variety of land uses present in the catchment had and may continue to evolve. Instead, this was tied to the *intensity* of land use. Another example was population health which is made up of many indicators – some of which would be available health statistics and others that would not.

It became clear that some participants did not see how this exercise contributed to the overall model. Moreover, they appeared to start being overwhelmed with technical detail and the complexity of the system, and failing to see how this was contributing to the model building.

4.2.2.8 System structure elicitation

This script was structurally the same as the first pilot workshop, but was supported by different technology and numbers of people. Firstly, it was only run by one person – the researcher acting as both facilitator and modeller. Secondly, a sticky wall was used to collate the model, rather than the document camera system. This was to test the option of building a model with paper resources (seeFigure 4.13). Paper was used for stocks and factors and shredded paper or string was used for connections. This method was drawn from the positive response that respondents had to the interactive sticky wall in pilot workshop I – this tool had appeared to keep them engaged in the process.

Figure 4.13 Using a sticky wall to build the model. Red paper was used for stocks, yellow for flows and green for other influencing factors. Shredded paper or string was used to draw the connections.



The sticky wall was highly interactive and highly problematic. The colour-coded paper was useful but the physical act of putting the paper on the wall detracted from the facilitator's ability to moderate the discussion. Part way through the exercise, one of the participants began helping the researcher by placing the paper and connections on the sticky wall, effectively taking the role of the modeller. This was useful and freed the facilitator to focus on the discussion, but created logistical challenges – there were now two people operating in the limited physical space in front of the wall and they kept getting in each other's way, which impacted the flow of the discussion. This approach was also found to take more time and while the paper adhered well to the sticky wall, the shredded paper or string did not and kept falling off.

The final model architecture as it was developed is shown as a photograph (Figure 4.14) and as a STELLA Software model drawn *ex-post* (Figure 4.15).

Figure 4.14 Final unfinished model architecture (photograph)

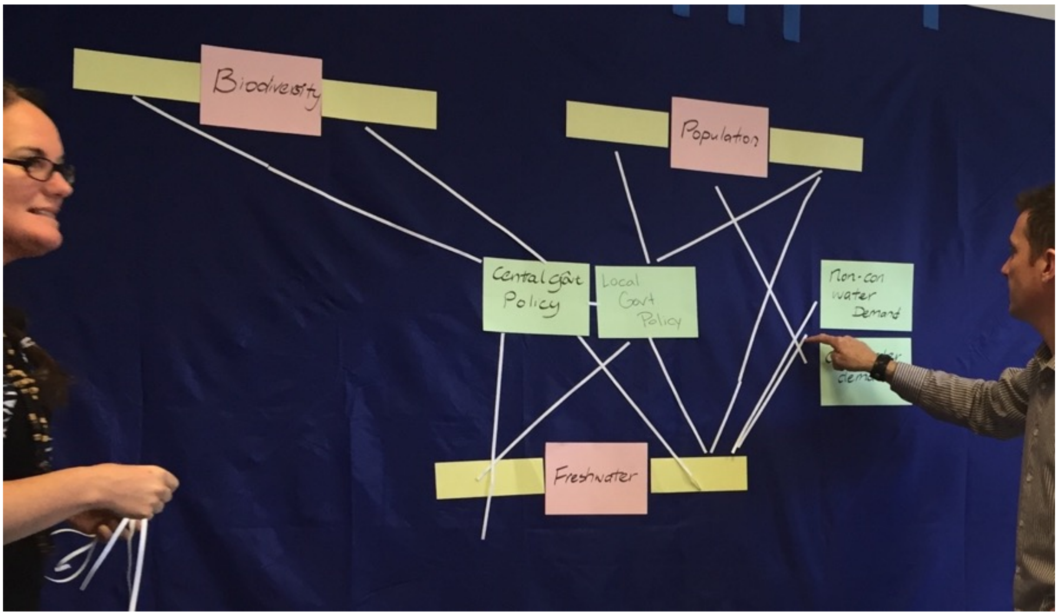
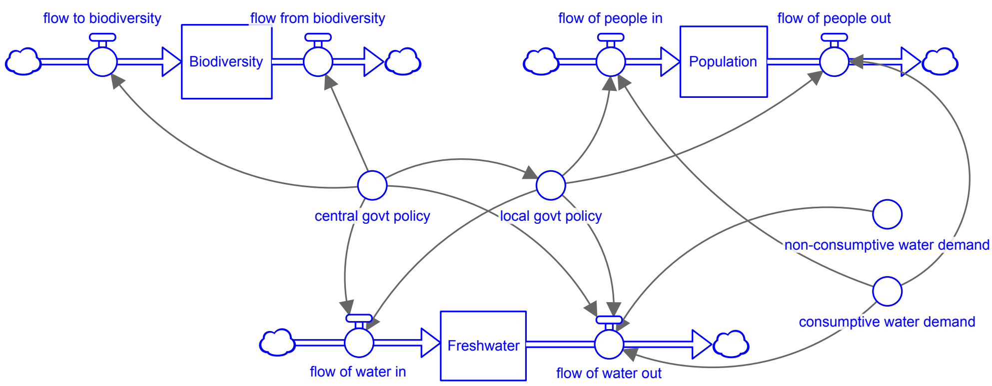


Figure 4.15 Final unfinished model architecture (STELLA)



4.2.2.9 Summary of lessons from pilot workshop II

A summary of the lessons from the second pilot workshop are:

- **Time continued to be a challenge**. Achieving a stock and flow model was an obvious challenge with a larger group.
- **NOT explaining CLDs made it easier to explain stock and flow models**.
- The **concepts of stocks and flows were easily grasped, but not how they worked** in dynamic reality. Research has shown that while

stocks and flows are easy to grasp, translating this conceptual understanding into an accurate understanding of the dynamic relationships between stocks and flows is surprisingly uncommon – even among highly mathematically articulate subjects (Booth, Sweeney & Sterman, 2000).

- **Having two SD examples (i.e. the bank account and predator-prey examples) remained confusing**. While the bank account was easily grasped, the predator-prey model was difficult. Once freshwater had been introduced and modelled there were *three* diverse topics that participants had considered.
- Participants found it **difficult to identify reference modes/'behaviours'** for the variables. this again highlighted issues of aggregation and geographic diversity.
- The **sticky wall was not an effective tool for building the model**. It was cumbersome, slow and unreliable.
- At least **two people were required to run the workshop**. At a minimum, the facilitator and modeller roles (Richardson & Andersen, 1995) are necessary (excluding the gatekeeper).
- **Limiting the number of variables generated** would be useful to focus participants on those most important to them. The literature does not provide guidance on the most efficient or effective number of variables generated, probably because it depends on the number of participants involved and the problem being modelled. However, it is noted that when a group is left with the option to generate an open number of stocks, they tend to generate all that they can think of and, 'analyse details rather than select the most important ones and synthesise the broad lines" (van den Belt, 2004, p. 86).

4.3 Revising the methodology

This research is focused on decision making processes involving stakeholders (internal or external) in a Regional Council policy-development process. This means that the *time* and *resources* that people apply to such processes are limited. To maximise the amount of shared understanding that was generated, subject to these resource constraints, the following amendments to the methodology were made.

4.3.1 Changes to the methodology

The main decision was to *move away* from a methodology that developed a *stock and flow model* as its intended output. Instead, *increasing group learning* and *shared understanding* of the freshwater system through using simpler SD formalisms was selected as the primary approach. *CLDs were selected as the chief tool* to apply to attain this higher-level understanding as this is noted as one of the main benefits of this tool (Sterman, 2000). This approach also seemed to *maximise the available time* (one-day workshops for each project), *funding and resources*, which were likely to be a consistent challenge across other potential sources of application.

While simulation modelling and the understanding that this generates about a system may generally be the aim of SD modelling (Sterman, 2000; van den Belt, 2004; Vennix, 1996), the work of Senge (1990) has shown that huge value can be obtained for organisations simply by having a better qualitative understanding of a larger system and the feedback loops that influence it. Moreover, CLDs and simulation models are not mutually exclusive, CLDs are often used to help develop a shared understanding of a problem before key relationships are quantified and simulation modelling occurs (Maani & Cavana, 2007). In this way, the decision to use CLDs contributes towards increasing the broad and general understanding of the issues and systems being dealt with (Vennix, 1996). This may provide an ideal foundation for future numerical modelling (to achieve the greater level of understanding that this approach is generally believed to deliver (Maani & Cavana, 2007; van den Belt, 2004; Vennix, 1996). Yet, the effort required to achieve robust simulation modelling is likely to be significant and should not be underestimated (Sterman, 2000; Vennix, 1996). Indeed, this was a key lesson from both pilot decision conferences. So, in relation to the objectives of this research – particularly the ability of SD to be applied within the *constraints of limited resources* – a focus on developing a widely understood and broadly supported *CLD is likely to be the best output from this approach*. This, of course, does not preclude any CLD from informing further detailed simulation modelling on a project, whether developed via GMB or not.

The time in between workshops was spent analysing the CLD for common patterns or system archetypes that may help with interpretation and application of the CLD. While discussion around possible generic structures in SD emerged in the 1970's and 1980's (Vennix, 1996), system archetypes were popularised by Peter Senge's (1990) successful management book *The Fifth Discipline: The art and practice of the learning organisation*. While the categorisation of archetypes has continued to evolve (Wolstenholme, 1999), those described by Senge (1990) provide a good overview and given the popularity of Senge's work (Warren, 2004) may have been encountered before by participants not familiar with SD – hence they are used here. These are reproduced in Appendix 21. These patterns help provide guidelines to the causes, implications and solution of the counterintuitive behaviour of systems that Forrester had described several decades prior (Forrester, 1971).

The focus on developing a CLD meant that several significant changes were made to the scripts/methodology:

1. The **first workshop** focused on **developing a CLD,** not a stock and flow model, yet a 'scripted' workshop approach was still used (Luna-Reyes et al., 2006; Andersen & Richardson, 1997). This seemed a pragmatic way of testing for an increase in shared understanding of the system (Senge, 1990; Sterman, 2000).
2. The **time in between workshops** was spent **analysing the CLD for any system archetypes** (Senge, 1990), as a way of providing insight into the system. Archetypes can be used to formulate or decompose a CLD (the latter was used here) to build understanding of a system.
3. The **second workshop** focused on **presenting the CLD and any system archetypes** that were identified. As this was still a form of SD analysis, it was like Luna-Reyes et al. (2006), only the output had changed from a stock and flow model to a CLD.
4. Increased focus on ensuring participants had the greatest opportunity to **learn from each other** and increase their level of **shared understanding** (Vennix, 1996) through dialogue and consensus building (Doyle & Straus, 1976; Schein, 1988), as well

as double-loop communication (Argyris, 1994). This was achieved through subtle changes to the scripts that made participants interact and discuss things more (e.g. working in pairs, discussing things with a neighbour).

5. **confusing examples** of CLDs and explanations of **stocks and flows** were **minimised or removed** from the introductory presentation.
6. The eliciting reference modes script was removed and focus put on **defining the most important variables** as a way of assisting groups to reach a level of shared understanding when starting 'from scratch' (Vennix, 1996).
7. **The workshop was run with only three people filling the primary roles of facilitator, modeller and gatekeeper** (the gatekeeper was not necessarily a participant) and a document camera and projector were used to develop the CLD. While Luna-Reyes et al. (2006) utilised all five roles (Richardson & Andersen, 1995), piloting here found the process coach unnecessary if the facilitator was skilled (one person could wear the 'hats' of both roles) and the recorder role unnecessary if the workshop was electronically recorded.
8. The accessible notation of ***same (s) and opposite (o)*** were used for defining the direction of relationships in the CLD, instead of the mathematically correct ***positive (+)*** *or* ***negative (-)***. While criticised for not allowing 'deep enough' thinking about the mathematic and accumulative aspects of causal relationships (Richardson, 1997), piloting this process found this nomenclature an easier concept for participants new to SD to understand (Sterman, 2000).

4.3.2 Overview of revised methodology

While the amendments resulted in quite a different *output* (a CLD), the GMB *process* remained similar.

Firstly, the data analysis components remained unchanged and data would still be collected from participants via surveys and *ex-post* interviews.

Secondly, the GMB process remained a script-based methodology involving a first and second workshop. It also retained many of the same scripts. For example, the *introduction*, *hopes and fears* and the *variable elicitation* script were retained, with minor process amendments – such as using a sticky wall instead of a whiteboard, and structuring more opportunities for dialogue and interaction between participants.

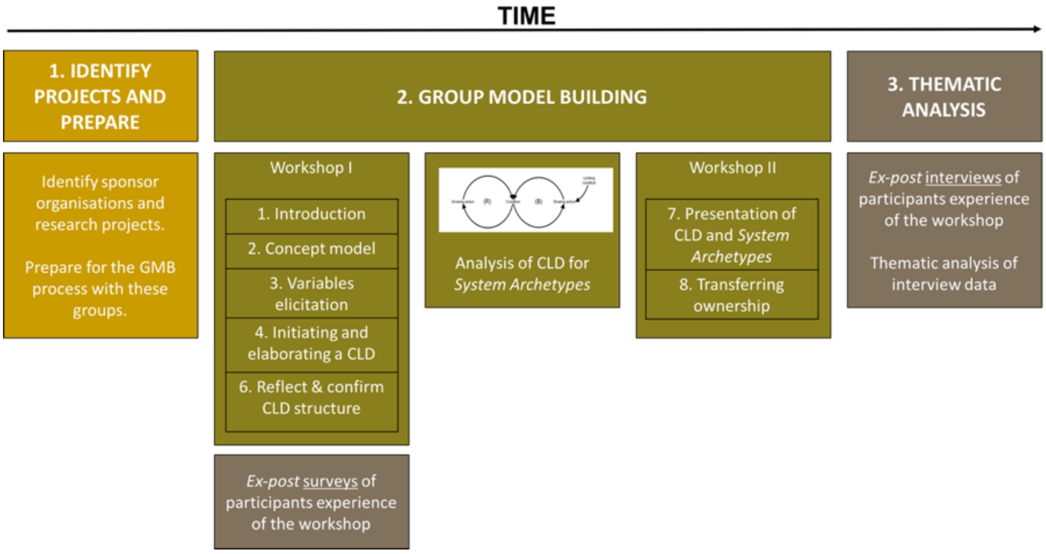
The *three major impacts* on the GMB process were:

1. **Two scripts were replaced with one new one**. The reference modes elicitation and structure elicitation scripts were substituted for the initiating and elaborating a causal loop diagram script from Scriptapedia 4.0.6 (Hovmand et al., 2013). This was similar to the structure elicitation script, taking group generated variables and building up a CLD. This script is explained in more detail in Table 4.5.
2. The time **between GMB workshops** was used to analyse the CLD and **search for *system archetypes,*** or 'common patterns' (Senge, 1990). This was instead of building a simulation model, as per Luna-Reyes et al. (2006). System archetypes are an efficient way of achieving insight into system problems (Senge, 1990) and help increase the shared understanding of participants through establishing the presence of core patterns that are perceived to be important contributors to established problems (Vennix, 1996).
3. The **second GMB workshop** was less of a script-based exercise than **a presentation about the archetypes** found in the CLD. It was not focused on the testing of model structure and sensitivity analysis of parameters, as per Luna-Reyes et al. (2006). A handover of ownership to the group still occurred for the CLD and archetypes.

An overview of the revised methodology is shown in Figure 4.16

below.

Figure 4.16 Revised methodology outline.



A summary of the scripts used to develop a CLD in the single-day workshops for each case study are outlined in Table 4.5. A detailed copy of the scripts is provided in Appendix 12.

Table 4.5 Summary of scripts, revised methodology – workshop I

Script	Description
Workshop I	
1. Introduction and hopes and fears script (amended)	Introduced the day, introduced participants to SD thinking and to the project. This included a ‘Hopes and Fears’ introductory exercise where participants each wrote down their major hopes and fears for the day and had turns sharing these with the group and collating them on the sticky wall. This helped to identify the expectations and concerns in the room, as well as identify areas of shared hopes and fears. The order that these are shared also provided insight into the relative priority in which these were held. This script was modified in the following ways: • It was **combined with participant introductions** to save time (participants introduce themselves and then describe their hopes and fears). • Participants were limited to **one hope and one fear** each. • Paper **colour was specified**: hopes were green and fears were red. • **Participants were actively and physically involved** by placing their own paper on the wall and by helping the facilitator identify themes. • A **sticky wall** was used to collate papers on the wall.
2. Concept CLD script (amended)	A simple CLD with two or three variables and feedback loops was presented to the participants as an example of what the main components of a CLD can look like. This helped participants visualise the anticipated outcome of the day by introducing participants to what a CLD looks like. This script was modified by no longer being an *interactive script* and simply became a **presentation of a sample CLD**.
3. Focus question	The focus question to guide CLD development was introduced.
4. Variable elicitation	As many variables in the model were identified as possible, trying to identify key stocks to be used in

Script	Description
script (amended)	the model. This also helped define the boundaries of the model. The first part used divergent facilitation techniques to help the group identify and collate as many variables as possible. The second part used convergent facilitation techniques to prioritise variables as a group. This identified the most important/relevant variables and determined if these were stocks, flows or other influencing factors. This script was modified in the following ways: • Participants were limited to generating **no more than six variables** each. • Participants **discussed their variables with each other**, learning about the different levels of aggregation and their own mental models from each other. • Participants were asked to group their six variables into **two groups of higher and lesser importance**, before sharing these with the wider group. • **Clusters** of variables labelled by the group became **new variables**. • **Participants were actively and physically involved** by placing their own paper on the wall and by helping the facilitator identify themes. • A **sticky wall** was used to collate papers on the wall.
5. Initiating and elaborating a Causal Loop Diagram	The variable(s) relating to the problem statement were placed at the centre of the screen/board. Ideally, a reference mode for this variable was available, around which to 'anchor' the discussion. Taking one variable at a time from the groups list, variables were added that ***cause*** a change in the problem variable. Drawing as discussion progressed, a range of feedback loops was elicited that were agreed by the group to cause the problem in the variable. After the *causes* have been identified, those variables that were influenced as a ***consequence of a change in the problem variable*** were added. Different feedback loops were then identified. This script was supported using a data projector and document camera, with the facilitator guiding the

Script	Description
	conversation and the modeller/reflector drawing the model structure.
6. Reflect and confirm model structure script	This script began with a reflection back to the group of the draft CLD that had been developed. This brought workshop I to a close and provided the material for the researcher to analyse the CLD for system archetypes.
In between workshops	
Analysis	The outcome of Workshop I was a draft CLD. The researcher took this away and formalised it in CLD software. It was then analysed for system archetypes, according to those described in Senge (1990).
Workshop II	
Presentation of CLD analysis and system archetypes identified	Workshop II was a presentation of the formalised CLD developed in Workshop I and any system archetypes identified within it. This was not strictly a script, but more a presentation from the facilitator. It incorporated any significant changes that the group identified as required. At termination of the workshop, the facilitator asked the group for their permission to confirm the structure of the CLD and endorse it to the council for use in the project.

This revised methodology is applied to two case studies; one involving BOPRC and the other involving WCRC. The application of the updated process to both case studies is described in the next section.

5 Results of the GMB process

The previous section outlined the methodology that was used in each of the research projects. This section will present each of the two projects in the research in more detail, and describe how each was run and what the outputs of these were.

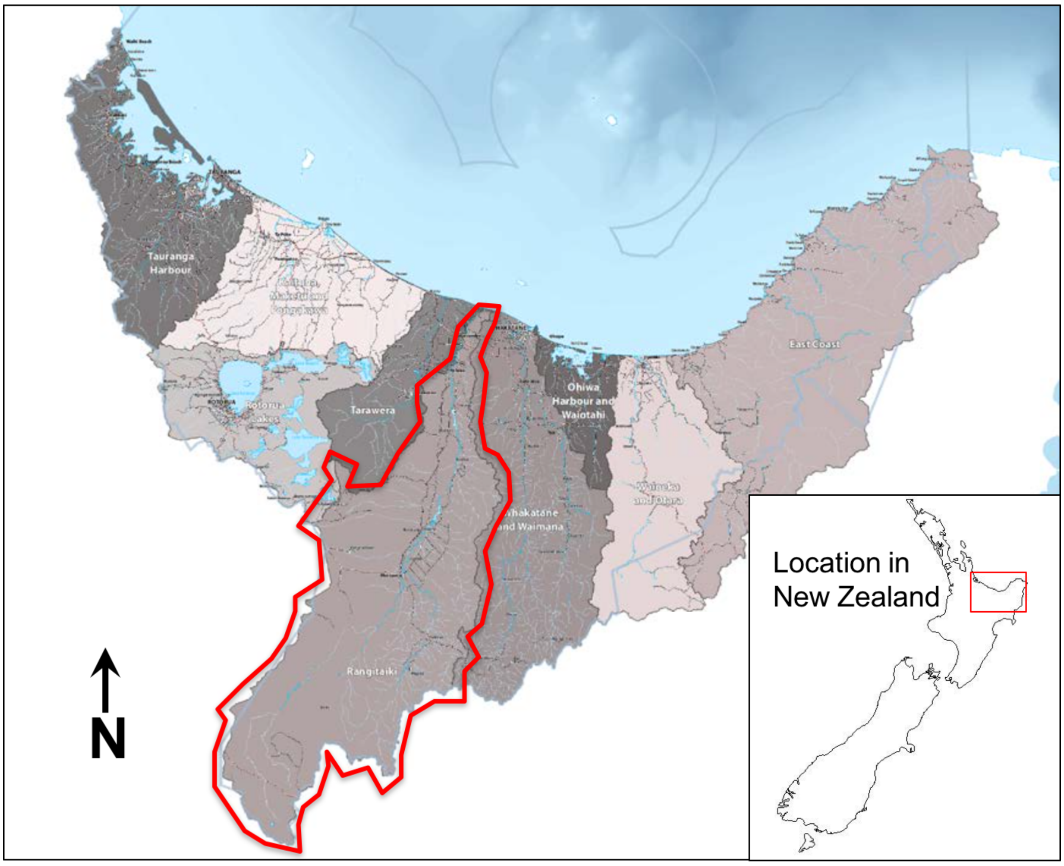
5.1 The projects

5.1.1 Project I: Rangitāiki catchment, Bay of Plenty

The first of the two projects were run in the Rangitāiki catchment in the Bay of Plenty Region of the North Island.

The Rangitāiki catchment is one of nine Water Management Areas (WMAs) in the Bay of Plenty region. An indicative overview of it is provided in Figure 5.1.

Figure 5.1 Indicative map of Bay of Plenty Water Management Areas, with the Rangitāiki catchment highlighted.



This map is adapted from one provided in Bay of Plenty Regional Council (2016).

The workshops were run with a sub-group of 10 people from the Rangitāiki Freshwater Futures Community Group that was working with BOPRC to develop recommendations for implementing the *NPS-FM 2014*. Estimates for the number of people that can be involved in a GMB process range from 5-25 (van den Belt, 2004; Vennix, 1996), indicating that 10 was an intermediate and appropriate amount.

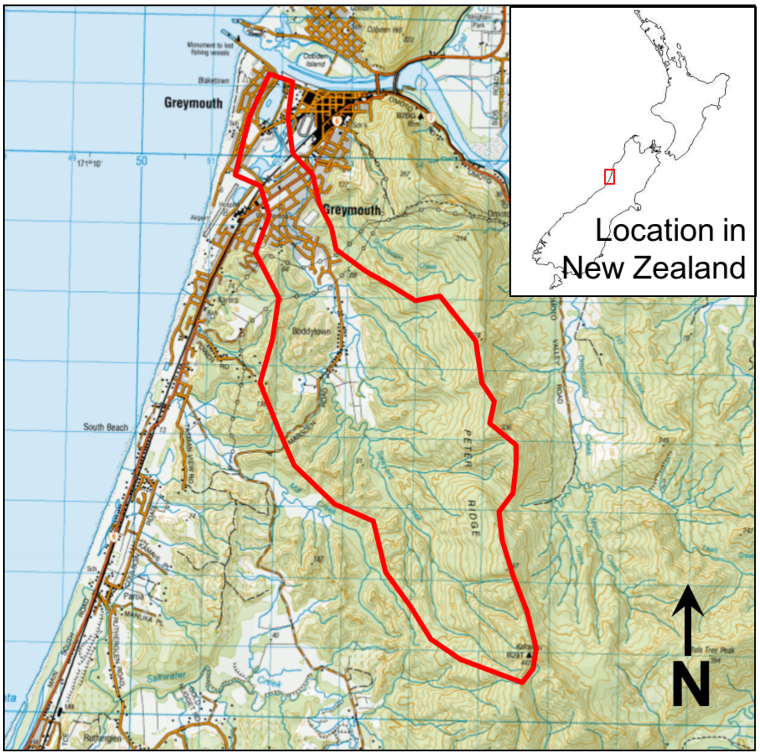
The first workshop was held in December 2016 and the second was held in February 2017. Both were approximately five hours long.

5.1.2 Project II: Sawyers Creek catchment, West Coast

The second of the two projects were run in the Sawyers Creek catchment in the West Coast Region of the South Island.

Sawyers Creek is a small stream that originates in the hills east of Greymouth and passes though the southern urban areas of Boddytown and Greymouth before joining the Grey River a few hundred metres before it discharges into the Tasman Sea. An indicative map of the Sawyers Creek catchment is provided in Figure 5.2.

Figure 5.2 Indicative map of Sawyers Creek catchment.



The approximate area of the Sawyers Creek catchment is shown on the above topographical from https://www.topomap.co.nz. Accessed on 29 May 2017.

To help explore the issue of *E. coli* contamination in waterways, WCRC gathered an informal collection of representative stakeholders together for the workshop, as no existing group had yet been formed. A total of six participants attended the first workshop. This group was made up of two regional-council staff members; one district-council staff member; one district councillor; one district health-board staff member; and a resident from the catchment who was also a part-time farm manager for small landholdings in the catchment. This number was around the minimum suggested for a GMB process (van den Belt, 2004; Vennix, 1996). Comments analysed in the thematic analysis (see Section 10.7) indicated that while greater representation could have been beneficial, there seemed to be adequate representation of diverse views in the group.

5.2 The first workshop

This section provides an overview of the experience of the first workshop for both projects.

5.2.1 Introduction

The importance of first impressions are well known and it has been shown that people are able to accurately predict the personality characteristics and traits of people with 70% accuracy within five minutes of being exposed to their behaviour (Ambady & Rosenthal, 1992). The introduction was an important opportunity for both the sponsoring council and the researcher to create a good first impression.

5.2.1.1 Introduction: Project I – Rangitāiki River

The Council's relationship manager for the Rangitāiki catchment area introduced the day and then the lead policy planner (who was acting in the 'gatekeeper' role (Richardson & Andersen, 1995)) quickly summarised the BOPRC *NPS-FM 2014* process that had occurred to date. They described how this research was both in addition to the existing process and experimental in nature.

The researcher then introduced himself and outlined his past professional experience, what he was currently studying and his research interests.

This entire section was brief, as intended. There was a sense that the group were keen to get going and thus little time was spent on providing much detail with regards to the background of the researcher.

5.2.1.2 Introduction: Project II – Sawyers Creek

The project sponsor and 'gatekeeper' (Richardson & Andersen, 1995) introduced the workshop and summarised the problem being investigated. This was that the creek failed the *NPS-FM 2014* bottom line (the lowest threshold consistent with appropriate water quality for this attribute) measurement for *E. coli*. It was explained that while informal, it was hoped this process would help council better understand the things contributing to the *E. coli* issue, both in this catchment and others.

The researcher introduced himself and outlined his past professional experience, what he was currently studying and his research interests.

5.2.2 Hopes and Fears script

The amended hopes and fears script (discussed in Section 4.3 and provided in Appendix 12) was used here. A summary of it is provided in Table 5.1. This section describes the use of this script in the two case studies.

Table 5.1 Summary of amended Hopes and Fears script used. Amendments are listed.

Introduction and hopes and fears script (amended)	Introduced the day, introduced participants to SD thinking and to the project. This included a 'Hopes and Fears' introductory exercise where participants each wrote down their major hopes and fears for the day and had turns sharing these with the group and collating them on the sticky wall. This helped to identify the expectations and concerns in the room, as well as identify areas of shared hopes and fears. The order that these are shared also provided insight into the relative priority in which these were held. This script was modified in the following ways: • It was **combined with participant introductions** to save time (participants introduce themselves and then describe their hopes and fears). • Participants were limited to **one hope and one fear** each. • Paper **colour was specified**: hopes were green and fears were red. • **Participants were actively and physically involved** by placing their own paper on the wall and by helping the facilitator identify themes. • A **sticky wall** was used to collate papers on the wall.

5.2.2.1 Hopes and fears script: Rangitāiki River

As the group was an existing group, there was a desire to move as quickly as possible into the discussions regarding variables and CLD structure and removing this script was considered.

However, the retention of this script, even in an abridged form, was considered important by the gatekeeper and facilitator as it gave the participants an opportunity to speak early on and hear any comment that might be best to acknowledge, rather than participants 'holding on' to any comments that may distract them from participating.

It was outlined that more about the process would be explained soon and participants were asked if they would like to verbally raise any hopes or fears for the day, based on the briefing document that they had read. In a deviation from the script, any participant could opt out of voicing either a hope or a fear, or writing them down.

A couple of questions were raised. One related to the simplistic nature of the sample diagram and the possibly of this being problematic for the level of detail required for decision-making. It was explained that the challenge for the group was to keep the variables and links at as high a level as possible to be understandable, but as detailed as possible to be of use. It was outlined that all participants brought different views and that it was hoped that the upcoming discussion about how the variables fitted together would help allay some of the concerns raised in this regard.

A second participant outlined their frustration that the river was being degraded and that the dam structures had contributed/were contributing to this. This was noted as an example of the inter-connected thinking that would be explored when building the CLD, so these concerns were allayed until the CLD-building stage.

No further major concerns were raised.

5.2.2.2 Hopes and fears script: Sawyers Creek

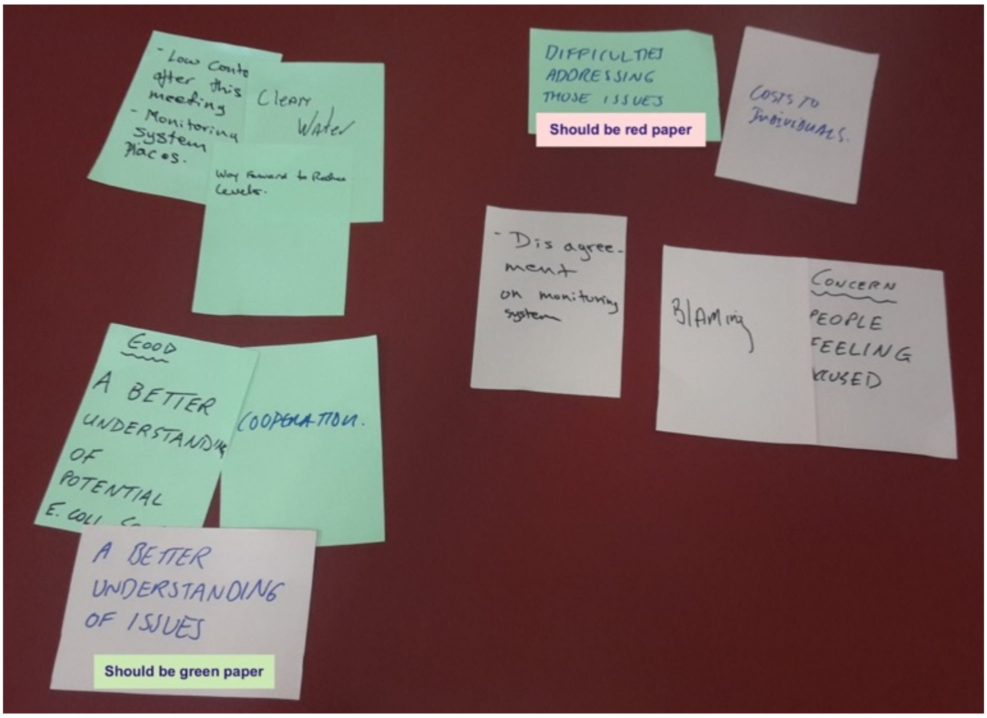
The Sawyers Creek group was convened for the first time (unlike Rangitāiki) and some participants were only meeting for the first time. Therefore, the script was used as outlined in Appendix 12, this introduced everyone and provided context from them on what they expected from the day.

Participants wrote one 'hope' and one 'fear' each and, while standing around the sticky wall, took turns introducing themselves, explaining their 'hope' and 'fear' and placing them on the sticky wall. The researcher then actively worked with the group to identify any similarity/commonality amongst the hopes and fears and if any themes could be identified.

The main **hopes** were: that a *better understanding* of the issues would emerge; that this work would help *identify a way forward* and that it would help achieve *improved water quality* in the future.

The **fears** related to: *people feeling blamed* or accused of causing the contamination issues; *potential disagreement* and the *difficulties and costs* associated with addressing the issue. These are shown in Figure 5.3 and Figure 5.4 below.

Figure 5.3 Hopes and fears identified by participants – photograph.



In the above image, the 'hopes' are written on the green paper (left hand side) while the 'fears' are written on the red paper (right hand side).

Figure 5.4 Hopes and fears identified by participants – table.

Low contam(ination) after this meeting Monitoring system in place	Clean water	Way forward to reduce levels
A better understanding of potential *E. coli* contam	Cooperation	A better understanding of issues
Difficulties addressing those issues	Costs to individuals	
Blaming	People feeling accused	
Disagreement on monitoring system		
LEGEND:	Green = Hope	Red = Fear or Worry

In the above diagram, the 'hopes' are noted in green squares and 'fears' in red squares. Those on the same line were grouped together by the participants.

5.2.3 What is a CLD? (the Concept CLD script)

Given the change to a CLD focus (see Section 4.3), this script was modified to provide a brief introduction presentation to SD and CLDs. It covered the concepts of:

- a CLD being a representation of a system;
- CLDs being a shared representation of how different people view the world (combined mental models);
- describing what a factor (or variable) was: and
- presenting and talking through a simple static example of a CLD.

A summary of the amended script is provided in Table 5.2.

Table 5.2 Summary of amended Concept CLD script used. Amendments are listed.

Concept CLD script (amended)	A simple CLD with two or three variables and feedback loops was presented to the participants as an example of what the main components of a CLD can look like. This helped participants visualise the anticipated outcome of the day by introducing participants to what a CLD looks like. This script was modified by no longer being an *interactive script* and simply became a **presentation of a sample CLD**.

The presentation explained SD as an accessible representation of an overall system – a system being a combination of variables or 'factors'[11] that could be anything that we define it to be. A CLD was explained as a tool to help understand the linkages within the wider system and their broad relationships and impacts over time, rather than focusing on certain parts in detail.

It was explained that the focus on high level factors was deliberate and helped map out an overall system. This may provide context for any specific, more-detailed studies that may be commissioned at a later stage.

CLDs (as a sub-set of SD) were outlined as being useful when systems are complex, relationships are non-linear, feedback is a feature of systems, understanding connectivity between issues is important, time delays between cause and effect are evident and there is be a lack of detailed data available (Sterman, 1994).

11 Most literature uses the term 'variable' when talking about variables in CLDs. to avoid confusion with some group members the term 'factor' was often used as this was considered more accessible. In descriptions of CLDs in this thesis the terms 'variable' and 'factor' are interchangeable.

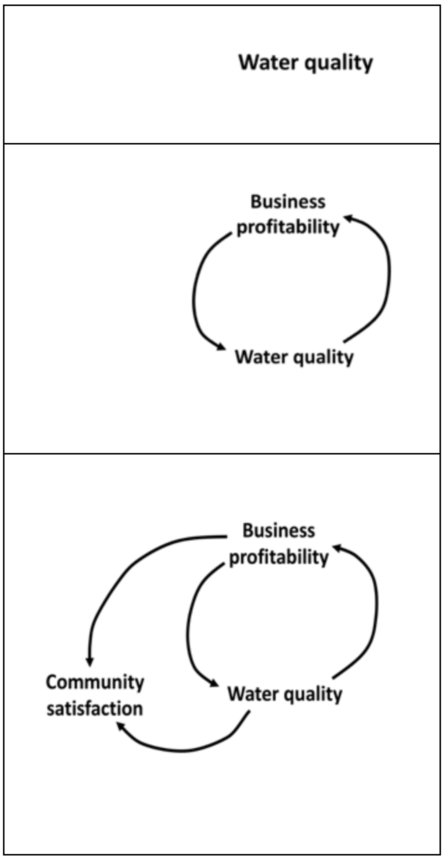
A **variable** was explained as something that can be *quantified OR qualified*, where the level or amount might change. The following examples were provided and discussed, note the use of *tangible and intangible* examples:

- Population of a town.
- Intensity of farming activity.
- Level of rainfall.
- Customer satisfaction.
- Profitability.
- Professional reputation.

An **influence** was explained as being interchangeable with 'connection' or 'relationship'.

The sample concept CLD was presented and discussed. This provided an opportunity to explain how different influences are not always linear and may end up in conflict with each other (see Figure 5.5 for an explanation of the influences in the concept model). It was also an opportunity to discuss issues of aggregation that were likely to arise and field questions about the concept of CLDs.

Figure 5.5 Concept model used in both projects and built up in stages.



1. *We start with a central factor (or factors). We want to explore the connections of this factor to other factors in the system.*
2. *We then identify other factors and draw the connections between them.*
   For example, if water quality is low, it may need to be treated before being used by businesses, which costs more money.
   Also, efforts to improve business profitability might drive the amount of treatment water receives before it is discharged; therefore, it is also linked to water quality.
3. *Other factors are identified and connections drawn.*
   For example, community satisfaction is identified as an important factor. Improved water quality and business profitability both improve community satisfaction.
   However, the first set of connections we identified (between business profitability and water quality) highlight a tension between these two factors. This is an example of a system where problems have no clear, single solution.

5.2.3.1 What is a causal-loop diagram: Rangitāiki River

In the observation of the researcher, this part of the workshop was well received by participants. It became apparent that participants started to appreciate how some influences could be conflicting. This was demonstrated when the group talked through the example in Figure 5.5, where there was a positive relationship between both business profitability and water quality on community satisfaction, but a potentially negative relationship between business profitability and water quality. Questions were also asked about the level of detail that was best to include – acknowledging that this example had been deliberately kept simple. This indicated the level of aggregation would be important with this group.

5.2.3.2 What is a causal-loop diagram: Sawyers Creek

As with the first group, when the concept CLD shown in Figure 5.5 was discussed, an increased understanding that some influences could be conflicting was observed with participants. In general, the concepts were well received and seemed clearly understood and overall there were few questions. It was observed that participants were keen to progress with the CLD-building.

5.2.4 Focus question

The focus question for both groups had already been provided in the briefing documents that were provided in advance to the participants. While not a specific script, this was an opportunity to restate the focus questions for the groups and focus their attention on what they were seeking to understand during the *variable elicitation* and *initiating and elaborating a causal loop diagram* scripts.

5.2.4.1 Focus question: Rangitāiki River

The gatekeeper for the Rangitāiki group hoped that the CLD would develop a clearer understanding of the inter-connections within the freshwater system in their 'water management area'. They expected water availability (for extraction and productive use) rather than water quality would likely be a more difficult issue when they were developing policy in response to the *NPS-FM 2014*. Yet, as it was unclear to the group how both were related, the focus question was outlined as:

What factors <u>influence or are influenced by</u> freshwater quality and quantity in the Rangitāiki WMA?

It is noted that there was a focus on both 'upstream' and 'downstream' influences, so that as many contributing and flow-on factors as possible could be identified.

5.2.4.2 Focus question: Sawyers Creek

As the Sawyers Creek group was dealing with a much more specific issue (*E. coli*), the gatekeeper developed the following focus question:

What are the factors that influence or are influenced by E. coli contamination in Sawyers Creek?

There was still a focus on both 'upstream' and 'downstream' influences so that, again, as many contributing and flow-on factors as possible could be identified.

5.2.5 CLD variable elicitation script

The amended script is found in Appendix 12 and a summary of it is provided below in Table 5.3.

Table 5.3 Summary of amended CLD variable elicitation script used. Amendments are listed.

Variable elicitation script (amended)	As many variables in the model were identified as possible, trying to identify key stocks to be used in the model. This also helped define the boundaries of the model. The first part used divergent facilitation techniques to help the group identify and collate as many variables as possible. The second part used convergent facilitation techniques to prioritise variables as a group. This identified the most important/relevant variables and determined if these were stocks, flows or other influencing factors. This script was modified in the following ways: • Participants were limited to generating **no more than six variables** each.

	• Participants **discussed their variables with each other**, learning about the different levels of aggregation and their own mental models from each other. • Participants were asked to group their six variables into **two groups of higher and lesser importance**, before sharing these with the wider group. • **Clusters** of variables labelled by the group became **new variables**. • **Participants were actively and physically involved** by placing their own paper on the wall and by helping the facilitator identify themes. • A **sticky wall** was used to collate papers on the wall.

It involved a two-step process beginning with participants noting a *limited number* of variables and then dividing these into groups based on their *relative importance* (higher and lower importance). Additionally, to promote teamwork, members were asked to *discuss* these in groups of two or three before partitioning them between the groups designated of higher and lower importance. These amendments were intended to focus participants' minds on both the *level of aggregation* that they were applying to their variables, as well as their *quantity and importance*.

Teamwork was promoted through identifying variables of higher importance (by discussing variables with their peers before rating them) and then by working together to group them into clusters that represented individual factors in the CLD. Once the group was happy with these clusters, the clusters were *named or labelled*. The number of variables identified in this first sorting activity influenced whether the group proceeded directly to building the CLD, or repeated the process with the variables of 'lesser' importance first. Once an adequate number of variables had been identified, they were prioritised via a simple voting mechanism.

The following two subsections describe the experience of this script within the two projects.

5.2.5.1 Variable (factor) elicitation and prioritisation: Rangitāiki River

This activity went well, probably partly because it was an existing group. Discussion was open and receptive and, by chance, most people paired up with someone from a slightly different perspective to their own – e.g. an environmentalist with a farmer.[12]

Working in pairs, participants combined their individual variables into a shared list that represented the aggregated views of the two participants. The group began to do this by themselves, indicating that perhaps the instructions had not been clear enough from the facilitator. With the small group of 10 (5 pairs), it was possible for the facilitator to circulate amongst the discussions. If the group had been larger (e.g. 15-20 people), this would have been more difficult. When the group reconvened, participants observed that there had been many common areas identified, often between non-aligned worldviews. They also noted that it was difficult to keep the factors at a high level, a tension that would remain throughout the workshop.

In their pairs, participants were asked to identify their three factors of 'higher' (numbered with a '1') and 'lesser' (numbered with a '2') importance. All 'higher' importance factors were then put on the sticky wall and the facilitator led a discussion that clustered common factors together. Once the group was comfortable with all the factors and how they were clustered, they generated labels for each cluster (7 in total). This was an example of generating labels for the clusters *inductively from the data* (Braun & Clarke, 2006) rather than making the data fit pre-determined labels.

Participants then added their second factors to the wall, not necessarily to any existing grouping. These were also discussed and clustered as a group.

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12 In reality, the world is not as binary as might often be thought and most participants wore multiple "hats" or would consider themselves to represent many different perspectives. For example, a farmer might also consider themselves to be an environmentalist, or an iwi representative might also strongly identify as a farmer. The pairing of 'perspectives' that is talked about here draws on the *predominant* perspective that the participants were considered to represent or identify with.

Some factors were added to existing clusters and some new groupings were created. This added 7 additional factors, increasing the total number to 14.

The discussion was driven by the participants and so the factors, clusters and labels reflected the groups own words. The factors that the group outlined are listed in Table 5.4 below.

Table 5.4 Factors elicited by the group (not in order), with notations of whether they were generated in either the first or second sort by participants.

Labelled in 1st/2nd sort?	Factor cluster title	Factors included from initial brainstorm	Identified in 1st/2nd sort?
1st	**Land characteristics**	Topography	1
		Soil type	1
		Land suitability	1
1st	**Mauri**	Naturalness of river	1
		Mauri	2
		Fish life	2
		Swimmability	2
		Clarity	2
1st	**Community vibrancy**	Social wellbeing	1
		Cultural practices	1
		Cultures connected	2
		People/ schools/ connected/ cultures/ flourishing	2
1st	**Business adaptability**	Business sustainability	1
		Land use flexibility	1
		Land use	1
		Environmental sustainability	2
1st	**Population**	Population	1
1st	**Climate**	Climate	1
1st	**Financial viability**	Money	1
		Profit	1
2nd	**Climate Change**	Climate change	1
2nd	**Recreation**	Recreational use	2
		Recreation	2
		Recreation	2

Labelled in 1st/2nd sort?	Factor cluster title	Factors included from initial brainstorm	Identified in 1st/2nd sort?
2nd	**Water allocation**	Water allocation	2
2nd	**Structures**	Dams	2
		Lakes	2
		Stopbanks	2
2nd	**Regulation**	Resource consent	2
2nd	**Energy production**	Energy production	2
2nd	**International reputation**	Competitive brand for NZ	2

	Green = this factor was identified in the first sort
	Orange = this factor was identified in the second sort

Photographs of the sticky wall at this event can be found in Appendix 14.

5.2.5.2 Variable (factor) elicitation and prioritisation: Sawyers Creek

This activity also went well with this group. There was open discussion and when people discussed things in pairs there were no two people from the same organisation discussing factors with each other. This helped to increase the diversity of perspectives that were shared.

In Project I, the pairs automatically began developing a combined list to present to the group. In this project, the facilitator was clearer that they were just discussing their choices, and that they would then prioritise them as individuals. After reconvening, the group again observed that there were many common areas, even though people were representing different viewpoints.

The group then marked their three top factors with a ‘1’ and placed these on the sticky wall. These were then sorted as a group to identify common clusters. Once comfortable with the clusters, these were labelled by the group. Again, labelling the factors after they had been sorted and discussed by the group was deliberate and was an example of generating labels *inductively from the data* (Braun & Clarke, 2006).

Unlike Project I, the first round of this process identified a high number of factors (12) and so participants were not invited to add their second factors to the wall at this stage. It was intended that the second 'wave' of factors would be sorted by the group later in the day and that the 12 factors identified by the group in the initial sort would be sufficient to attempt the structure-elicitation script. It was felt that a larger number of factors would have been confusing and this was an example of the flexible and sometimes unclear skills that the facilitator role requires (Richardson & Andersen, 1995). The factors that the group generated in this first wave are listed in Table 5.5 below.

Table 5.5 First-wave factors elicited by the group (not in order). Note the notation where the group identified whether each factor was an 'influencer' or 'influenced' by *E. coli*.

Labelled in 1st sort	Factor group title	Factors included from initial brainstorm	Identified in 1st sort	Influencer of *E. coli*	Influenced by *E. coli*
1st	**Urban run-off**	Stormwater run-off	1	✓	
		Stormwater run-off	1	✓	
1st	**Clean thinking attitude**	People way of thinking (referring to an attitude or sense of value)	1	✓	
1st	**Septic Tanks & Sewerage**	Sewage	1	✓	
		Sewage	1	✓	
		Wastewater	1	✓	
		Intensity of urban development and style of WWT system	1	✓	
1st	**Land use**	Vegetation cover (land use)	1	✓	
1st	**Farming**	Farm	1	✓	
		Farming	1	✓	
1st	**Costs of action**	$$$, costs of mitigations	1	✓	
1st	**Natural characteristics**	Lay of land	1	✓	
1st	**Ecological Health**	Ecological health	1		✓
		Flora and fauna	1	✓	

Labelled in 1st sort	Factor group title	Factors included from initial brainstorm	Identified in 1st sort	Influencer of *E. coli*	Influenced by *E. coli*
1st	**Tourism**	Tourism increase thru image & income	**1**	✓	✓
1st	**Recreational use**	Amenity, people using it	**1**		✓
1st	**Public health**	Human health	**1**		✓
		General health	**1**		✓

*** While generated from the same set of factors, it was acknowledged that *septic tanks* and *sewerage* reflected two different types of land use, so were labelled as separate factors.**

The *initiating and elaborating a causal-loop diagram* script was then run (see Section 4.3). Completion of this task signalled completion of the workshop. All the factors identified had been used in this script and resulted in a very comprehensive CLD.

When the factors marked with a '2' were added to the sticky wall it was found that all additional factors, bar one, were accounted for under the factors that had already been generated or further identified during the *initiating and elaborating a causal-loop diagram* script. The additional factor identified was *regulatory requirements*.

Photographs of the sticky wall at this event can be found in Appendix 17.

5.2.6 Initiating and elaborating a causal-loop diagram script

Having identified the factors to include in the CLD, building a CLD was the next step. As discussed earlier, this was different from the Luna-Reyes et al. (2006) process and is summarised in Table 5.6 below. This script was used un-altered from that available in *Scriptapedia 4.0.6* (Hovmand et al., 2013).

Table 5.6 Summary of initiating and elaborating a causal-loop diagram script, as described in *Scriptapedia 4.0.6*.

Initiating and elaborating a Causal Loop Diagram	The variable(s) relating to the problem statement were placed at the centre of the screen/board. Ideally, a reference mode for this variable was available, around which to 'anchor' the discussion. Taking one variable at a time from the groups list, variables were added that ***cause*** a change in the problem variable. Drawing as discussion progressed, a range of feedback loops was elicited that were agreed by the group to cause the problem in the variable. After the *causes* have been identified, those variables that were influenced as a ***consequence of a change in the problem variable*** were added. Different feedback loops were then identified. This script was supported using a data projector and document camera, with the facilitator guiding the conversation and the modeller/reflector drawing the model structure.

5.2.6.1 Initiating and elaborating a causal-loop diagram: Rangitāiki River

The central factors of water quality and water quantity were placed at the centre of the page where the CLD was to be drawn. Then, all those factors identified in the first sort of important factors were placed around them. The group then worked through each factor and began describing the relationships between each factor that they saw or understood.

At first, this was easy to do with a single factor, but as the discussion progressed many connections began to be drawn between different factors, or a line of influence was traced through various factors. The group was challenged to try and ensure a minimum number of influences were placed on the diagram. Sometimes, this resulted in detailed discussion of an influence that had been described, to ensure that it was captured by an existing *indirect link* via a different factor and not duplicated with an *additional link* between two factors.

After a few influences were drawn and the group was comfortable with the process, the concept of determining whether the influences were the ***same*** quantitatively ('positive') or the ***opposite*** ('negative') was introduced and the group quickly understood these concepts.

Because of the high level of aggregation in this project, the influences — much like the factors that they were present between — often consisted of multiple influences, sometimes with opposing polarity (e.g. one influence was a **same** while another was an **opposite)**. It was therefore not always possible to label all influences clearly with 'same' or 'opposite' labels, although this was done where possible. Developing the CLD took the balance of the remainder of the workshop. Photos of the CLD as it developed are provided in Appendix 14 and the CLD redrawn in specialist software is shown in Appendix 15.

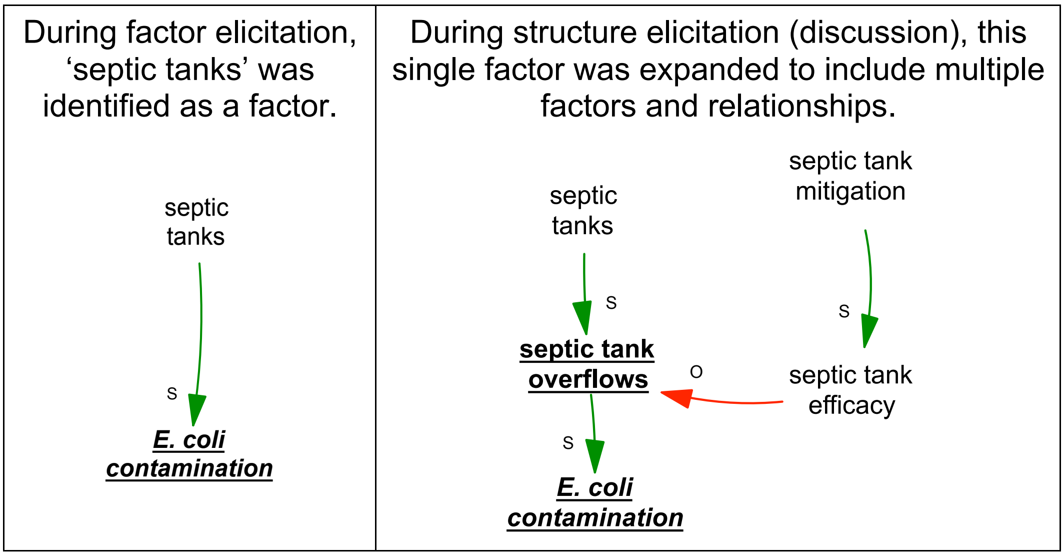
5.2.6.2 Initiating and elaborating a causal-loop diagram: Sawyers Creek

Once again, a document camera and data projector were used to display the space where the CLD would be drawn to the stakeholder group. The focusing factor of *E. coli* contamination was placed in the middle of the screen and those factors that had been identified in the first 'wave' (or 'sort') of factors were slowly added to the diagram as the various relationships were discussed.

Again, the need to determine whether influences were the ***same*** quantitatively (positive) or the ***opposite*** (negative) was introduced after a few relationships had been identified. The group responded well to this, which may have been in part aided by the fact that this focus question was more clearly defined. The terminology of **same and opposite** was easily grasped by the group.

Gradually, the group worked through all the factors that had been elicited, describing the relationships between other factors that they saw or understood. During this script, it became obvious that because of the more focused nature of the question, some factors were more difficult to describe relationships for, and so it was necessary to break some factors down into more detail. For example, when the group considered the contamination that came from ‘septic tanks’, the group identified that contamination did not in fact come from septic tanks, but septic tank *overflows*. The group further identified that septic tank overflows were dependent on the *number* of septic tanks as well as their *efficacy*, and that their efficacy could be improved through septic tank *mitigation*. The facilitated discussion of the group therefore led to the single factor of ‘septic tanks’ evolving into the additional factors of ‘septic tank overflows’, ‘septic tank mitigation’ and ‘septic tank efficacy’ and the various relationships between them (Figure 5.6).

Figure 5.6 Example of factor expansion during discussion – septic tanks.



Eliciting the system structure was the largest part of the deliberative-conference, taking the bulk of the time. However, during that time, many of the factors were broken down into more detail than had been achieved in the Rangitāiki, so the number of factors represented in the CLD at the end of this process was 27, much more than the 12 originally identified. Progress photos of the development of the causal CLD can be seen in Appendix 17. The final CLD has been drawn in Vensim Software[13] and is shown in Appendix 18.

13 While the Rangitāiki CLD was drawn using STELLA, the Sawyers Creek CLD was drawn using VenSim. This provided an opportunity to use both pieces of software in the research.

5.2.7 First workshop summary

This section has described the scripts used and the experience of the first workshop for both projects. This was the main GMB session and introduced participants to the concept of CLDs; introduced participants to each other (if necessary) via the activity of sharing their hopes and fears for the session; generated and prioritised a range of variables for inclusion in the CLD; and spent the bulk of the session initiating and elaborating a CLD.

In the process described by Luna-Reyes et al. (2006), the final script in the first workshop was the reflector feedback script. In this, the modeller took the lead in presenting back the model structure developed by the group, building it up in the layers or parts by which it had been built during the day, telling the ‘story’ of each part as had been elicited during the day. This script was not used at the end of the GMB sessions described above, although informally the sessions were closed with a summary and a reflection on what had been covered by the group. As a single whiteboard was used to draw the CLD (see Section 4.2 for the discussion as to why acetate layers were removed from the process), it was difficult to reflect the model back in stages. In summary, however, there was a general feeling of satisfaction from the groups with regards to the quality and content of the discussions that they had had, coupled with a sense of being overwhelmed by the complexity of the CLD they had drawn.

After this first workshop, the CLDs were drawn clearly in software and analysed for archetypes before being presented back to the groups for discussion in the second workshop. Some minor amendments were then made to the final CLDs for both groups and any archetypes updated. For simplicity, brevity and clarity, the next section describes the experience of running the *second workshop*. As this research is focused on participants’ *experience* of the GMB process, the description and discussion of the *final CLDs* and the resulting *system archetypes* are discussed in Appendix 20.

5.3 The second workshop

This section will describe the scripts and output of the second workshops held for each case study.

The time between workshops was different for each project (see Section 6.3); yet, the workshops were approached in the same way. They began with a 'recap' presentation of the first workshop, which was effectively based on the *reflector feedback* script that Luna-Reyes et al. (2006) had used at the end of the first workshop (see Appendix 11). This began with a reminder of how the group had generated variables, prioritised variables and then worked as a group to build the CLD. The groups were shown a photograph of the 'raw' CLDs drawn during the first session. They were then presented with *parts* of the CLDs drawn more clearly using systems dynamics software, with this gradually being built up into the final CLDs.

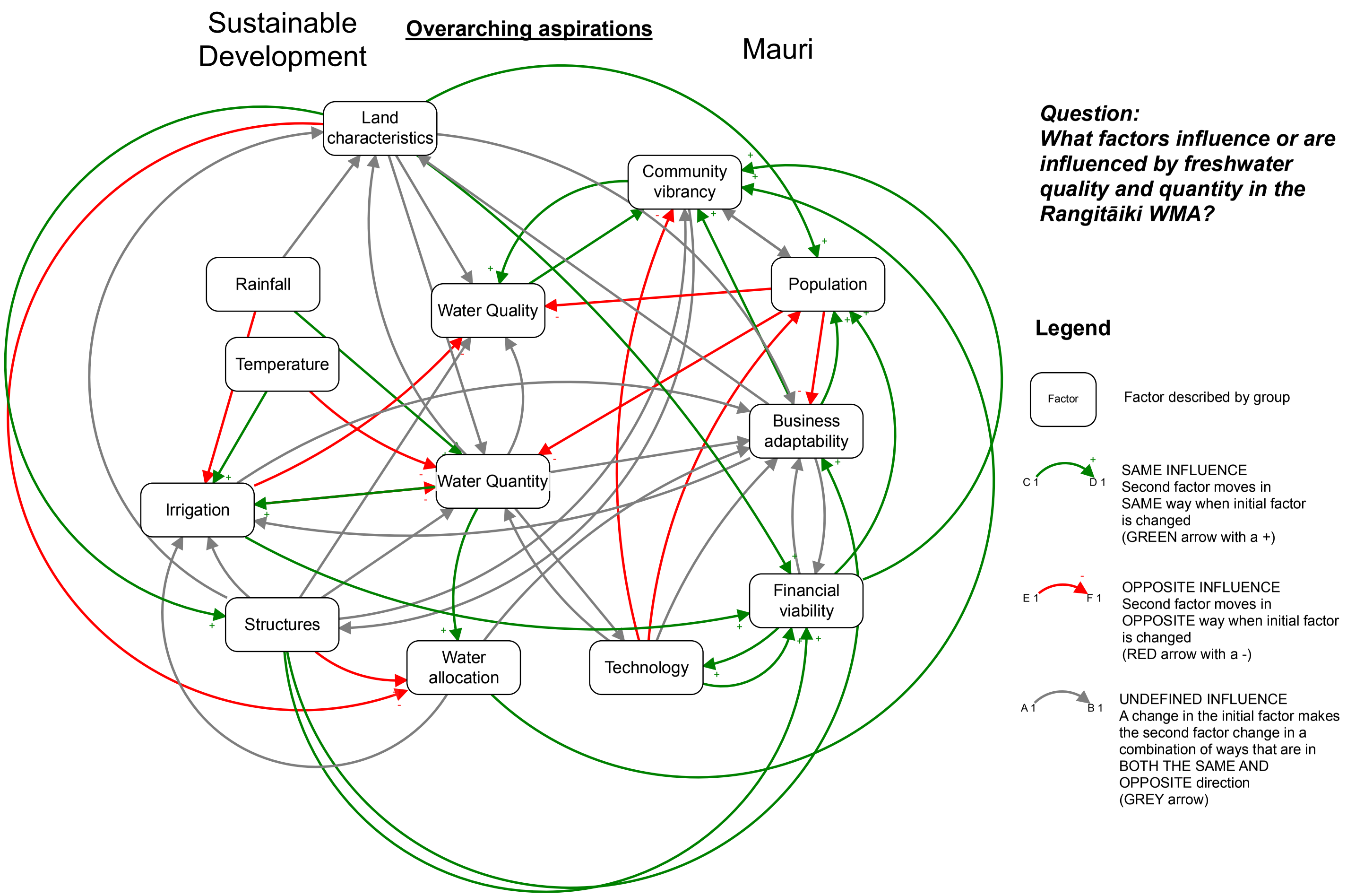
Different types of *feedback loops* and *system archetypes* (or 'common patterns' as archetypes were termed in these presentations) from systems dynamics theory were then presented to the group, followed by various examples of these that had been identified from within their diagrams. Discussion of each feedback loop or archetype followed.

5.3.1 The second workshop: Rangitāiki River

The CLD drawn by this group was high-level and comprehensive. Most links in the diagram were left as 'undefined' as they were a combination of Same and Opposite relationships, given the high level of aggregation. When identifying feedback loops and archetypes, aspects of these relationships were focused on to ensure the necessary polarity existed that was required to complete feedback loops. These assumptions were all clearly stated in the presentation. The researcher also stated that given the large number of possible archetypes in the diagram, only those archetypes that might be useful to the group were focused on – primarily those involving water quality or water quantity. Some minor amendments for the CLD were also suggested to the group, these influenced the final CLD and archetypes.

The group found partial analysis of the CLD useful and had mixed responses to the archetypes. Some found them very useful, while some found them confusing or misunderstood them as recommendations for action being made by the researcher. Others found them useful, but retained a level of scepticism about them as they rightly noted that only some had been focused on by the researcher because of the high level of aggregation. Based on this scepticism, they struggled to understand which were the right ones to focus on. Concerns around the *weighting* of factors and how this would influence the impact that different archetypes would have was identified by several participants. For a summary of participants' responses to the CLD analysis and archetypes, see Appendix 20. The final revised version of the CLD is shown in Figure 5.7.

Figure 5.7 Rangitāiki River catchment – final causal-loop diagram.



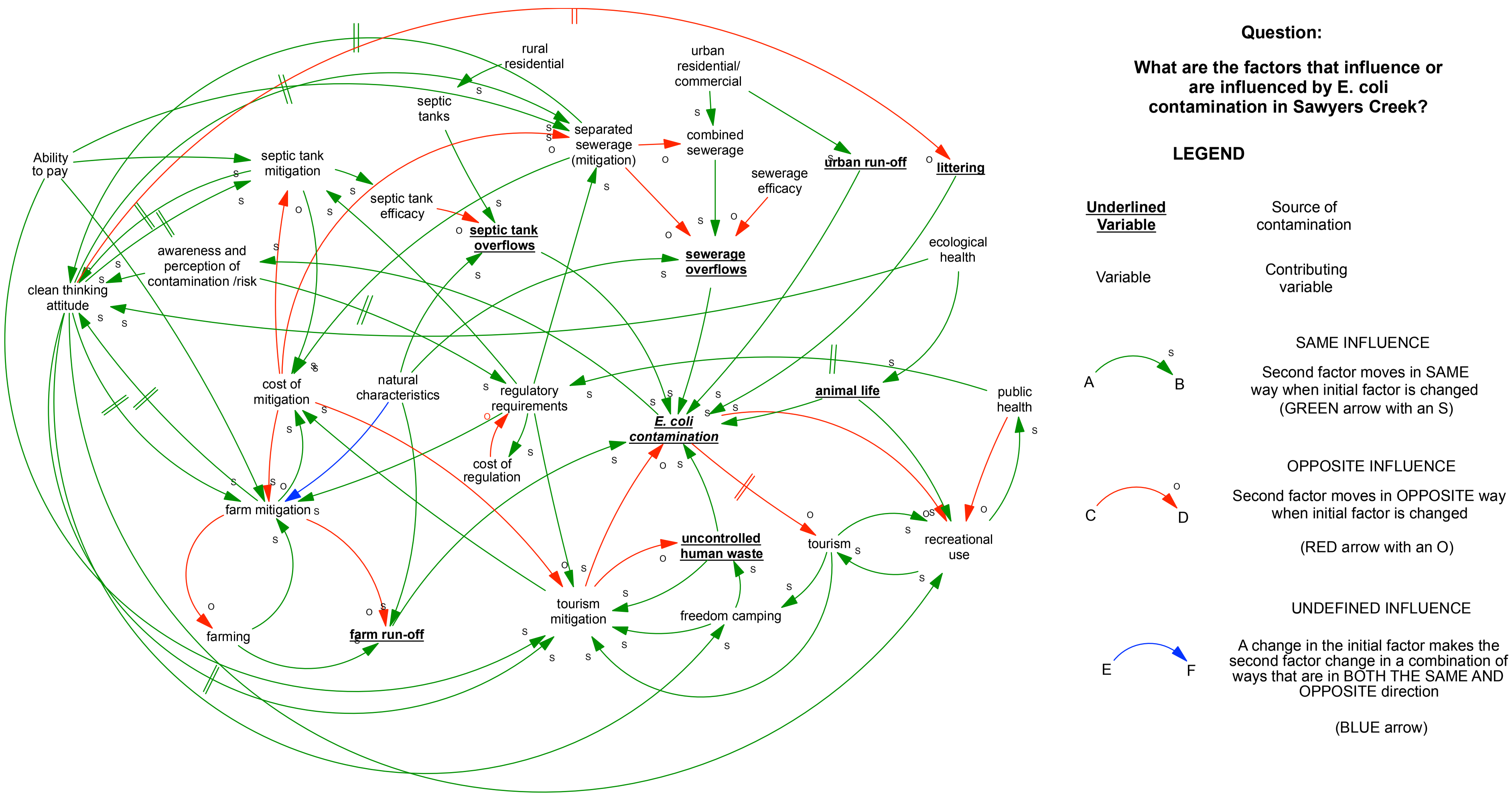
5.3.2 The second workshop: Sawyers Creek

The CLD drawn by this group contained nearly double the number of variables as the Rangitāiki group, and was at a much higher level of dis-aggregation, given the more focused problem question. All links were clearly marked as ‘Same’ or ‘Opposite’, except one. This enabled the polarity of feedback loops to be clearly understood and discussed. Again, the group found partial analysis of the CLD very useful. It was gradually built up from the *physical sources* of contaminants, then their *physical causes*, followed by their *social causes*, then their *social and physical impacts*. Some minor amendments for the CLD were suggested to the group or by the group during discussion. Some of these influenced the final CLD and archetypes.

All participants responded positively to the partial analysis and archetypes. While some demonstrated a more-developed understanding of them and their implications, there was little controversy around whether they represented the system that the group had described or not. The greater clarity provided by the archetypes also generated a more consistent appreciation in the group that the *weighting* of the factors would influence the impact that different archetypes would have.

For more discussion of the CLD analysis and system archetypes see Appendix 20. The final CLD as agreed by the group is shown in Figure 5.8.

Figure 5.8 Sawyers Creek catchment – final causal-loop diagram.



6 Discussion of the GMB process

The previous section provided a *description* of the GMB process undertaken across two workshops for each project. This section will *discuss* elements of the GMB process outlined in previous sections.

6.1 The iterative nature of learning

Like all post-graduate research, this work was a learning process for the researcher involved. It was inevitable that the project that was scheduled second was likely to benefit from lessons gained from the application of the GMB in the first project.

Given the applied nature of the research, the initial scheduling of the first workshop in both projects relied heavily on the requirements and availability of people within the sponsor organisations. This was the only reason that the Rangitāiki River project commenced first – there was no other deciding factor.

6.2 Preparing for the GMB process

With the benefit of hindsight, it may have been more appropriate to schedule the two projects the opposite way around – Sawyers Creek then Rangitāiki River. There are several reasons for this. The first was the simple matter of scale, given that it was a much smaller catchment, the Sawyers Creek application may have been an easier project to begin with. The second was the fact that, while both catchments were responding to a need or an issue identified by the *NPS-FM 2014*, the Rangitāiki River group was already working through an active *NPS-FM 2014* objective and limit setting process. The *E. coli* contamination issue in Sawyers Creek will need to be addressed under the *NPS-FM 2014*, but it is important to note that when this research was undertaken, no such programme of work was underway. The use of SD and CLD thinking is particularly useful early on in a project, when trying to understand a complex system (Sterman, 2001), so its application at this stage in the Sawyers Creek process is appropriate. However, if scheduled the other way around, the Rangitāiki River project may have benefited from some of the lessons arising from the Sawyers Creek application. Unfortunately, real world constraints did not allow this and while this does not detract from the useful and insightful application of this GMB process in the Rangitāiki catchment, it is mentioned in case it may help guide future applications of the GMB process in the future.

6.3 Impacts of scheduling

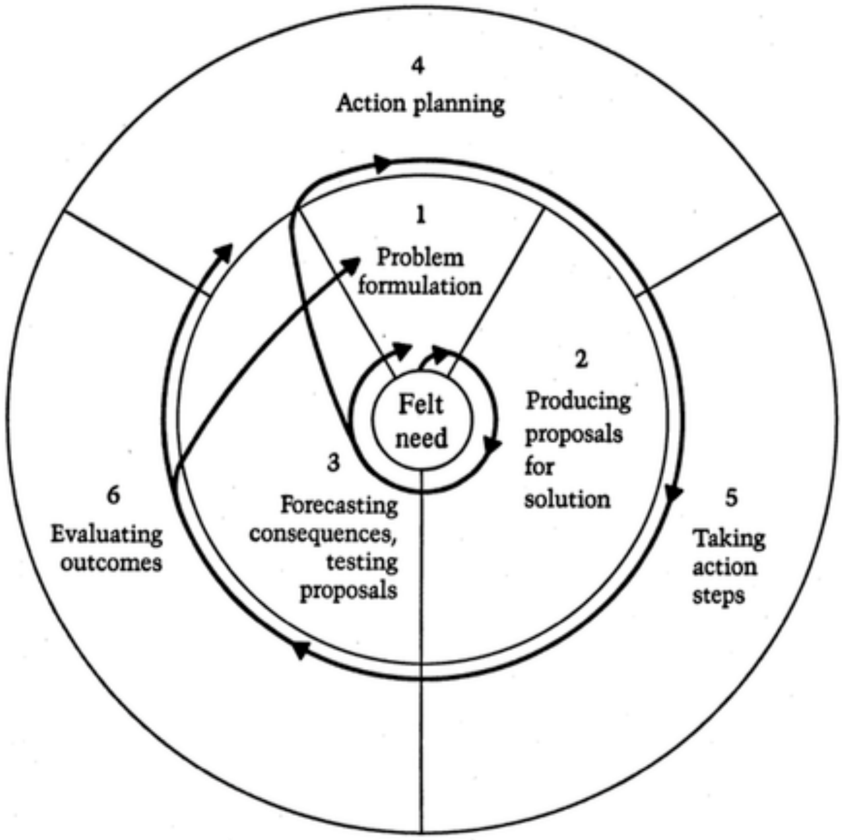
There were slight differences in the way the two projects were scheduled, as described in Section 5.1. The Rangitāiki workshops were held several months apart due to the summer holidays, while the Sawyers Creek workshops were held within two weeks of each other.

The workshops that were held closer together meant that the subject matter of what was discussed in the first workshop was fresher in peoples' minds. For the workshops that were further apart, people needed reminding of much of what was discussed in the first meeting. This would indicate that it would be preferable for workshops to be scheduled reasonably close together (within a week or two), but this may not always be possible in applied settings. Where they are scheduled further apart, it would be beneficial to ensure that adequate briefings or reminders of what occurred in the first workshop were provided to participants (either before the second workshop or as the first part of it – or both).

Successful scheduling is reliant on the coordinated approach of a multi-disciplinary team, which in many ways is what GMB involves (van den Belt, 2004). For scheduling to be successful, it requires an appreciation of what will occur in between meetings and how this is coordinated with the overall project/decision approach. In Jay W. Forrester's early work *Urban Dynamics*, he describes a process where urban experts were gathered on a regular basis every week or every other week, while the dynamics described in these sessions were modelled by computer in the intervening periods and presented back to participants (Forrester, 1969). This was an early form of GMB and is an example of the type of iterative GMB process described by Vennix (1996) and van den Belt (2004).

The iterative nature of problem solving is also highlighted in the decision-environment literature. Edgar Schein (1988) demonstrates how problem solving is a continuous, non-linear and circular process that sometimes requires a return to earlier steps before being able to progress again (see Figure 6.1). This should be borne in mind when scheduling GMB processes and supporting resources. This iterative process can also be seen in the image from the NPS-FM shown earlier in Figure 2.1.

Figure 6.1 The iterative nature of problem solving (from Schein, 1988). Note how problem-solving is a non-linear process that sometimes loops back to an earlier step.



6.4 Differences in the application of the hopes and fears script

Because the Rangitāiki group was already an existing group, no introductions were done and an invitation was simply extended for participants to verbalise any hopes and fears that they had. With Sawyers Creek however, the amended script (see Appendix 12) was applied. The different application of this script in each project is a good example of the "improvisation and *ad hoc* adjustment" that is often necessary in GMB (Andersen, Richardson, & Vennix, 1997, p. 193).

The Sawyers Creek group – and some participants within it – were meeting for the first time. This amended script that incorporated group introductions

(Appendix 12) proved a useful way of helping people to introduce themselves, outlining their expectations for the day and helping to more efficiently use time, it acted also a power-leveller and linked people's introductions with their hopes and fears, not the position they held or reason they were attending. This was also an important foundational step on the day in which all participants were encouraged to participate. Getting participants involved and encouraging them to ask questions is a key way of beginning to build a 'team' atmosphere. This atmosphere is important as it allows people to work towards sharing a common goal and understanding of a problem, rather than simply being a 'group' or a collection of people (see Vennix, 1996, pp. 163-164).

6.5 The focus question

The focus question is a critical part of the GMB process and the experiences with the focus questions across these two projects were quite different. The main lessons relate to the focus and scale of the questions.

The first major lesson was that the two projects had quite different foci and this difference demonstrated the influence this had on certain outcomes. The Sawyers Creek question was specifically interested in determining *what* was causing *E. coli* contamination and in turn, *what that contamination was impacting on*. The Rangitāiki River question, on the other hand, was simply interested in trying to understand what variables *influenced and were influenced* by the two variables of water quality and water quantity. The 'upstream' and 'downstream' elements of both focus questions (what *influences* and what is *influenced by*) align with the approach that Vennix (1996) describes to developing a CLD, but the other subtle differences between the *focus* of the questions had a significant impact.

The SD literature strongly indicates that SD modelling (Richardson & Pugh, 1989; Sterman, 2000) and GMB (Vennix, 1996; van den Belt, 2004) should be specifically problem focused. The sharper contaminant focus involved in the research question of the first group seemed to enable this group to be more focused on the causal factors and how things linked together. A high level of dis-aggregation need not be necessary to achieve this, however. The successful application of problem-focused SD has been demonstrated by the work of Forrester (Forrester, 1961, 1968, 1969) and more recently has been advocated by him as necessary (Forrester, 2007). The inexperience of the researcher meant that a sponsor organisation's desire to pursue a non-problem focused question in the Rangitāiki was pursued and the likely impacts of such were not appreciated. As a result, the Rangitāiki CLD has a far greater number of undefined influences and linkages (see Appendix 20 and Appendix Table 9) – this was a specific result of the focus question not being problem focused enough. It was also trying to accommodate two major variables (water quality and quantity), which detracted from its ability to be focused. In contrast, the Sawyers Creek CLD had a very clearly defined focus and, as such, achieved much greater clarity (see Appendix 20).

The second major lesson was whether the physical scale that the questions sought to address was a major influence on success. While Sawyers Creek produced a CLD that provided greater insight into its specific problem, it is noted that it was also a much smaller geographic catchment. It is unlikely that the level of scale or aggregation had much to do with this, as there are numerous examples of simplistic SD modelling being successfully applied to high-level problems. The mediated modelling approach has been applied to New Zealand freshwater issues at a regional catchment scale and was found to provide greater understanding of the overall system (van den Belt et al., 2013), in conjunction with other more detailed modelling. Small, highly aggregated models have also been shown to be effective for providing insight into problems at a national (Ghaffarzadegan et al., 2011) and even international (Forrester, 1973; Meadows, Meadows, Randers & Behrens, 1974) scale.

One of the keys to the success of SD modelling has been found to be the ability of a CLD or a SD model to be *useful* – the fact that they are built so that a wide range of people can learn during their development and/or application (Winz et al., 2009). In later sections, it is highlighted that participants found both projects *interesting* and *useful*. However, the CLD output from the Sawyers Creek project is likely to be *more useful* moving forward, given its specificity. Important advantages arising from this are an ability to use the model to: show others the key factors involved; identify the input data required; guide conversations around appropriate model boundaries; and provide a conceptual foundation for numerical modelling.

One final thing also worth considering with the focus question is whether an external agent determining the focus question could have influenced things. The first two steps of a SD modelling project are **problem definition** and **system conceptualisation** (Vennix, 1996; Winz et al., 2009). In applied situations, it is likely that these will, at least initially, be generated by the project sponsor or owner. Problem structuring is a key part of GMB and the problem-solving process has been demonstrated to potentially be highly iterative, with people often needing to return to refine their definition of the problem as their understanding of it increases (Schein, 1988) (see Figure 6.1, p. 109). Thus, it is important that GMB participants are given the opportunity to help refine the question at a later stage. Nonetheless, this does introduce a tension, as the sponsor organisation still has a defined need to meet and thus retains some dominance on the direction of the process. If this is not done, then participants may feel that they have less control and input, affecting their level of investment. (This factor aligns with the general reluctance of people to accept other peoples' definition of a problem (Schein, 1987) and was observed during the pilot stage, see Section 4). In practice, the focus questions for both groups appeared sufficiently broad that they were deemed unlikely to have constrained the groups much, if at all, except for the lack of problem focus in Rangitāiki.

6.6 Variable elicitation

In response to the objectives of the research, this script was amended to accommodate *limited time frames* and to help build a sense of *teamwork* early in the workshop. Vennix (1996) defines groups as simply a collection of people and teams as a collection of people with a common goal, who are more cohesive and are generally more accepting and accommodating of differences. Ensuring all participants were contributing to the discussion is an important way of building this sense of *team* (Vennix, 1996), and was the reason this script was developed to make participants discuss the variables they generated with a partner.

Further, the act of prioritising variables and then collating and sorting them on the sticky wall were all ways of encouraging participants to “figure things out themselves” (Schein, 1987, p. 33) and overcome their natural psychological defences that prevent them from being ‘told’ what the problem is. Working with the group to collate variables on the sticky wall still required the hard-to-define skills of facilitation (Vennix, 1996), but also provided an excellent opportunity to utilise ‘double-loop’ communication (Argyris, 1994), through testing peoples’ diverse understanding with regards to the variables elicited by the group with deeper questions. Deliberately structuring the GMB process to involve everyone and use ‘double loop’ communication is important, research has shown that groups that actively embrace the discomfort of their differences of opinion and actively try to involve all members in the process tend to achieve better results (Hall, 1971). In both workshops, all factors identified were generated by the participants in their own words and, through careful facilitation, were also labelled using their own words, all of which contributed to an increased sense of team ownership of a common goal or purpose (Vennix, 1996).

A *recorder* role was one of the five described by Richardson and Andersen (1995), but one of the two that was not managed as a stand-alone role in this amended GMB process (Section 4.3.2). The sorting of variables on the sticky wall was one occasion when a separate person acting as a recorder would have been useful to support the process, as no detailed description of each variable was recorded on the day. However, it must also be considered whether there was *time* to do this in the time constraints facing this GMB process? As Richardson and Andersen (1995) originally stated and others have reinforced (e.g. Rouwette, 2003), the five roles can be shared among a lesser number of people. In this case, it was found that with adequate electronic recording devices (audio and visual) and prompt writing up of notes (that night or the next day), sufficient detail for each of the variables was recorded. It is also worth noting that there were examples in *both* projects where the definition of the variables evolved as the discussion progressed, highlighting the apparent need to maintain flexible variable definitions.

Noticeably, the number of variables elicited by the smaller Sawyers Creek group was nearly twice that of the larger Rangitāiki group. This is considered to mostly relate to the differences in the specificity of the focus questions, which has already been discussed. When the Rangitāiki group wanted to disaggregate a variable, the lack of focus of the question meant that this provided no guidance as to how the variables should be disaggregated, and so this was resisted as it would likely lead to the generation of a huge number of variables. With the Sawyers Creek group, on the other hand, the disaggregation of variables was often an obvious and necessary thing to do, in response to the specificity of the focus question. Ensuring the GMB process is focused on a specific problem – in line with good practice (van den Belt, 2004; Vennix, 1996) – will ensure that the more positive result experienced in Sawyers Creek is likely to be replicated in future applications of this process.

6.7 Initiating and elaborating a causal-loop diagram

The CLDs generated by the two groups are shown in Figure 5.7 (p. 103) and Figure 5.8 (p. 105). A comparison of them shows that there are a greater number of variables on the Sawyers Creek CLD and that a greater number of the influences were clearly labelled as either **same** or **opposite** (all bar one). While these differences themselves are discussed in more detail in Appendix 20, consideration is given here to whether the process of initiating and elaborating a CLD contributed to this difference or not.

The *initiating and elaborating a CLD* script was the only script applied from *Scriptapedia 4.0.6* (Hovmand et al. 2013) in its original form. This script is based around the accepted convention that considering the effects that impact on a variable, then considering the flow-on effects of that changed variable, are an appropriate way of building an understanding of causality (Vennix, 1996). Given the inexperience of the researcher, however, this script was applied in slightly different ways in each project.

In the Rangitāiki process, once variables had been elicited and prioritised, they were all drawn on the screen around the two focus variables. A discussion was then facilitated that explored how each variable, in turn, influenced others or was influenced. While not necessarily an incorrect way of approaching this, it contrasted to the application of this script in Sawyers Creek. There, the process of gradually adding variables to the screen was more strictly followed as per the script. This was also partly influenced by the fact that approximately twice as many variables had been elicited by this group, so for them to be manageable they were added one-by-one. The gradual addition of the variables provided much more methodical structure to the conversation. In contrast, the Rangitāiki conversation tended to meander around the different variables (not that this was a bad thing).

Another slight difference when this script was applied in Sawyers Creek was that, because so many variables were identified in the first sort or 'wave', the second 'wave' of variables was not sorted until after the first wave had been put into the CLD. What was found when this second wave of variables were added to the first was that all bar one could be grouped under the first variables labelled, or those that had been added during discussion and development of the CLD. This created a strong sense of achievement within the group and seemed to indicate that their collective knowledge had been comprehensively represented in the CLD. Repeating the process with a similar focus on a specific problem across a select but representative range of stakeholders would likely produce the same result again.

6.8 The second workshop, feedback loops and system archetypes

The second workshop focused on the presentation and discussion of the CLD drawn in the previous workshop and any feedback loops and system archetypes that were identified within these. This research is focused on the *experience* of participants in the GMB process, therefore, that is what is described in this section. The resulting *detail* of the feedback loops and system archetypes identified and a more detailed discussion of how these were analysed and what was found is included in Appendix 20.

Both groups found partial analysis of the CLDs useful, as both projects featured comments at the end of Workshop I that people felt overwhelmed by the CLDs they had just drawn.

The Rangitāiki CLD contained a higher number of ‘undefined’ influences; thus, when these were included in feedback loops or archetypes, the influence that was relevant to complete the feedback loop had to be stated. This seemed to generate a certain level of distrust as participants felt that they were being ‘told’ something rather than generate it themselves (Schein, 1988), even though these statements were based on the influences that the group had described in the previous workshop. With the Sawyers Creek CLD, this problem did not exist and a much higher level of acceptance of the feedback loops and archetypes was experienced.

Also, because the focus question was not targeted on a specific problem in the Rangitāiki application, it was not possible to identify and discuss *all* possible feedback loops and archetypes. The researcher therefore focused on those that were thought or judged to be of interest to the group (e.g. archetypes surrounding water quantity or allocation). This also had the effect where participants felt they were being ‘told’ or ‘led’ to an outcome and were not sure whether to trust this ‘advice’ from the researcher as they had not generated it themselves (Schein, 1988). In contrast, because the Sawyers Creek problem was specific, all feedback loops and archetypes were specifically focused around that problem and there was an immediate and high level of acceptance of them. Both experiences strongly reinforce the need to ensure a refined problem focus when undertaking a GMB process.

Based on this scepticism, participants struggled to understand those that were best to focus on, which highlighted that becoming familiar with system archetypes is itself a learning *journey* – much like learning to write sentences as a child – becoming more easily recognised and understood the more regularly people use them (Senge, 1990). While it is likely that participants’ understanding of archetypes and how they can be useful will grow in accordance with their exposure to them (Braun, 2002; Senge, 1990), achieving such familiarity within the limited time of this research (i.e. a single-day workshop) is unlikely. This highlights the need for sufficient time to get the most out of GMB and the potential value of providing material that participants can read prior to involvement in workshops.

Some people demonstrated a more-developed understanding of the feedback loops or archetypes and their implications. However, it was difficult to determine which type of participants found them easier to understand, due to the small sample size involved and the broad backgrounds of many of the participants. For these reasons, understanding how the demographic characteristics of participants influence the success of GMB has not featured strongly in the literature (Huz, Andersen, Richardson & Boothroyd, 1997).

Several participants identified that the *weighting* of factors within a system would be important. Structured weighting of which variable is more important than another is not possible in qualitative modelling, like CLD. It does not negate the insight provided by such modelling (Senge, 1990). However, it highlights the value of progressing to simulation modelling, which inherently weighs the relative importance of different influences based on available data. It is an essential step for some leading SD practitioners (Forrester, 2007; Sterman, 2000; Vennix, 1996), yet it also involves greater complexity, which makes it harder to utilise in GMB. Moreover, it requires much more resources, in terms of required data, expertise, and time.

7 Quantitative analysis and discussion

This section summarises and discusses the quantitative results from this research. It provides insight into the self-reported assessment of the GMB workshop process. The quantitative survey results are reported and discussed (Section 7.1), while a ‘word cloud’ for both case studies demonstrates the proportion of regular words used in the follow-up interviews (Section 7.2).

7.1 Quantitative survey results

Participants were surveyed at the end of the first workshops and the results are described and discussed here. The relevant quantitative questions are reproduced below (Table 7.1), while a copy of the survey (which utilised a 7 point Likert scale for quantitative responses) can be found in Appendix 3.

Table 7.1 Quantitative questions in participant survey.

Quantitative questions	
1.	This process helped me better understand the perspectives of other people in the group relating to freshwater issues.
2.	This process has helped me to learn more about our freshwater system.
3.	I found Causal Loop Diagrams easy to understand.
4.	Using Causal Loops Diagrams has increased the agreement of the group on factors that influence our freshwater system.
5.	I believe the Causal Loop Diagram Model developed today will be useful for this project in the future.

7.1.1 Description of data

Overall, the participants saw much value in the workshops, as is shown by their scores shown in Table 3.1. Most participants either moderately or strongly agreed with the 5 statements. There were only four responses (from three participants) that disagreed with any of the statements. One participant strongly disagreed that they had learned more about *other peoples' perspectives*, and they moderately disagreed that they found CLDs *easy to understand*. Two other participants moderately and slightly disagreed that the process had helped them *learn more about the freshwater system*.

Table 7.2 **Quantitative survey results for both case studies.**

	Strongly disagree	Moderately disagree	Slightly disagree	Neither agree or disagree	Slightly agree	Moderately agree	Strongly agree
Q1	1				2	8	5
Q2		1	1	1		10	3
Q3		1		1		8	5
Q4						12	4
Q5					3	7	5

n = 16

The three statements that most participants agreed with all related to the benefits of the process or of the CLD that was developed. These were: Question 1, *this process helped me better understand the perspectives of other people in the group relating to freshwater issues*; Question 4, *using Causal Loops Diagrams has increased the agreement of the group on factors that influence our freshwater system*; and Question 5, *I believe the Causal Loop Diagram Model developed today will be useful for this project in the future*. This provides clear quantitative evidence that the process had been beneficial for the participants.

7.2 Word count data and word clouds

Word counts are a simple way of quantifying an amount of qualitative data by presenting the most frequently used words in a data set. These results can also be represented in a word cloud that presents these words visually and scales them depending on their frequency of use, a larger size depicting a word used more frequently. A *word count* and *word cloud* for each project has been provided here, as a novel way of demonstrating the variety of individual words used in both the qualitative survey results and the semi-structured interviews.

This technique, however, is separate to the thematic analysis that is provided in Sections 8 – 12. While the many words represented provide some insight into the interviews, word counts and word clouds are limited because they do not provide insight into the context in which these words were used. A more detailed investigation of interview data is what is covered in the thematic analysis. The word counts and clouds are shown for the Rangitāiki River case study in Table 7.3 and Figure 7.1; and for the Sawyers

Creek case study in Table 7.4 and Figure 7.2. The word count tables list the top 20 words and the word clouds show the top 200 words.

Table 7.3 Top 20 words from surveys and interviews: Rangitāiki River – Table.

Word	Count	Similar Words (included in count)
person	570	person, personal, personalities, personality, personally
thinking	460	think, thinking
group	250	group, groups
things	250	thing, things
process	194	process, processes
really	187	really
going	165	going
people	153	people, peoples
question	151	question, questioned, questions
causal	137	causal
different	136	difference, different, differently, differs
understanding	125	understand, understandable, understanding, understandings
interesting	121	interest, interested, interesting, interestingly, interests
might	119	might
water	119	water
probably	112	probably
terms	111	terms
talking	107	talked, talking
discussions	98	discuss, discussed, discussing, discussion, discussions
around	93	around

Figure 7.1 Top 200 words from surveys and interviews: Rangitāiki River – Word Cloud

Table 7.4 Top 20 words from surveys and interviews: Sawyers Creek – Table.

Word	Count	Similar Words (included in count)
thinking	346	think, thinking, thinks
person	299	person, personal, personalities, personality, personally
things	173	thing, things
people	164	people
really	144	really
process	115	process, processes
might	86	might
councils	79	council, councils
understanding	77	understand, understandable, understanding
actually	72	actual, actually
quite	67	quite
problems	64	problem, problems
group	63	group, groups
going	62	going
maybe	58	maybe
talking	57	talked, talking
probably	49	probably
thought	49	thought, thoughts
diagrams	48	diagram, diagrams
stuff	47	stuff

Figure 7.2 Top 200 words from surveys and interviews: Sawyers Creek – Word Cloud.

It is interesting that the top words used in the interviews for *both* case studies are *'person'* and *'thinking'*[14]. Some of the implications of the word 'thinking' might be that during the interviews, interviewees were either talking about what they thought ("I think…"); describing themselves as thinking; or talking about the act of thinking in the workshop. This would seem to indicate that people were certainly engaged in the act of problem-solving, and where it was describing thinking within a group context, this may be an indication of mutual exploration, questioning and exploring of

14 Please note that the 'thinking' word count included other similar words such as thinking/think/thinks and the 'person' word count included similar words like person/personal/personalities/personality/personally. This is thought to introduce little bias given the low incidence of these additional words and their relationship to the primary heading.

issues, as described by Doyle and Strauss (1976) and Schein (1988), or as 'double-loop' communication as described by Argyris (1994).

While the use of the personal pronoun of "I think…" may be benign, it is noted that sometimes it may also be in an adversarial or defensive context, when someone is outlining or defending their position. This was observed in several interviews; for example, a perspective on an interview with Person B who made a statement about how something might be used in the future: "I think it's going to mire us right back down…".

The regular occurrence of the word 'person' may have similar implications with regards to its variants, which included 'personality' and 'personalities'. This indicates that the social dynamics of the group, their industries or historical freshwater processes were a subject of discussion. The personal variants of person – personal and personally – hinted at both positive and negative uses of this. For example, as above with "I think...", "personally I…." could also appear as a defensive statement, depending on the context. Also, it may just as likely indicate discussion relating to the tension of needing to determine collective action and consider personal implications (the greater good versus the individual impact).

Other frequently used words related to people (*people, peoples)*, *things* or *processes*. This was likely to indicate that the surveys and interviews discussed issues related to the GMB process or other government or economic *'processes'*, the people they affected (*'people(s)', 'groups'*) and possibly what some of the actions resulting from these may be or their impacts (*'things'*).

While insightful, these quantitative tools lack the ability to convey the rich context within which these words were used. The qualitative thematic analysis discussed in the following sections analyses the follow-up interviews and provides insight into this context.

8 Undertaking the thematic analysis

The approach to thematic analysis was outlined in (3.3.3). This section describes the *journey* of undertaking the thematic analysis by chronicling the steps outlined in Braun and Clarke (2006) (Section 3.3.3.2.3). Subsequent sections will discuss the resulting *themes* (Sections 9 – 12).

Qualitative data was collected via open-ended survey questions (Table 8.1) and semi-structured *ex-post* interviews (Appendix 5), the qualitative data from the surveys and interviews was transcribed then analysed using NVivo software.

Table 8.1 Quantitative questions in participant survey.

Qualitative questions	
6.	If you agreed with the statement in Q5, why do you think the diagram developed today will useful in the future? If you disagreed, why do you not think it will be useful in the future?
7.	What parts of the process worked well? Why?
8.	What parts of the process did not work well? Why?

The interviews were by far the largest single source of qualitative data utilised here and made up the bulk of the thematic analysis, the qualitative survey questions only accounting for a small amount of text. If there are major differences or points of interest relating to the prevalence of data through recurrence, repetition or forcefulness (Owen, 1984), then individual project data sets, on occasion, are discussed individually (Rangitāiki River or Sawyer's Creek). Outside of this obvious demarcation between projects, little division of the data has been undertaken. This reflects the fact that the bulk of the data is from the qualitative analysis, as well as that the groups were not large enough to compare demographic sub-sets (e.g. gender, ethnicity or profession) within them.

The experience of the thematic analysis process is described in the following sections: data familiarisation; generating initial codes; searching for themes; reviewing themes and defining and naming themes.

8.1 Data familiarisation

The process of data familiarisation was undertaken by listening to and transcribing the ex-post interviews. Not only did this make the data very familiar to the researcher, the revision also provided new insights to the data through allowing further examination of each participant's use of tone and emphasis that had not been noticed on the day. Taking the facilitator role (Richardson & Andersen, 1995) in the GMB process meant that the workshops were busy for the researcher. Reviewing the data after focusing so intently on this role allowed new insights to be gained into the content of the conversation. The intent of this step is to immerse oneself in the data, becoming familiar with it through actively reading and re-reading it (Braun & Clarke, 2006). This process is likely to provide insights into the obvious content of the data (Braun & Clarke, 2016), and minor initial note-taking on the data may help guide coding later (Braun & Clarke, 2006; Terry, 2016).

Different subtleties and nuances of the conversations were often viewed in a different light after listening to the recorded discussions or reading the transcripts. For example, on a couple of occasions, recollections of a participant's tone or choice of words were altered. Also, by recognising the diversity of participants' voices, it was also found that the conversation had been more balanced than thought.

In keeping with good practice, no codes were sought at this stage (Terry, 2016). Data that referred to the GMB process was noted, while the specific subject matter or experiences of participants in other processes were generally not of interest for the thematic analysis. This approach was justified to focus the analysis on participants' experience in this research.

8.2 Generating initial codes

The process of generating initial codes was delayed until all surveys and interviews were transcribed and available as a single data corpus. This was to ensure a consistent approach to generating initial codes was undertaken and to avoid, as much as possible, inconsistent coding due to possibly evolving definitions of the codes in the researcher's mind – or 'coding drift' (Braun & Clarke, 2016). The ability to move between transcripts and projects was important and ensured the generation of initial codes was as consistent as possible (Braun & Clarke, 2006) and as systematic as possible (Terry, 2016).

Around 250 individual codes were initially generated across the data corpus, which was made up of 16 interviews (the bulk of the data) and answers to the qualitative questions from the follow up surveys. This was a very large number and simply reflects a numeric count of them, with no reflection on their similarity. Also, some of these codes may have been applied with more prevalence than others, which is an important element to bear in mind when undertaking thematic analysis (Owen, 1984). A list of these initial codes is provided in Appendix 22.

8.3 Searching for themes

The 250 initial codes were reviewed and grouped where there were logical similarities, consistencies or overlap of intent. This process resulted in 30 initial headings being generated, which are listed in Table 8.2.

Table 8.2 30 draft headings developed from 250 initial codes.

Background	Group representation
Drivers for involvement	Visual tool
Personal perspective not appreciated	Understanding through involvement
More in common than thought	Increased understanding
Frustration with council or other processes	Uncertainty in subject matter
Curiosity of process a driver	Decision-making
No expectations	Weighting of factors
Complexity and longevity of problem	Time
Efficiency of process	Versatility of process
Challenges with process	Involvement in person
Ownership of outcome	Concentration required
Facilitation	Use in the future
Overall CLD daunting	Communication tool
Archetypes	Being problem focused
Group size	Māori world view

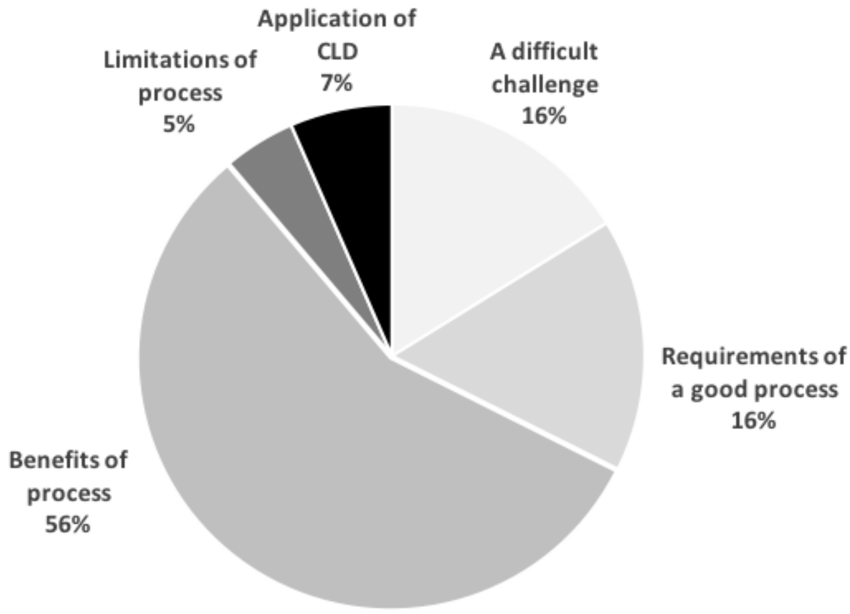
Two of these initial headings are important to note: *Backgroun*d and *Drivers for involvement*. *Background* included details of participants' personal and professional background, while the *Drivers for involvement* included how they were invited to be part of the process or how they were there to represent their community, professional, business or personal interests. Because much about the identity of the participants could be drawn from the codes within these headings, their content has been excluded from further analysis to preserve the anonymity of the participants. This does not impact on the detail of the analysis, as these codes mostly included comments made about their profession and how they came to be involved in the process. While this background information may impact on the *content* of their discussions within the GMB process, it is not considered to impact on participants' *experience* of the GMB process, which is the focus of this research.

After these headings were clustered according to their related content, a series of draft themes were identified. These were *Benefits of the process*, *Limitations of the process*, *Application of CLD*, *A difficult challenge* and *Requirements of a good process*. The headings that relate to these draft themes are tabulated in Table 8.3. Also, their *prevalence* according to how many data extracts were coded to each theme from the entire data corpus is shown in Figure 8.1 (and shown in brackets in the table). Note that a data extract may be coded in more than one theme.

Table 8.3 5 draft themes based on 28 draft headings. The number in brackets indicates the total number of coded extracts within this draft theme.

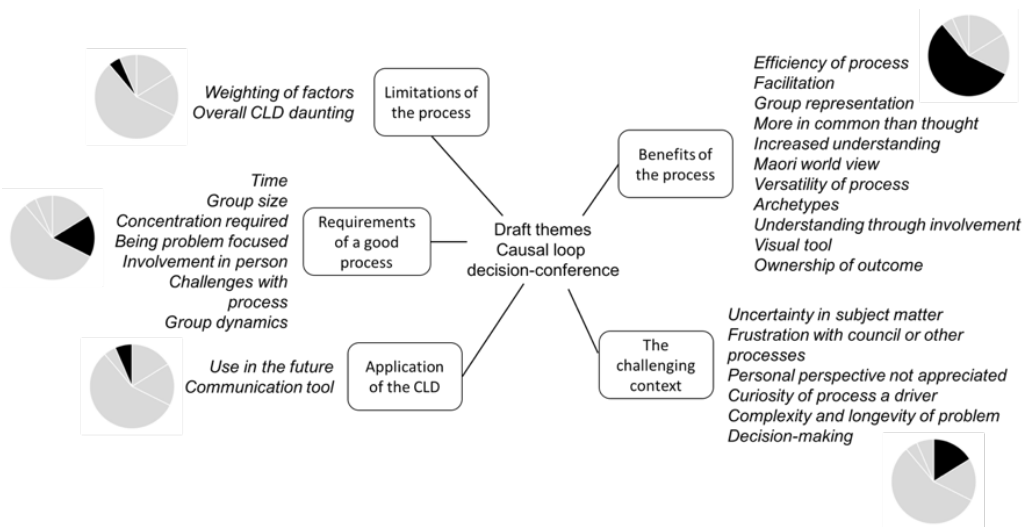
Sentiment of draft theme (no. of coded instances)	Draft headings
A difficult challenge (168)	Uncertainty in subject matter
	Frustration with council or other processes
	Personal perspective not appreciated
	Curiosity of process a driver
	Complexity and longevity of problem
	Decision-making
Requirements of a good process (169)	Time
	Group size
	Concentration required
	Being problem focused
	Involvement in person
	Challenges with process
	Group dynamics
Benefits of process (587)	Efficiency of process
	Facilitation
	Group representation
	More in common than thought
	Increased understanding
	Māori world view
	Versatility of process
	Archetypes
	Understanding through involvement
	Visual tool
	Ownership of outcome
Limitations of process (48)	Weighting of factors
	Overall CLD daunting
Application of CLD (68)	Use in the future
	Communication tool

Figure 8.1 Prevalence of draft themes according to the percentage of codes extracts from the data corpus.



These 5 draft themes are shown visually in Figure 8.2 along with a representation of the extent that each draft theme has been coded in the data. This is based only on the number of times this has been coded and is independent of the context of that coding. Some data extracts are coded to multiple codes.

Figure 8.2 Diagram of the five draft themes and the key draft headings that each describe. Note the pie charts indicate the prevalence of each theme by total coded extracts.



8.4 Reviewing themes

Having generated initial themes, these were then reviewed by further re-reading of the data. With the objectives of the study in mind, this process was a useful ‘quality check’ (Braun & Clarke, 2016). Some re-coding of extracts was undertaken and the initial themes were also reviewed with external input. This led to a significant revision of the themes.

When reviewing the draft with external input, the strong tendency for *functional* groupings in draft themes was noted. There was concern that this was a very *deductive* approach (they were being grouped into pre-determined themes) to codes that had been generated *inductively*. Consequently, a significant re-arrangement of codes and headings was considered along the lines of what *story* was being told by the data, rather than what information it was felt was *required to run* a process.

Some headings were merged or amended, but there remained a similar amount of them. The most significant change came from how they were *grouped* to reflect the experience of participants in the GMB process as “central organising concepts” of themes (Braun & Clarke, 2016). Four central concepts underpinned these revised, unnamed, themes: *Why were people involved; How did people find the process; What did the process achieve;* and *Reflections on the process*. These were made up from 27 headings and are shown in Table 8.4.

Table 8.4 Reviewed themes – tabulated. The number in brackets indicates the total number of coded extracts within the reviewed theme.

Central organising concept of reviewed theme (no. of coded instances)	Reviewed heading
Why were people involved? (76)	Complexity and longevity of problem
	Personal perspective not appreciated
	Frustration with council or other processes
How did people find the process? (307)	Being actively involved
	Facilitation was beneficial
	Group size
	A focused process
	Simplicity
	Being problem focused
	Group representation
	Need for a strong start
What did the process achieve? (493)	Decision-making
	More in common than thought
	Māori world view
	Group dynamics
	Increased shared understanding
	The tools as a visual aid
	Ownership of outcome
	SD terminology and concepts sometimes difficult
	Overall CLD daunting
	Archetypes
	Communication tool
Reflections on the process (164)	Uncertainty in subject matter
	Time availability and efficiency
	Versatility of process
	Weighting of variables (factors)
	Future use

8.5 Defining and naming final themes

The final step was for the themes to be labelled and described. While the sentiment of the themes had already been applied in the previous step, in this step these were named and had a description applied to each of them. This is shown in Table 8.5.

Table 8.5 Final themes and definitions. Note the 'central organising concept of reviewed theme' is carried over to provide continuity and progression.

Final theme name (no. of coded instances)	Central organising concept of reviewed theme	Definition
A desire for something different (76)	Why were people involved?	The first theme discusses the long-term nature of the issues being dealt with, as well as elements of participants' backgrounds and why they were motivated to be involved. The least prevalent theme, this provides good contextual background regarding people involved in the GMB process.
A refreshing new process (307)	How did people find the process?	This theme discusses the elements of the process and how participants found it or reacted to it.
Building a group AND a group model (493)	What did the process achieve?	This theme describes how the outcomes from the process have not simply been the development of the CLD, but also a contribution to the further development of the group and its dynamics.
Useful yet more detail required (164)	Reflections on the process	This theme draws together participants' reflections on the usefulness of some elements of the process, considers some shortcomings and identifies possible future applications.

A revised representation of each theme's *prevalence*, according to how many extracts were separately coded to that theme, is shown in

Figure 8.3 (and shown in brackets in the table). A visual demonstration of the final themes, with an indication of their prevalence, is shown in Figure 8.4 (this data is also presented in brackets in the table).

Figure 8.3 Prevalence of revised themes. Note the lesser number of themes compared to previous drafts and the dominance of the second and third themes.

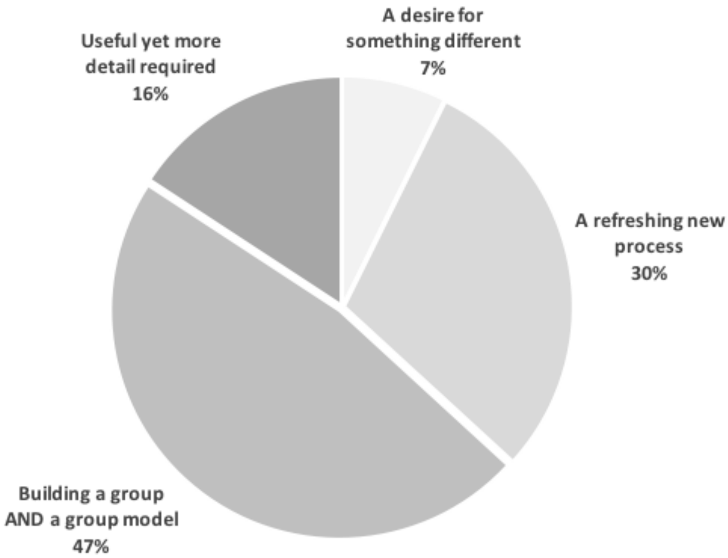
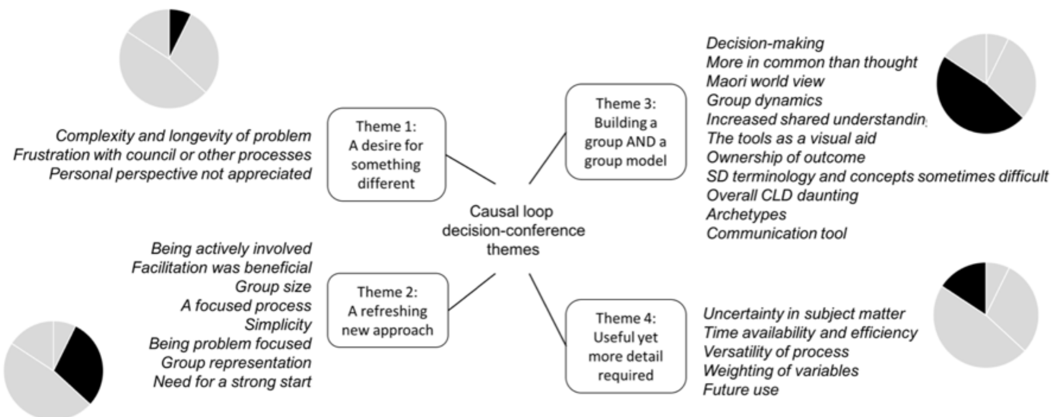


Figure 8.4 Diagram of 4 final themes and headings. Note pie charts indicate the prevalence of each theme by total coded extracts.



Having described the *journey* of developing the themes, the actual themes are *discussed* in the following sections.

9 Theme 1 – A desire for something different

The first theme discusses the long-term nature of the issues being dealt with, as well as elements of the participants' backgrounds and why they were motivated to be involved in the case studies. Whilst this is the shortest of the themes, it provides good contextual background to the other themes that provide a stronger focus on participants' experiences and reactions to the GMB process.

9.1 Complexity and longevity of problem

Earlier discussion of the freshwater management issues covered in the case studies (Section 5) outlined the complexity involved across biophysical, regulatory, social and decision making domains. Freshwater policy issues are often 'wicked' problems (Gluckman et al., 2017; Rittel & Webber, 1973) and have high levels of dynamic complexity. These are the type of problem that SD has always sought to deal with (Sterman, 1994, 2000), by helping identify inherent sources of policy resistance that result from what Forrester (1971) called the 'counterintuitive behaviour of social systems'.

The coding of complexity and the longevity of freshwater management issues was prevalent in half of the data sources. Most comments related to the *complexity* of issues and the *interconnectedness* of all the various elements that are often discussed as part of policy development, not necessarily always in a coordinated way. Participants talked about how 'everything is connected', how much 'commonality' and 'connectivity' there was between issues and how "you just can't look at this issue in… silos" (Person A). The complexity of the many different businesses within the system was also discussed by some. There was an appreciation that many different perspectives needed to be included when addressing the issue and that trade-offs would need to be made:

> *"if they're going to take property rights away then there should be some… not necessarily just straight compensation, but there should be some trade-off for the individual." (Person F)*

Some noted the potential complexity and confusion of guiding legislation, such as how the *RMA 1991* worked in relation to the recent acts granting Te Urewera National Park special and distinctive rights, such as that of a legal entity or person (Te Urewera Act, 2014).

Almost as many comments across both projects referred also to the *longevity* of problems and their *long history*. In Rangitāiki, decisions made around farming and irrigating the Galatea plains 30-40 years in the past were discussed by some, as were future issues of consent renewals that others could see looming 15-20 years hence. In Sawyers Creek, issues relating to the impact of council decisions made 30 years previously and the general legacy of activities on the West Coast from circa 100 years ago were mentioned by some, while others talked about the longer-term impacts that current activities would have in the future, if they were not addressed.

There was also an appreciation that remedies to current (for example water allocation issues) or potential problems (for example, the impact of changing technology on farm practices, including employment rates) would take time to implement. It was noted that moving towards a culture of improved environmental practice would take a while, one participant demonstrating this by sharing their experience over 20 years of championing, and only recently starting to implement, a solution to something that had been identified as a major problem in the CLD.

Yet, it was not always known how widespread problems were or what the exact solutions were. One person noted a perceived mal-alignment between what they saw as current best-practice environmental mitigation action and the desired water quality outcomes of others, hinting at what van den Belt (2004) describes as the potential conflict and trade-offs that are likely to emerge in GMB:

> *"Ahhh, well a lightbulb went on and I went "Oh my". You know this isn't going to be a quick fix for one, for two a little bit um dis... what's the word... disappointed... no that's not the word neither, um...what's the word. You know like [Sighs heavily] 'What am I doing this for if you're*

> *never going to be happy with me?'. Like the child who can't please the mother." (Person A)*

Participants were clear that the issues being dealt with were complex and 'messy' (Vennix, 1996), possibly even 'wicked' (Rittel & Webber, 1973), and that they would take time to fix.

9.2 Personal perspective not appreciated

The comments coded under this heading were of a very low prevalence (coded in only two data sources), yet are worth noting because of their forcefulness (Owen, 1984) – participants who felt that their personal perspectives were not, or had not always been, appreciated.

These comments predominantly came from farming participants and indicated that they sometimes felt attacked by others for their activities as farmers; that people had a low level of understanding of their farming practices; or that they had unrealistic expectations of what farmers should be doing or achieving. The comments below highlight this frustration:

> *"Sometimes as a farmer that's how you feel anyhow. You know from New Zealand society you're like "What do they want from me!?". You know what on earth are their expectations, they are so far removed from reality. So sometimes that gets me that frustration. And you know there's no celebration, no recognition of success by the general public." (Person A)*

> *"[I wanted] to be involved in the process and to make sure that agriculture got a fair hearing, that it didn't get hijacked by other interest groups that didn't have a full appreciation of the importance and what's actually happening on farms. Because I don't think a lot of people appreciate that." (Person F)*

This tension was also evident with some of the iwi participants and seems to highlight the mal-alignment of mental models going in both directions – for example, farmer's views of non-farmers and non-farmer's views of farmers, as well as iwi views of non-iwi and non-iwi views of iwi. This reinforced that this was a situation where a GMB process might help to explore these views and build shared understanding (van den Belt, 2004; Vennix, 1996). Furthermore, it is highlighted by van den Belt (2004) as a potential determinant of when GMB has much to offer. The extent to which this was achieved in this process is explored in more detail in Section 11.5.

9.3 Frustration with council or other processes

As well as the feeling of one's personal perspective not being appreciated, there was also a sense of participants' frustration with council and/or their decision-making processes – there was a perception that they had a compartmentalised way of looking at things. SD has value in this context. Some literature describes that its value lies in: helping to understand systems holistically rather than in parts (van den Belt, 2004); trying to avoid 'policy resistance' (Ghaffarzadegan et al., 2011; Sterman, 2000); or attempting to avoid sub-optimal implementation of policy (Sterman, 1994).

Comments coded here were moderately prevalent (in around half the sources) and reinforced these aspects of the literature. Some were also expressed with moderate *forcefulness* (Owen, 1984), indicating their relevance. Some participants felt frustration with the way that, they felt, scientific studies were disjointed from policy development or were only approached in parts, with one participant noting that when this research began "everybody was frustrated [with council] possibly by the lack of the linking to different parts" (Person A). Or, they expressed concern that the direction of policy development was not always clearly articulated or known. Some felt that the mechanisms and process of local government were sometimes difficult to navigate: "We tend to be banging our head against a brick wall here and there, you know, I find it quite frustrating" (Person M). The counterintuitive nature of a bureaucratic organisation was also a source of perceived difficulty. Itself responsible for making things happen, it was perceived as actually making things more difficult, perhaps due to 'policy resistance' (Sterman, 2000).

Other participants indicated that council's usual approaches to involvement in decision-making made participants feel 'rushed' or 'pushed' in terms of time, and that they felt they were *provided information to approve* rather than *generate their own input* and models. Comparing a 'traditional' approach that they were involved with, to the GMB process in this research, one participant noted of the traditional process:

> *"A lot of it's being developed for us and that we're going to have a look at it and that in itself doesn't sort of... is not a good way of giving you confidence... You know, something is gonna be put in front of you as a model and it's what you're going to be using. Whereas with this, we got to give a lot of feedback into how the model was going to be developed and [this is] probably why I felt comfortable with it." (Person I)*

These sentiments from participants tend to highlight the desire and need for *dialogue* – allowing for more consideration of what people say – as opposed to *discussion* – which is simply the act of sharing information (Bohm, 1960, as cited in Senge, 1990). A more detailed discussion of this is found in Section 11.4.

9.4 Summary – a desire for something different

This first theme has discussed some of the contextual issues surrounding the running of GMB processes and provides insight into some of the motivating factors for people to be involved. The issues are complex in nature and have been a long time in gestation, while those who have been invited or sought to be involved feel passionately about having their perspective heard, often feeling it has not been heard previously. Frustration with the traditional approach to decision-making was present with some participants and should be borne in mind as useful context while reading subsequent sections.

10 Theme 2 – A refreshing new process

This section discusses the first of the two larger themes from this research – '*A refreshing new process'*. It is structured under a range of headings that discuss elements of the process and how participants reflected or reacted to it.

10.1 Being actively involved

Involvement in the model building process is obviously a central concept of GMB (van den Belt, 2004; van den Belt et al., 2013; Vennix, 1996). The involvement in modelling of those with the relevant mental models was stressed as important by the father of SD, Jay W. Forrester (Andersen, Vennix, Richardson, & Rouwette, 2007), given that this is deemed important to improve learning, change attitudes towards policies, align mental models and generate consensus and commitment to the policy or course of action (Andersen et al., 1997). While a high-level of involvement is important, it may also highlight the need to consider extended time frames and impress the need to ensure that meetings of the group are run well (more on this in Section 10.2), so as not to descend into non-productive chaos (Vennix, 1996).

More discussion of participant comments regarding the pros and cons of what the process *achieved* are discussed in Section 11, while comments about their *reaction to* and *observations of* the process are mainly discussed here. This heading was coded moderately prevalently across approximately half the data sources.

Some participants expected that describing what they had done in these workshops to people who were not there would be a challenge. This was evidenced not only in their comments but also in their actions when, at the end of the first workshop in the Rangitāiki, project participants were asked if they wanted to include more people in the next workshop and they declined. The main reason given was that new people would need to take *time* to come up to speed and that this would *slow* the process down because they would need to go on a similar journey to the one they had just been on to achieve the same level of understanding – they needed to be *involved*.

Involvement is required both for *understanding* and because it has the benefit of building *trust and relationships*. For the Rangitāiki project, this was highlighted by one participant who noted that:

> *"Ultimately, they would come to something very similar but it is just not in the nature of human beings, particularly ones that get into focus groups, to say "yes that's right" and agree with it and not want to have input, Because I couldn't. So,* ***for the group involved*** *I think it's been really good." (Person B, emphasis added)*

This exemplifies the sentiments laid out by Schein (1987; 1988) in his works on *process consultation*, where he describes process consultation as "…a set of activities… that help the client to perceive, understand, and act upon the process events that occur in the client's environment…" (Schein, 1987, p. 11). He described how this guided self-diagnosis for problems is better and more durable than the 'purchase of expertise' and 'doctor-patient' models. In contrast, these alternatives rely on being *told* the problem and solution (expertise) or allowing someone to diagnose the problem then provide options for solution (doctor-patient). Both rely heavily on the desire to *accept* external advice, something which Schein suggests most humans, by nature, are less likely to do if they had the choice (Schein, 1987; 1988).

This provides insight into the value of SD modelling in general, where the focus is making the various mental models present in the group explicit and attempting to align them around a common interpretation of a complex system (Forrester, 1961). Such elicitation will help avoid a group's collective knowledge being simply a collection of perceptions or observations, and instead help organise or view it as a structure or theory (Forrester, 1968). In practice, this comes from active involvement which is not simply 'turning up', but being able to enter into a *dialogue* – a meaningful consideration of others' ideas – in discussion with people, rather than just sharing information in written form. This was also evident in one comment from the Sawyers Creek project:

> *“You know, someone puts something in writing to you and trying to understand what they're actually trying to say or what their actual concern is, sometimes isn't obvious until you actually get right down to [it]... And it's so much easier when people are talking about things and you can ask them questions, or "why do you think that?", or "how does that relate to this?" (Person P)*

Participants described being involved in the process as an opportunity to dispel ‘myths’, an opportunity to ‘share or explain’ technical knowledge and a chance to get people’s ‘opinions’ on different things.

However, it was the active participation that many described as being useful and increasing their (and others) understanding. People were appreciative of the opportunity for active involvement, saying “we could all have a say and all do things” (Person L) and “there was a lot of ability to explain yourself, so that was good” (Person A). The process provided an opportunity to engage in elicitation, discussion and clarification of mental models in a range of ways:

> *“Initially I thought a few things were just being blustered out and not being fully thought through. But the more you dig down the more apparent it becomes that those things are important to those people and they've thought about them.” (Person B)*

> *“Also, it's a good way of debating with people that you've got different - if I could say - vested interests in the process and to be able to hear what they think. So that was my favourite thing about the process, was to hear other sides of the story, to discuss different challenges” (Person I)*

> *“We're quite interesting because we learn from each other… like our farmers have a different perspective around things and they're totally different to our orchardists. Everyone is really different.” (Person E)*

> *“I really liked all the different types of ways that we did things. So, writing on paper and putting it up and then going and talking about it, and then the talking and transcribing onto the diagram at the same time so you can actually see things starting to map out as you're talking” (Person P)*

The face-to-face involvement of people in the process is an integral part of the GMB process (Luna-Reyes et al., 2006; van den Belt, 2004; Vennix, 1996; Winz et al., 2009). Indeed, the interviews shared that one of the key benefits of the GMB was the *process* of developing it, not necessarily the resulting CLD. The CLDs themselves were rather complex – reducing their potential suitability as a learning tool for others. However, their importance as a vehicle for structuring a conversation among diverse people should not be underestimated. Future work should continue this involvement both for its efficacy in achieving the objectives highlighted earlier and for other benefits, such as building trust and being a power leveller (Scott et al., 2016b).

10.2 Facilitation was beneficial

One of the *most prevalent* headings across the entire data corpus was that the facilitation of the group was beneficial in many ways, which is widely supported in the literature. Many of the comments in this heading were also made with a reasonable level of *forcefulness* (Owen, 1984), reinforcing their relevance as a heading. When describing mediated modelling and its role, Marjan van den Belt (2004) described it as aiming for “a collaborative team learning experience to raise the shared level of understanding in a group” (p. 11) and that, echoing the thoughts of Schein (1987; 1988), this was “in contrast to an expert dispensing ‘answers’” (van den Belt, 2004, p. 11). Facilitation is important because both the subject matter and the group meetings are complex phenomena; accordingly, there is benefit to having specialists focused on designing and running the process (Doyle & Strauss, 1976; Vennix, 1996). The Facilitator, therefore, is there to guide the *process,* while the participants manage the *content* (Black & Andersen, 2012; Hunter, 1994). Yet, while structure is important, the level to which facilitation is impacted or driven by personality also means that this component is still as much an art as it is a science (Vennix et al., 1992).

Participants expressed their perception of the benefit of facilitation in different ways. Many described the facilitation as being well executed and well planned, one referenced the well laid out room and that “the horseshoe seating arrangement made for easy & inclusive discussions”, which is an endorsement of the planning undertaken beforehand. Some referred specifically to the benefit of the process, with one noting that:

> *“…it flowed and when people get engaged it just grew and, people were going "Oh yeah, yeah no - what about this, and what about that...". And so, I think the process worked really well because you could have easily lost some people.” (Person F)*

This skill of developing a group process *structure* is one that is noted as being important by Vennix (1996), as were the skills of maintaining *neutrality* (or not voicing your own opinion), being *authentic* and having an *attitude of inquiry*. The presence of these skills and their benefits are evident from the interviews, with participants noting that there was “no judgement” from the facilitator and that the process was objective, with everybody being able to contribute “on the same level”. One follow-up survey noted that the process “was participant led, rather than council led.” These comments support the findings of facilitated GMB being a ‘power-leveller’ (Scott et al., 2016b).

The need for an *attitude of inquiry,* as described by Vennix (1996), is captured not in a GMB sense, but in a facilitative sense, in the book *The art of the focused conversation* (Stanfield, 2000). Here, the agile modern organisation is described as a ‘learning’ organisation, one that facilitates inquiry and questions rather than dictating decisions. This aligns with the work of Senge (1990), whose work focuses on the ability of systems thinking to be the ‘fifth discipline’ that helps organisations become ‘learning organisations’. To be such an organisation requires a participatory process, the principle of which requires inquiry, impartiality and “the art of asking questions” (Stanfield, 2000, p. 13). Evidence that the process achieved this and was objective, in contrast to the type of process where experts dispensed ‘answers’ (Schein, 1987; 1988; van den Belt, 2004), is best captured in the words of one participant who said:

> *“[The facilitator] had a non-judgmental, seeking-type facilitation to your process. Whereas the council's been presenting to us in a top-down process. Throwing information at us - telling. So, two different, two totally, two opposite really, processes.” (Person A)*

In addition to the skill of facilitation, the benefit of having specialists in SD as part of the workshop was articulated by several participants. While this may seem obvious given it was a SD process, it has been noted that even CLDs that appear ‘simple’ require a good understanding of SD theory and solid experience to develop well (Richardson, 1999). It has also been found that both facilitation and modelling skills are required for successful GMB (Langsdale, Beall, Bourget, Hagen, Kudlas, Palmer, Tate & Werick, 2013). The extent that it was useful is evidenced by comments such as those below:

> *“You've got your academic knowledge of these systems that the rest of us don't have. But you've provided some good basic explanation of that to us. And we weren't able to do that ourselves obviously, so that's been really good.” (Person N)*

> *“I think what helped the understanding for me is when you described it as "more of this leads to more of that" or "more of this has a counterbalancing effect which will lead to less of that.” (Person O)*

> *“It was almost like I needed you to talk me through how it worked. You know, this goes up so this goes down and this this this this... you know I needed, if I'd looked at it, I'd have to look at it for a long time and literally go through it all in my head to try and work it out.” (Person P)*

The benefit of *well-structured* and *independent* facilitation was a strong theme from the interviews. While for some participants this may have been influenced by the frustrations with regulatory bodies discussed earlier (see Sections 9.2 and 9.3), it reinforced the importance of this factor for knowledge elicitation (Vennix et al., 1992). Many participants noted their satisfaction with the style of facilitation, indicating that this also plays an important role. This finding reinforces the need for facilitation to be incorporated more fully into SD training programmes, not so much so that practitioners become ‘one-stop-shops’ with all these skills, but so that they can appreciate these skills and can recognise when they need to be incorporated (Vennix, 1999).

Many participants also described the benefit of the sticky wall that was used to help the group share their thoughts and sort the information that they generated. While not an obvious feature of the GMB literature, this tool enhances other applications – such as those described in Luna-Reyes et al. (2006) – by enhancing facilitator-group interaction in a dynamic and cost-effective way.

10.3 Group size

Reviews of the effectiveness of GMB have found a correlation between the number of GMB groups involved in research and the number of people in each of the GMB groups. Case studies with a smaller number of GMB processes tended to have less people in each of the GMB groups, and vice versa (Rouwette et al., 2002; Scott et al., 2016b). While this tends to reflect the fact that smaller studies (like this one) usually involve exploratory research (Scott et al., 2016b), Rouwette et al. (2002) note that most groups that interact face-to-face are between five and 12 people. As discussed earlier, for group size, Vennix (1996) defines a minimum number as around 6 and a larger group as more than 10-12 people; while van den Belt (2004) suggests that the minimum is 10, an optimal size is 20-30, and the maximum is 40. It is noted, however, that the work of van den Belt (2004) targets consensus, which may require a larger number of participants to achieve. The key trade-off when determining group size is that a larger group may increase the level of agreement or stakeholder buy-in, but at the same time risks less participation and therefore a greater risk of dissatisfaction among participants (Vennix, 1996).

This heading of group size was moderately prevalent in, featuring in nearly half of all sources. Most were references to the group size being good or appropriate. Those in the Rangitāiki project were part of a larger stakeholder group outside of this research (approximately 24 people). Many commented that the smaller group used in this research (10 people) was much more beneficial and enabled better discussion, while also not allowing strong individuals to dominate (power-levelling). Those involved in the Sawyers Creek project also generally agreed that their group size (6 people) was good, allowing fruitful discussion. While some people from both groups highlighted the fact that more people would be good for representation (discussed further in Section 10.7), the point was also made by several people that they did not want the group to be *too* big. The main reasons mentioned for this were the logistics of managing it, the impact it might have on some people speaking (with some people being *less likely* to speak in larger groups) and the impact it would have on time frames.

The group sizes used in this research were consistent with sizes in most other small-scale GMB research projects (Scott et al., 2016b; van den Belt, 2004; Vennix, 1996), although the sample size of 6 in the Sawyers Creek project was at the lower limit. While both projects might have benefited from one or two more people, it would be difficult to infer the impact of this outside of a controlled environment.

10.4 A focused process

This section discusses the way the workshops resulted in focused and appropriate discussion.

Increased understanding of an issue and greater alignment on resulting courses of action are fundamental objectives of GMB (van den Belt, 2004; Vennix, 1996) and the effectiveness of GMB in achieving this, compared to traditional meetings, has been noted by Rouwette et al. (2002) and Scott et al. (2016b). The bulk of participant comments coded here related to the effectiveness of the *structure* of the process delivering *balanced* and *holistic* conversation, as well as comments relating to its *robustness* and ability to *build momentum*.

The benefit of getting diverse parties together in a balanced and objective way was highlighted by some:

> *"Anything that promotes inter-agency collaboration is of real value. And this is a great way that you can do that and it's sufficiently objective that you can get people on board." (Person N)*

> *"You only need a couple of dominant people in a group and they can railroad any topic. And… you might end up at the wrong conclusion. So, I see this causal loop philosophy as getting a better group representation of things." (Person F)*

The holistic nature of the discussion that resulted was also noted:

> *"So, I think…. this approach brings together as I said previously the different ideas, but also it outlines the generic, you know like everything, like a holistic view of the contributing factors. Rather than focusing on one aspect or factor. So initially I think if we didn't do [it] this way, it would have been like we will focus on one aspect." (Person K)*

The efficiency of this process with respect to time is discussed in Section 12.2, but links here with the ability of the *structure of the process* to get to a result quite quickly:

> *"If you didn't have that process, that structure, you could talk for hours and hours and days and weeks about that, and never really get to quite a concise summary of individual parts of the collective whole. Yeah it does synthesise and kind of cut to the chase pretty quick I guess." (Person P)*

While some participants' frustration with council or the traditional approach taken has been highlighted (Section 9.2), a belief that the GMB process was better than other such process was implied or stated by some:

> *"I'm in similar sorts of meetings where you have to come up with a plan and make compromises. Comparing it to those other experiences I've had I think that went a lot better than a lot of the other kind of meetings I've had." (Person N)*

The nature of participants' comments here indicate that the *structure* of the GMB process has benefits for providing *balanced*, *holistic* conversations in a *more-effective manner* than traditional approaches. This is consistent with the findings of Ansell and Gash (2007) who found *structure* to be an important element in collaborative governance. This was also the case with the findings of Scott et al. (2016b) and previously, Rouwette et al. (2002) in relation to GMB specifically. While the *effectiveness* of such decision-making is itself significant, it is important that Scott et al. (2016b) note no evidence of the improved *efficiency* of these processes in reaching such decisions. Yet, the results here would indicate that there are efficiency gains that can be realised, that may have not yet been adequately tested for.

10.5 Simplicity

This section considers comments coded to the heading of simplicity. CLD development is noted as being a simple way of portraying a system (Sterman, 2000), and this simplicity seems to have resonated with many of the participants, being prevalent in around half of the data sources.

Many of the comments coded here came from respondents being questioned about the relative difficulty or simplicity related to different parts of the process. Overall, the process was described as easy to follow as well as, quite insightfully by one person, not 'really hard or really easy'. Several participants thought that the process was basically common sense and often made these comments in conjunction with how insightful the process had been and how much had been learned by all (see Section 11.5). Yet, there was generally a theme that the simplicity of both the process and the language had been useful, and hinted that other processes they have or had been involved in, by contrast, required a certain level of specialist or process knowledge:

> *“The other thing I've enjoyed too… is that there hasn't been a lot of what I call ‘bureaucratic speak’ - local government stuff. While obviously, we need to be cognisant of what the rules are and what have you, I've enjoyed being able to sort of think critically and sometimes creatively, or even hear the creativity and the critical thinking from others in this process, because we haven't been sort of bombarded, if you like, with too much policy and all the rest of it, through local government. So that's been useful as well.” (Person J)*

When applying SD to specific problems or subject-matter, the bureaucratic context will likely always apply – especially if being used in the development of public policy. Given the application of GMB processes in many public policy settings (Mingers and White, 2010, as cited in Scott et al., 2016a, p. 79), future research may be able to explore the merits of ensuring simplicity and a minimum of ‘bureaucratic speak’ in the GMB process.

10.6 Being problem focused

It is obvious from its name that the discipline of SD studies systems. Yet, the purpose of SD *modelling* is to attempt to address specific issues or problems (Richardson & Pugh, 1989; Vennix, 1996). Indeed, in the publication that became the genesis of the discipline of systems thinking, *Industrial dynamics*, Forrester (1961, p.21) stated that “The first step in a system study is to identify clearly the problem to be explored and the questions to be answered.”

Through a combination of researcher inexperience and trying to include as much as possible in the CLD, this research resulted in different experiences across the two projects with regards to this fundamental rule. The first project (Rangitāiki River) started by identifying two important freshwater factors and attempting to map *as wide an understanding of the system as possible* from there. The second project (Sawyers Creek), in contrast, addressed a *specific freshwater problem* that was being experienced and sought to develop an understanding of the wider system from that. The second project was also focused on a much smaller catchment, but it is not considered that this overly influenced the ability of the group to provide a more refined description of the problem (see Section 5 for more detail here).

Because the two groups had different experiences, most comments about the benefit of having a clearly defined problem came from participants in the Sawyers Creek project, where they referred to the fact that being problem-focused helped. People described this focus as necessary, that it was useful and that it was ‘easier’ and ‘less confusing’ than a wider focus would have been. Most comments from Sawyers Creek were supportive of the problem focus as they had experienced it. Moreover, one participant from the first project did think that more focus would have benefited their project, noting that “you have to have an objective to pursue to use it [GMB]” (Person B).

While being problem focused was good, it was noted by one participant in Sawyers Creek that one issue was humans “always jumping to the solution” and that going with the first solution identified was not the main objective or benefit of this process. This behaviour was demonstrated by a different participant who had the expectation that the workshop would lead directly to action, rather than greater understanding of the issue then *eventual* action, indicating the presence of the action-oriented mind-set that the previous person had described. This was a good example of the difference between *analytical* and *synthetic* thinking described by Ackoff (2001). *Analytical* thinking breaks a system into its constituent parts and is good at improving *knowledge*, whereas *synthetic* thinking acknowledges that only studying a system *as a whole* can help to increase any *understanding* of it (Ackoff, 2001). Yet another participant felt that being highly problem-focused came with the risk of possibly not exploring some wider and deeper reasons for the experience of that problem. This would suggest that while being problem focused was useful, it is important to not let the process become too focused and maintaining an ability to explore issues through *‘double-loop’ communication* (Argyris (1994) and *dialogue* (Doyle & Strauss, 1976) should be a key focus.

Few comments from the first project specifically noted the benefits of being more problem focused, given that it was lacking from their context. This is reinforced by several comments around the need for more data (see the discussion of the uncertainty of subject matter in Section 12.1) and the fact that more links were clearly labelled as either Same or Opposite in the second project (see Appendix 20).

The experiences then within both projects certainly reinforced the need for specificity when formulating the problem being addressed, as described by Forrester (1961), Richardson and Pugh (1989) and Vennix (1996) and as suggested as critical by Winz et al. (2009). The differences in catchment sizes, while large, between the two case studies is not thought to have adversely impacted on this experience. There is a long history of the application of SD approaches at different levels of aggregation, this is discussed in more detail in Section 12.3.

10.7 Group representation

While the focus of the process is important, so too are the range of people involved, which is the focus of this section.

Group representation is much less dependent on process and will be influenced by the type of problem being addressed and the exact nature of the objective of model building. Vennix (1996) notes that while diversity will tend to increase a model's quality, this may also create more tension within the group and inhibit group performance. Some intricacies to the process of identifying stakeholders have been outlined by van den Belt (2004) and include viewing the GMB process as an opportunity to build a longer term relationship with those involved, that could be used again when addressing future problems; appreciating how much time getting the right people may take and appreciating that different attitudes are important – those with divergent views should not be avoided. In short, she stresses that the process is interested in gathering "relevant institutions and stakeholders together to understand acute or anticipated challenges." (van den Belt, 2004, p. 62).

Representation was a key subject of discussion in preparation of the workshops but was determined ultimately by the sponsor council.

Most comments from participants highlighted the fact that appropriate group representation was important with many expressing satisfaction that the group was well represented and that this, at least in part, contributed to their satisfactory experience of the process. One participant described it as 'democratic', while others noted that the variety of views that were evident among participants made the discussion wider and able to include more perspectives, including non-technical ones. Some people with a non-technical background described their experience of being involved as quite a steep learning curve and they were unsure that they were adding value. Such self-doubt appeared ill-founded though, as comments from the technical participants tended to highlight how much they appreciated non-technical people being involved. Ensuring that the contributions of such people are acknowledged more clearly on the day would be a useful strategy to apply in the future when facilitating this process.

With regards to technical knowledge, one person suggested that it would be useful to have relevant technical people on hand; not as part of the group, but in case they were needed for clarification. This support was available at the project that this person attended; yet, it does highlight that it is something to be aware of at future workshops of this kind.

Some spoke of the need to live in their world or 'in their shoes' to be able to understand their situation. Both Māori and European participants expressed this view; a Māori example of this is described in Section 11.3. This highlighted the importance of involving people who have a deep understanding of the issues involved from life experience, even though that understanding will not be able to be fully imparted to others simply through dialogue. Senge (1990) talks about the concept of leadership being intimately linked to *wisdom,* not only *power or authority.* He quotes Confucius saying: "To become a great leader, you must first become a human being" (Confucius (nd), as cited in Senge, 1990, p. 318). The importance of continuing to ensure that such people are represented in GMB processes would seem to be critical.

While broad representation was desirable, a couple of people noted that true representation was difficult to achieve, one participant commented that they had *not* had success in getting other people interested in attending.

This may have reflected pressure on peoples' time, as discussed in Section 11.1.

Passing comments from participants within both projects indicated that some people thought that representation was good, but not complete, with a desire for more environmental representation expressed in the first project and more recreational and iwi perspectives expressed in the second project. It is important to note that these comments were not suggesting that the outcome was unsatisfactory, but were reflecting on how that may have improved the outputs:

> *"…It's just a shame that we didn't include the whole group, but… I don't know whether we would have concluded at the same place or not? Probably not. I don't know." (Person F)*
>
> *"It's a real shame more people couldn't come because the whole group might have come up with a few more different bits and pieces." (Person B)*

These comments appear to be expressing the opportunity that other people could have contributed rather than criticisms *per se*; either way, it is impossible to infer the impact of such a change of representation. These comments are consistent with findings across collaborative processes in freshwater management in New Zealand where having key individuals involved was important and different ways of identifying and selecting key people were suggested (for a discussion of this see Cradock-Henry et al., 2017). However people are selected, it is better to have one too many, than one too few (Vennix, 1996).

10.8 Need for a strong start

This section will deal with a moderately prevalent heading – the need for a strong start. The beginning of a GMB process is an opportunity to establish ground rules, expectations and to introduce the non-initiated to the concept of SD (van den Belt, 2004). A well-planned structure is important (Vennix, 1996) and this can be developed via scripting in preparation (Hovmand et al., 2013; Luna-Reyes et al., 2006).

Whilst the data indicates that participants were very pleased with the process, some recognised in the *ex-post* interviews that the beginning was a critical time for setting the tone for the rest of the workshop:

> *"It might have lost, it didn't lose people, but you know we could have lost some people at the start." (Person F)*

Very few of these comments were unprompted and they tended to come from an interview question relating to what parts of the process people found challenging. When prompted by this, some participants suggested that the beginning was the more difficult part for them for a range of reasons, partly because the entire process was new to them and partly because achieving the right level of aggregation of the factors was, in hindsight, recognised as important. The difficulty of aligning the level of abstraction or aggregation with the level of understanding that the process is trying to achieve was identified by Rouwette et al. (2002) and is highlighted by the following comment, in response to querying what were the more challenging parts of the process:

> *"I think probably the first part, the part where you know, articulating… you know those little sticky things you put on the wall? What's your first choice, what's your second choice, and having that conversation with somebody else and trying to get your language the same was probably... a good process but it took a while to get the hang of that." (Person A)*

The novel nature of the process for most participants and in some cases simply being involved in the discussion, meant that the need for this first part of the workshop to 'strike the right chord' was important. One or two comments from the Rangitāiki project reflected that some had perceived inexperience of the researcher with GMB, while a comment from the Sawyers Creek project highlighted that the introduction of SD as a concept had been successful and well timed:

> *"Some people will always struggle with things like that and switch off maybe. But no, I thought it was good. Not too*

much detail, I mean you didn't take that long going through all that [introductory] stuff, it was probably only about 15-20 minutes." (Person N)

Rigorous planning and preparation for any GMB process should be the norm (Andersen & Richardson, 1997; Luna-Reyes et al., 2006; van den Belt, 2004; Vennix, 1996) and will help deliver a strong start. The experience of this research supports this and the evolution of the methodology discussed in Section 4 bears testament to the benefits of rigorous planning and conducting pilot workshops.

10.9 Summary - a refreshing new process

This section has discussed the important theme of *a refreshing new process*. Participants reacted positively to the fact that the process actively involved participants through impartial facilitation, that it was a simple and focused process, based around intimate group sizes of an appropriate cross-section of people. Where the process was problem-focused, it was found to be even more useful.

11 Theme 3 – Building a group AND a group model

This theme discusses how the process helped develop and improve the group dynamic and relationships, as well as the actual CLD.

11.1 Decision-making

Modelling to gain insight into a system and the impacts of different policy actions is done with the aim of making a decision of some kind. This is the 'pointy end' of any process that involves public or stakeholder input (Twyford et al., 2006) and is a normative exercise in the environmental-economics sense (Tietenberg & Lewis, 2015). The more that a problem is 'wicked' (Rittel & Webber, 1973) or 'messy' (Vennix, 1996), with no single right or wrong answer, the more firmly it sits in this normative decision-making space.

Some people in the Rangitāiki project noted that the size of the decisions that they were charged with making were significant and that there were no simple solutions (Rittel & Webber, 1973). Their comments indicated that they took this responsibility very seriously but knew that, 'at the end of the day', they would need to make decisions that would impact on peoples' livelihoods. They demonstrated an awareness that this would be controversial; that 'consensus' and having a 'long-term vision' would be important; and that they needed to agree actions and put them into 'some sort of order'. These are good examples of situations where GMB would be useful (van den Belt, 2004) and indicate the existence of what Senge (1990) describes as *creative tension* in decision-making. This is the *gap* between the *current reality* (e.g. current freshwater quality and quantity) and the *vision* of where a group/community/organisation hopes to be in the future. This tension can be both daunting and discouraging, or positive and a source of energy – how a group views this will determine whether this creative tension helps hold a group to a vision, or encourage it to 'erode its goals' according to the archetype described by Senge (1990). For more detail of this archetype see Appendix 21. This tension was noticed by respondents and may have contributed to several wanting or needing support tools to help make the best decision possible:

“Because as the process has grown it's dawned on me, I realise the seriousness of what we're doing and how it's going to impact on our entire communities and our country. Anything I can get that will help me feel better equipped to do it I think is worthwhile doing.” (Person B)

The challenges and constraints of decision-making were discussed by some, with mention of people being ‘time-poor’ and traditionally dealing with problems piecemeal and therefore being ‘task-focused’ or fixing the ‘symptom not the problem’. This type of decision-making would qualify as the second level of four types of decision-making described by Ackoff (1994). He describes “absolution’ as ignoring the problem; ‘resolution’ as doing something ‘good enough’ that ‘satisfies’; a ‘solution’ as something that ‘optimises’ the best outcome and a ‘dissolution’ as a re-design of the system or entity, so that the problem/mess is removed and the system can do the best that it can (Ackoff, 1994). In general, participants felt that there was scope for better decision-making, indicating that there was an opportunity to move up Ackoff’s scale of decision-making from ‘resolution’ towards the preferred states of ‘solution’ or ‘dissolution’. However, the re-design of current practice is non-trivial, given ingrained ways of thinking and doing in the systems involved in freshwater management in NZ.

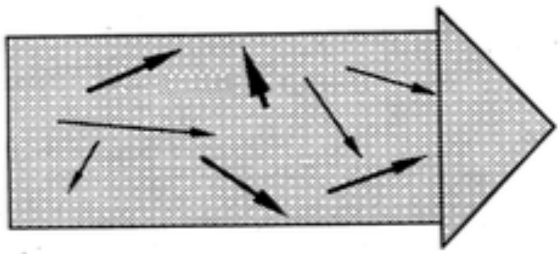
Evidence indicates that knowledge sharing and improved communication are regular results of GMB; yet, there is little evidence to support an increase in decision-quality (Rouwette et al., 2002; Scott et al., 2016b). However, the extent to which such processes form part of a larger *journey* should not be underestimated – the use of systems thinking is a practice, not a one off event (Senge, 1990), which suggests that, perhaps, there may be opportunity to improve how such processes are incorporated into decision-making of sponsor organisations.

11.2 More in common than thought

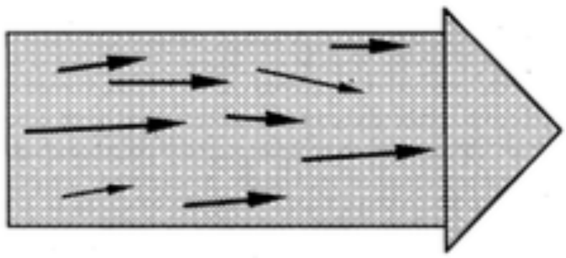
One thread that was prevalent in the data, being coded in a third of the data sources, was that some participants realised that they had more in common with one another than they had thought. Those that did make this observation or comment also made it with moderate *forcefulness* (Owen, 1984), reinforcing its relevance. Much of the GMB literature recognises the ability of both individuals and groups to learn and the benefit that comes from being involved. By comparison, having more in common than first thought aligns best with elements of the literature that deal with alignment of mental models and *shared vision* and is considered separate to the *shared understanding* of issues discussed previously.

Senge (1990) describes how groups, teams or organisations achieve things through their combined (rather than individual) energies and that, when those energies are aligned in their pursuit of an objective, they are far more effective than when mal-aligned. Describing this as ‘coherence’, or pulling in the same direction, he describes it as a ‘necessary condition’ for achieving results (Senge, 1990, pp. 217-218). A visual demonstration of how he described it is shown in Figure 11.1.

Figure 11.1 Visual representation of the ‘coherence’ of two different teams: note that those with more in common will tend to ‘pull in the same direction’.



The small arrows in the top diagram represent the individuals in a relatively unaligned team, where their individual focus is mal-aligned with the overall team direction, leading to wasted energy.



The bottom diagram represents a relatively aligned team, where the focus of individuals is generally aligned with the overall team direction. This leads to ‘coherence’ in understanding, commonality of purpose and shared vision.

Adapted from Senge (1990).

More coherence arises from less diversity in viewpoints, meaning there is less selective perception or selective memory (Vennix, 1996). As consensus is often desired for complex environmental decision-making (Salmon, Sundström & Zilliacus, 2005; van den Belt, 2004) and may be the objective of some New Zealand regulation (Ministry for the Environment, 2015), it is argued that the presence of this trait is a helpful first step in this direction.

Being able to explore and recognise these similarities of mental models is a result of the *dialogue* (Bohm, as cited in Senge, 1990) and *double-loop communication* (Argyris, 1994) discussed in Sections 10.2 and 11.5. Participants described satisfaction with the number of people who were passionate about similar environmental outcomes and noted a level of commonality with regards to things that people agreed upon. This reflects that more people were 'pulling in the same direction' than realised. While people used different language, it was often portrayed in a similar sense. One participant noted that "even though we don't use the same words, we mean the same thing" (Person A), another described it this way:

> *"I think Māori, some Māori, don't think that Europeans have the same connection to the water or the land but we bloody do. It's just, we just don't have a name for it." (Person F)*

While an alignment of objectives and direction was often noted, subtle differences in how these might be achieved remained. One participant noted that while aspirations were common, there were different levels or meanings tied to these aspirations. Another participant noted that:

> *"…essentially, we want the same thing, same thing or things, and I just think we just all see a slightly different pathway which is all interrelated." (Person J)*

Having more in common than thought is likely to increase the chance of a common goal being identified, and consequentially, more shared understanding (see section 11.5). It is also a step toward the desired consensus described by van den Belt (2004). However, the residual differences should not be understated and are demonstrated by the participant who noted:

> *"[another participant] was explaining [their] aspirations for the river and I'm going, explaining, 'look if with all the heart, soul and blood sweat and tears and money I'm putting into improving the waterways isn't improving the well-being of the river, then why am I doing it?!'" (Person A)*

11.3 Māori world view

The comments coded under the heading *Māori world view* were not highly *prevalent*, but were made with a level of *forcefulness* (Owen, 1984) that indicates their *relevance* to the discussion. While no specific literature was found discussing the Māori world view in relation to SD and system thinking, it has been found that GMB can result in consensus when applied within cultural contexts with highly diverse worldviews (Olabisi, Adebiyi, Traoré & Kakwera, 2016). Other previous discussions relating to the incorporation of various mental models is also relevant here.

Participants who identified as Māori tended to articulate that the holistic and connected view of SD was highly consistent with the Māori world view. One participant outlined how they had taken time in the workshop to reinforce that everything was connected and that was how Māori viewed the world, and that this was consistent with how the causal-loop approach worked. There was an inherent suggestion that the Māori world view was well-suited to deal with the complexity of these freshwater-management issues. Another participant thought that the causal-loop approach would resonate strongly with iwi at a community level because it would work well with the way that they approached decision-making. This is the first time that this consistency appears to have been identified, and reinforces the SD approach as a useful way of framing complex problems in the NZ context. Further exploration of the use of SD thinking with iwi or within iwi organisations would likely be an interesting and fruitful area of further research.

Several of the iwi participants highlighted that te reo Māori[15] was in fact not just a language that could be learned, but in fact a way of life that had to be lived and experienced, of which the spoken component was only a part. One participant spoke of the need to ensure connection with nature to remain grounded with the Māori perspective, while another described learning te reo Māori as:

> *"Learning te reo the language, it's not just like putting it on paper and you repeating it over and over and over so you know it. That's only a very small step towards learning Māori. You gotta understand the meanings, you got to practice, you got to actually live just about every word. To have a clear understanding, then [you] can say yes, I have learned Māori... The other way I can put it for you is that the knowledge that I have, I lived it!" (Person C)*

11.4 Group dynamics

Senge (1990) describes the work of the physicist David Bohm who, working in the 1960's, sought to understand factors that enabled *dialogue* as opposed to *discussion*. The origins of the word *discussion* are related to concussion and percussion, implying both or all sides contributing their views as much as possible in the hope that theirs eventually wins out as the dominant view. *Dialogue*, on the other hand, has its origins in words related to seeking *meaning* and that meaning is not something that is able to be 'won' (Senge, 1990, pp. 221-227). Bohm describes three conditions that are necessary for dialogue to occur: participants must be non-judgemental; participants must treat each other as colleagues and a facilitator must champion the process (Senge, 1990, p. 226). While the role of facilitation is dealt with in Section 10.2, the *attitude* of participants (which covers the other two pre-requisites) was very prevalent across the data, being coded in three quarters of all data sources.

While most comments related to the satisfaction of being involved with the process and the quality of the group, some specifically noted the need for

15 *Te reo Māori*, or *te reo*, is the Māori term for Māori as a spoken language.

an appropriate attitude. While people had volunteered to be involved in both projects (Rangitāiki River and Sawyers Creek), even though some were there as part of their job, there were several comments that talked about a ‘commitment’ to being involved and a ‘desire’ to contribute as best as possible, in line with the standards that the group had set for itself. While the group in the first project benefited from having already worked together (a factor found to be important in collaborative freshwater groups across New Zealand (Cradock-Henry et al., 2017)), both groups identified that the GMB process had helped build relationships and respect, both attributes that are likely outcomes of a GMB process (Langsdale et al., 2013; van den Belt, 2004), as well as being necessary conditions towards achieving any kind of meaningful result with model output. This outcome appears to be both the result of and, through a reinforcing loop, an enabler of *dialogue* in the group. A group dynamic is something that is highly individual to each group though, and no two groups will be the same. Thus, the time and effort required to establish a positive group dynamic cannot be taken for granted, particularly because each group has its own ‘group life’ (Phillips & Phillips, 1993).

Comments in around a third of the data sources analysed also indicated the curiosity of participants as a driver for their involvement, perhaps also indicating that it was a useful mind-set to help make the process successful.

While having people with the right attitude is important, ensuring that they have their optimal frame of mind when they are involved in activities is also important, as several people described being distracted or not in the optimal frame of mind due to other commitments or pressures that were weighing on their mind:

> *“Maybe I just wasn't in the head space to hear that at the time” (Person B)*

> *“I was probably a bit tired too perhaps and not thinking clearly” (Person F)*

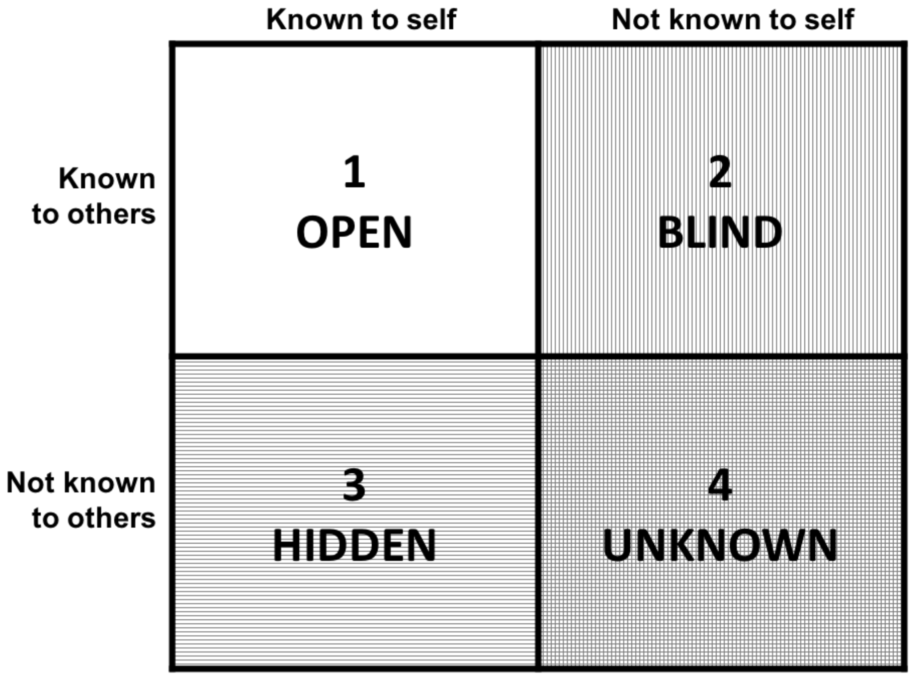
Other comments alluded to the challenge of working with people with varying comprehension of, or experience with, the issues, indicating this as a potential frustration within a varied group. This highlights the importance of facilitation to maintain effective discussion, while also emphasising the utility of the broad approaches used to promote interaction in a GMB process (e.g. writing; physical interaction, placement of things on walls, graphics, sketching and dialogue).

11.5 Increased shared understanding

By far the single largest heading to which comments were coded, and the only one to be applied to every single source of primary material (both semi-structured interviews and *ex-post* surveys) was that of *increased shared understanding*. As noted at the beginning of this thesis (Section 1.2), the identification of whether SD modelling helps increase the shared understanding of participants is a key objective of this research.

A useful guide to the level of understanding generated by human interaction was developed by Joseph Luft and Harry Ingham and is known as the 'Johari Awareness Model' or, less formally, as the 'Johari Window' due to its resemblance to a window frame (Luft, 1969). This simple matrix is based on two scales – what is *known and unknown only to one's self*; and *what is known or unknown to others*. This generates a matrix that provides a useful guide to 'shared understanding' and is shown in Figure 11.2 below.

Figure 11.2 The Johari Awareness Model (i.e. 'Johari Window') (Luft, 1969).



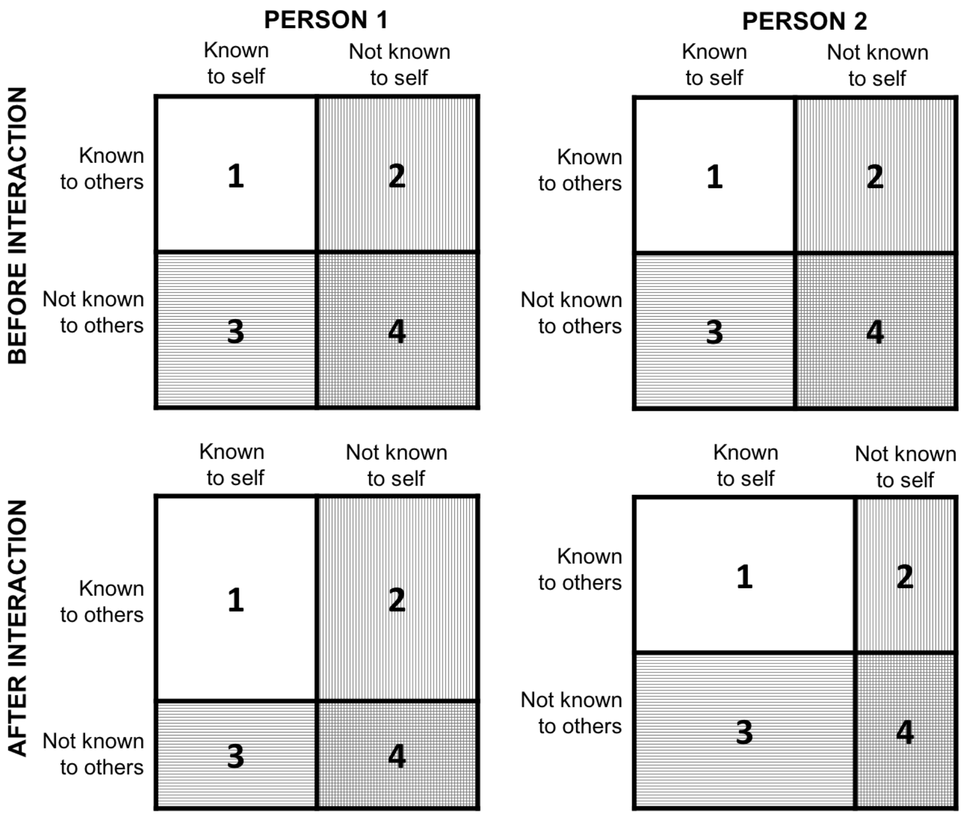
Adapted from Luft (1969).

According to this model, common knowledge or shared understanding is only found in the first or 'open' quadrant, this is knowledge that is *known both by one's self and others*. Something that is *known to one's self but not to others* is known as 'hidden' to others – i.e. it is something that a person (consciously or unconsciously) hides from others. Similarly, 'blind' knowledge is that which is *known to others but not to one's self* and one is (consciously or unconsciously) blind to it, while information in the 'unknown' quadrant is literally that, it is *not known to one's self or to others* (Luft, 1969).

In this important work, Luft (1969) goes on to describe a range of different interactions between people. He characterises a range of personality-type profiles, based on the patterns of interaction that he observed. While the personality profiles that he generated are of less interest here, what are of interest are the 'eleven principles of change' that he identifies. One of these principles states that "a change in any one quadrant affects all the other quadrants" (Luft, 1969, p. 14). The choice between whether something is *known* or *unknown* is binary, so the line that divides these two factors on either of the dimensions (horizontal and vertical) can be clearly drawn, but it will remain the same line across the entire length or width of the model.

To demonstrate, by example, refer to Figure 11.3 below. Before interaction, the squares in the quadrant for each person are equivalent in size. However, if Person 1 was to share some information with Person 2 that the latter had previously not been aware of, this would simultaneously reduce the size of Person 1's 'hidden' area and Person 2's 'blind' area, whereas Person 2's 'hidden' area and Person 1's 'blind' area remain the same. This is shown as a downward shift of the horizontal line in the "After interaction" quadrant for Person 1 and a rightwards shift of the vertical line in the "After interaction" quadrant for Person 2. Importantly though, the respective size of the 'open' areas for both people would increase and the size of their respective 'unknown' areas would decrease.

Figure 11.3 A change in any quadrant of the 'Johari Window' affects all the other quadrants.



Adapted from Luft (1969).

Legend
1: 'Open' area (shared understanding); 2: 'Blind' area; 3: 'Hidden' area; 4: 'Unknown' area.

In this research, ‘shared understanding’ relates to the amount of knowledge considered common, understood and broadly agreed amongst all participants in the GMB process – what would be the *open area (#1)* in the Johari window model. This definition has guided the semi-structured interviews and the coding process and, in terms of SD, relates to the extent to which the mental models of participants have become aligned regarding specific issues.

People’s mental models are rich in intuitive detail, but can cause “misunderstanding, miscommunication, and misapplication” (Richardson & Pugh, 1989, pp. 3) due to their implicit and fuzzy nature. The development of a formal model (such as a CLD) helps make these assumptions explicit and observable, allowing criticism and reformulation (Richardson & Pugh, 1989, pp. 2-3). The focus of shared understanding as an objective here reflects the importance of understanding and combining individuals’ mental models to meaningfully understand systems and the potential interventions that systems thinking can provide (Senge, 1990). Senge (1990) describes how limited understanding of mental models is a key reason why the best ideas fail, and that building increased understanding forms the basis for being able to develop team learning. Team learning leads to an aligned team, resulting in a minimum of wasted energy within a group, a pre-requisite for achieving improved results. Senge (1990, p.128) describes this as a “the process of aligning and developing the capacity of a team to create results its members truly desire” and a “necessary condition” to empower a team to achieve high-performance results.

Similar goals to increasing shared understanding are likely to have been motivations in the growing focus on stakeholder involvement in NZ freshwater decision-making discussed earlier (Land and Water Forum, 2010; Ministry for the Environment, 2012b, 2014). In this context, shared understanding is key to developing pragmatic solutions. The following description of the benefit of common understanding in decision-making comes from the facilitation literature, but also has much relevance to the context of GMB:

> *"While each piece of participant data can be assumed to be valid, no piece is the whole picture. Everyone has a piece of the puzzle, but the whole picture comes together through hearing and understanding all the perspectives. There are always conflicts, as people fail to understand each other's perspectives and experiences. But… any group can arrive at a common understanding. Whether that understanding is precisely true and complete is a matter of opinion. For that group, at that time the understanding they arrive at is appropriate wisdom. It is temporarily true for them. For truth is not set in concrete, forever immovable. It is a moving target, an evolving construct. The group always has to come to its own understanding of its own business." (Stanfield, 2000, p. 36)*

Indeed, a *shared understanding of the problem*, rather than a perfect SD model, is the primary goal of a GMB intervention (Vennix, 1996). Put more succinctly:

> *"An increased level of shared understanding of a problem improves the chances that a mutually acceptable solution can be found." (van den Belt, 2004, p. 9)*

While the extent that this was achieved will be discussed soon, the question remains *how* is this achieved? While the influence of process and facilitation have been discussed in earlier sections, the Johari window model provides useful insight into the *impact* of independent facilitation (Doyle & Strauss, 1976), structure and focused conversation (Stanfield, 2000). Having an *attitude of inquiry* (Vennix, 1996); being *non-judgemental* and treating other group members as *team members* (Senge, 1990) maximises the opportunity for 'double-loop' communication (Argyris, 1994) to occur. The process of a well-run GMB process reduces the relative size of the 'blind to' and 'hidden from' quadrants for each participant involved; therefore, maximising the 'open' quadrant denoting the extent of shared understanding. The more a group is willing to explore each other's different mental models and ask questions, the higher the likelihood that they will maximise the ‘open’ area of the quadrant of group knowledge and achieve an outcome that is successful (Hall, 1971).

Quantifying the extent to which mental models have evolved in a group is difficult and methods are still developing (Fokkinga, Bleijenbergh, & Vennix, 2009). The *ex-post* surveys discussed above (Section 7) possess the associated issue of self-reporting bias (Scott et al., 2016b). Accordingly, this thematic analysis provides an alternative viewpoint. The research participants had a wide range of experiences relating to the shared understanding of the group, mostly with high levels of alignment. Yet, a variety of things were identified. The different world views of the participants were highlighted, with some noting how the process was good for eliciting different peoples’ opinions on things. Person D noted that “if you’d asked everyone there to do their own [CLD], they would have all been quite different.” Some told how the perspectives that some participants expressed had not been what they had expected. Others articulated that pre-conceived ideas they had held about some land-uses or farming practices had been altered due to the discussions. (While it is noted that those in the Rangitāiki project had benefited from such discussions in prior workshops, this same theme was also identified with the Sawyers Creek participants, who had no such history.) One participant even described the GMB process as a far less controversial process than they expected, this comment itself representing a change in mental model relating to how the group would interact and a likely increase in the size of the group’s ‘open’ quadrant (Luft, 1969).

Some of those with a highly technical background or a wide exposure to group processes did not find that the process introduced any new information about the physical system, suggesting that their ‘known to self’ sector (Luft, 1969) was likely to be more developed than others:

> *“I think it's the same things that are cropping up.” (Person G)*
>
> *“I don't want this to sound, sort of, whatever the word is, a bit snobby. I don't know that it added a lot to my understanding, but mostly because of my previous*

experience I've got quite a high level of understanding already. I may not have put it in in that structure or portrayed it in the way that it's portrayed in the causal loop diagram. But the factors that are operating, I'm pretty familiar with all of those factors and been in discussions about them many times before, so it wasn't anything new from that point of view". (Person H)

Yet, others with a high level of technical knowledge described significant changes or advances in their personal understanding (or mental models) of parts of the system not related to their technical knowledge, an indicator that the 'known to self' quadrants in their personal Johari window models were evolving considerably, a necessary pre-requisite for an increase in shared understanding (the 'open' quadrant) (Luft, 1969). This was demonstrated by a comment responding to a question about how the process had improved one participant's understanding:

"From an environmental perspective, I don't think a great deal. But from a social perspective, it has." (Person B)

With the Rangitāiki interviews, a range of comments related to a detailed conversation that occurred in the first workshop around the concept of Māuri, or the 'life force' of natural things. Many of the non-iwi participants in this group commented on this theme and it appears to be an example where a higher-level of shared understanding developed within the group. If this subject had its own Johari Window model, then it is likely that this would have experienced one of the largest increases in its 'open' quadrant out of all subjects discussed. The fact that this concept was discussed appeared to benefit the process, allowing it to be explored in more detail – in effect, promoting 'double-loop' communication (Argyris, 1994). One pākehā participant (The te reo Māori term usually attributed to a New Zealander of European descent is *pākehā* and this term is in common usage in New Zealand) described this learning thus: "for me that was, and I suspect the other European members of the group, that was quite a bit of a revelation", while another pākehā member described this discussion as a "lightbulb moment”. This is another example of the CLD being a vehicle to help the *group dynamic grow*, not solely a *result to be achieved*.

Beyond that specific issue, other descriptions of the entire experience included the following:

> *“I think I built a bigger understanding of some of the things that I don't understand and where people are coming from”. (Person A)*

> *“it's bloody interesting this stuff. The ideas that come out of the group and you think ‘man - yeah I never thought of that, yeah that's right’” (Person F)*

Overall, there were a range of comments that provided evidence that for both groups there was an increase in the size of the communal ‘open quadrant’ (Luft, 1969) or shared understanding of the system being discussed. Person E described how factors and subjects were brought up that had not been covered previously. Person M described how their understanding improved “quite a bit”, and that “the flow-on effects, the causes” became more obvious during the group process. One survey response captured the benefits of this quite well, when it noted:

> *“It helps understand [the] perspective[s] of others and the links to the factors. It is important to think of the whole rather than individual segments of the water.” (survey response, Person A)*

Many participants clearly used words such as ‘understanding’, ‘collective’ and ‘common’ when describing the lessons of the group – all words that relate to the ‘open’ quadrant (Luft, 1969). The experience was alternatively described as improving everybody's ‘collective understanding’, ‘crystallising’ people’s thinking even though they came from different places and points of view, helping grow a ‘holistic’ and ‘broader’ view, providing ‘uplift’ to the collective understanding of the group and being an “improvement to the group, overall” (Person O). Several comments from participants that articulate this sense of improved shared understanding are captured below:

> *"I've always had an open mind and I'm quite a big picture thinker. But… I found it really interesting as to how much commonality and how many issues are all interconnected." (Person F)*

> *"Everyone is really different. But I think there is some things in there that we kind of agree on. There seems to be a commonality of factors sitting in there that we would all agree on regardless of our different backgrounds." (Person E)*

> *"I'd like to think that people sitting around in that room. That they would look at that and say it's not just that one thing that I thought it was, it could be other things. And that's a useful conclusion to get to." (Person P)*

The above demonstrates a variety of experiences of the participants involved. While some participants judged that their understanding of the system did not improve dramatically, the extent that the group understanding was seen to improve is evident, thereby enlarging the 'open' quadrant in the Johari Awareness Model (see Figure 11.2). One participant even described the experience in SD terminology when they said that it "synthesised" the "individual parts of the collective whole" (Person P).

The Johari window model is an accessible means of assessing conversations about collective knowledge. This is a useful tool for guiding conversation or helping groups to estimate a level of commonality that they may have about an issue, as most people can relate to concepts of what is 'known' and 'unknown' to each of them. Certainly, it is a simple yet powerful way of demonstrating the real benefits that come from attitudes of inquiry (Vennix, 1996), non-judgement and respect for other group members (Bohm, as cited in Senge, 1990), and the benefits of seeking deeper understanding from each other (Argyris, 1994; Doyle & Strauss, 1976; Hall, 1971), particularly in a GMB process.

11.6 The tools as a visual aid

Much of the analysis of themes has so far been dedicated to the *discussion* that occurred in the workshops. This section will focus on the tools as a *visual aid* to increasing shared understanding.

In the absence of being able to replicate the real-world in a model, the use of abstract or 'boundary objects' may be useful (Black & Andersen, 2012). Boundary objects are tangible and shared, and more visual than descriptive; they portray dependencies and relationships among participant's objectives, expertise, decisions and actions and can be modified by input from any participant (Black & Andersen, 2012). It is argued that the CLDs developed in this research can act as boundary objects and many comments from participants appear to support this viewpoint.

Comments regarding the visual aspects of the tools were *moderately prevalent* across the data. Those that supported this perspective were also made with reasonable *forcefulness* (Owen, 1984). Participants found the document camera a useful tool and took satisfaction from the fact that their input was being incorporated, literally, as they spoke. The diagram evolving in front of them also helped expand their understanding:

> *"So, with the guy who was drawing, we could see what was going on. And then we started to understand what was going on with the diagram. And then it kind of made us, then we started to pause, because things were then "ah okay, now we know what he's looking at" and we kind of all jumped in with what was influencing what" (Person E)*

> *"…It was really useful for me, because I don't have a background of science, I don't have a background in … water issues, to see it all up like that and hear people talking about those connections made lots of things really clear to me." (Person P)*

The main benefit for most was the *understanding* that the visual aid helped generate, but some also described it as providing *clarity* and being *tangible*.

Some noted that it was the knowledge that they knew the group had, but it was presented in a novel format. One also described the visual component as a power-leveller, minimising the risk of strong personalities dominating.

The visual output of the workshops was therefore very important. Not just for facilitating the workshop itself, but to increase understanding, agreement and trust, which is consistent with the benefits of boundary objects described by Black and Andersen (2012).

11.7 Ownership of outcome

This section discusses participants' ownership of the outputs from the GMB process.

Much work in the early decades of SD saw the pursuit of 'micro-worlds', or the development of stylised descriptions of the world in simple, dynamic simulation models (Rouwette et al., 2002). While SD is a tool for working across both these elements – building understanding and insight as well as developing micro-representations of reality – work in the last decade or so has seen the emergence of two broad groups – those focusing more specifically on attempting to develop micro-worlds and those focusing on using models as abstract tools to develop trust and agreement (Scott et al., 2016b). The latter group has taken a deliberate move towards involving clients and stakeholders in model building, to foster greater ownership of the models developed and generate implementable solutions (Rouwette et al., 2002). It does this through sufficient deliberation and consensus building (Vennix, 1996). It is therefore appropriate that the ownership of outcomes from GMB was identified as a heading in the thematic analysis and that it is prevalent across most data sources.

The generation of implementable solutions is considered more likely when there is a high level of involvement or ownership (Rouwette et al., 2002; Schein, 1987; Senge, 1990; Vennix, 1996). This theme was demonstrated at a practical level by one participant who noted that:

> *"if a government or a council says, "this is a problem and we want you to sort it out", there's quite often a rebellion*

against that. Whereas I think if it comes from [the community], that's quite different." (Person P)

Such a level of ownership is evidenced by the *prevalence* of comments in the data that refer to the group's understanding being 'captured' in the output and the fact that it, to an extent, reflected them or that they felt 'connected' to it. Most comments in this heading were made with reasonable *forcefulness* (Owen, 1984), indicating their importance. One participant talked about the 'collective' generation of the output, while another noted how "we've all collaborated on creating that thing [the CLD]. So... it's the product of people working together, and doing it very actively as well" (Person N).

This extended into an oft-expressed sentiment that participants would own the presentation or description of the output back to wider groups, or those involved in or responsible for decision-making.

Another strong indication of the level of ownership was a high level of 'comfort' with the CLD. For example, the comments of Person I (used earlier in Section 9.3) are also relevant here: "we got to give a lot of feedback into how the model was going to be developed and [that's] probably why I felt comfortable with it." Others talked simply about the satisfaction of being involved, describing it variously as good, excellent, positive and enjoyable. One person noted that "I'm really pleased I went and I don't think there's anyone that isn't pleased they didn't take part in it." (Person B).

There was therefore a lot of evidence to indicate that there was a strong sense of satisfaction and ownership of the outcomes attained from the workshops.

11.8 SD terminology and concepts sometimes difficult

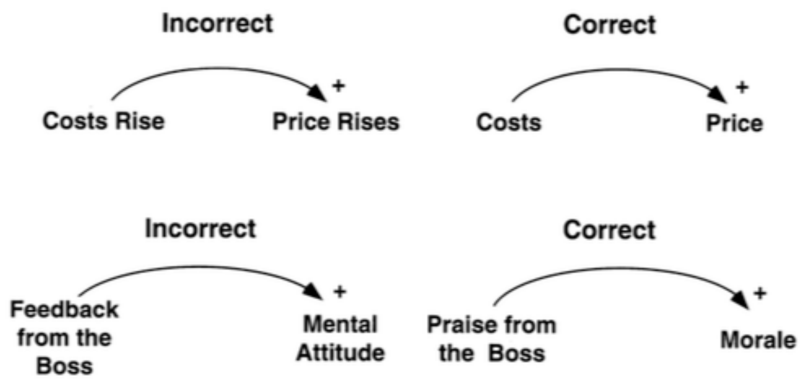
The issue of SD terminology and concepts sometimes being difficult to understand is discussed here. While of lesser prevalence, it is important to note that some participants found the terminology particularly challenging.

The piloting process (Section 4) identified that some people struggled with understanding the "+" and "-" signs used to denote the direction of relationships in CLDs. Accordingly, following Sterman (2000), the terms *Same* and *Opposite* were substituted for *Positive* and *Negative* to help those people who found the initial terminology difficult. While some comments noted that the *concept* of same and opposite was easy to understand, a few people found it difficult to determine in practice. This indicates a challenge not necessarily with the *relationship* itself, but with the *variable* and the need to clearly define it. A couple of participants described it as a challenge to clearly determine if a variable *increased* or *decreased*. This is a common challenge when drawing CLDs and Sterman (2000) noted (see Figure 11.4) that variables should be *nouns or noun phrases* and the variable names should have a *clear sense of direction* (i.e. it should be clear how they go up or down).

Figure 11.4 Common mistakes when labelling variables and relationships.

Variable names should be nouns or noun phrases

Variable names should have a clear sense of direction



From Sterman (2000).

Describing the impact of relationships on variables back to participants during the workshop was a deliberate tactic to ensure their polarity was understood and properly recorded. For example, when a link was labelled by the group, the facilitator usually talked the group through it and posed it as a question – "so, more of this will lead to less of that?". This was a successful strategy in practice and a useful demonstration of the Facilitator and the Modeller roles needing SD experience (Richardson & Andersen, 1995); it also appeared to clarify the polarity in most peoples' minds. A visual way that the facilitator tried to reinforce the polarity of the relationships was by colour coding the links when they were presented back to the group in the second workshop. While this was found to be useful, the choice of colour could be improved – the facilitator used green for positive/same and red for negative/opposite, which one or two people seemed to confuse for the *quality* of the relationship (i.e. "oh, it's green so a *positive* relationship must be a *good* thing").

Every effort was made to both explain these relationships clearly, and keep a description of them on-hand (such as on a chart on the wall during the workshop). As discussed previously, electronically recording the workshops was also useful as it provided the opportunity to refer to these recordings at a later stage.

11.9 Overall CLD daunting

The previous section outlined the challenges with some of the terminology of SD. This section discusses the moderately prevalent heading (coded in more than half the sources) of the overwhelming nature of the entire CLD.

While qualitative modelling in the form of CLDs is one of the objectives of GMB (Vennix, 1996), representing too much on a single CLD may only serve to confuse and overwhelm people (Sterman, 2000). This potential pitfall was certainly observed in both projects in this research. At the end of both workshops, participants appeared highly satisfied with the process and the understanding they had generated but, at the same time, were overwhelmed by the complexity of the diagram they had developed. Descriptions of the two diagrams included 'bolognaise', 'birds nest' or 'spaghetti junction', and many participants expressed that they had no idea what the researcher would then do with this diagram and wished him 'good luck' with interpreting it. Key lessons arose when the models were presented back to the groups and they had the opportunity to discuss partial analysis and archetypes in the second workshop (see Section 11.10). Nonetheless, the complexity of the final models was not viewed as a limitation; rather, the diagrams themselves can potentially be considered mainly a vehicle to facilitate discussion during their development. In this context, the complexity of the resultant CLD can be a benefit and indicative of rich and broad discussion among group members.

Large, confusing CLDs are viewed as a limitation by some. Sterman (2000) suggests that it might be possible to mitigate confusion by building up the CLD in stages. Similarly, van den Belt (2004) suggests a similar strategy, but in the context of numerical simulation models. The gradual development of a model by sector was also suggested in the structure-elicitation script originally trialled from Luna-Reyes et al. (2006), where the use of clear acetate layers was suggested as a means of building up a stock and flow architecture in parts (see Section 3.2.1). While the acetate approach was found to be clumsy during testing and was subsequently abandoned, future applications of this approach may test the use of dividing the system into sectors at the beginning of the GMB process, as advocated by van den Belt (2004), and building each in turn. A much clearer understanding of the system was gained by participants when the CLD was presented back in stages in the second workshop. Certainly this, along with the use of archetypes, was endorsed by some members as the easiest way to present and discuss the diagram with those who were not part of the process.

11.10 Archetypes

The archetypes that were found in the CLDs are described in Appendix 20 and participants generally found them useful and of interest. This was noticeably more so on the second project, where the problem focus was much more specific and all the relationships in the CLD, bar one, were clearly identified as either Same or Opposite. The archetypes were useful because participants often found the complete CLD overwhelming (see Section 11.9), speaking of a more positive reaction to a partial or more focused representation of the overall diagram. Once broken down into parts, participants spoke of the CLD being ‘useful’, ‘meaningful’, ‘making sense’ and ‘being put in context’. One person noted that it helped make the relationships clearer, even though the subject matter had been discussed at length in the first workshop and that it was effectively ‘common sense’.

While most found the archetypes useful, some did not find them to be a natural way of thinking. Rather, it took some concentration and explanation for the archetypes to make sense. One participant noted that "…it was a weird way to look at it. But when you look at it and listen to what you were saying - it's got merit" (Person B). This same person also described the archetypes as 'a bit of an epiphany' and the *reverse* to what their natural understanding would have been. This seemed to reinforce the need for more time to help participants become more conversant with the system thinking approach.

Others spoke of the clarity around relationships within a system that came from the identification of archetypes, also noting that those relationships might not have been obvious otherwise:

> *"So, there were some kind of, quite eye opening, obvious conclusions that... Well they weren't obvious, I guess they're not obvious, that's why it was so interesting that even though they were complicated relationships, it's really easy to see - although not obvious - how one thing can affect another and can spiral downwards or spiral upwards." (Person P)*

These comments provide more evidence of how CLDs can provide insight into the counterintuitive nature of social systems (Forrester, 1971). They also highlight the benefit that comes from the involvement of practitioners that are familiar with CLDs and archetypes, something that is discussed in more detail in Section 10.2.

Some participants found the archetypes useful for understanding the system:

> *"I find it hard to follow diagrams, but that was when we had the first ones done the first couple days and then you come back and you broke it down into areas, you can understand it easier… when you isolated the areas and then sort of bought it back in, you could actually see the system more - well I could easier." (Person L)*

System archetypes either provide insight on their own (Senge, 1990); provide the basis to build up a model; or are identified within a completed model (Braun, 2002). Overall, they have been found to provide huge insight into the *nature of* and peoples' *understanding of* a system (Braun, 2002; Senge, 1990; Wolstenholme, 1999; 2003). Some participants came to insightful realisations once the CLD was presented to them in terms of different archetypes. Person P noted:

> *"Like I know, I know that those links exist and, but I don't… until I'd seen them - and it's not a complicated diagram - but until I'd seen it in a diagram and had been talked through it, I just didn't even really understand the potential implications." (Person P)*

Other participants, however, noted that while archetypes did provide some insight, they may not have been at a high enough level of detail:

> *"You could actually see how it can be helpful. At least in terms of understanding the different interactions and the levers that you can pull. It's not going to solve where there is, it's not going to solve any contention I guess, that you might have in a collaborative group, but at least it will highlight the areas where you can try and tinker with to realize some improvements, or win-wins or some benefits in what you're trying to achieve." (Person G)*

Risks with applying archetypes have been noted. Vennix (1996) describes the danger of 'premature recognition'; here, an archetype may be applied when a closer look may drive the need to adapt the CLD slightly, producing a vastly different dynamic result. Issues of system boundaries crossing through archetypes has also been raised, where some components of an archetype structure will be *exogenous* to a system (Wolstenholme, 2003). Certainly, while they provide excellent insight into the behaviour of a system (Senge, 1990; Wolstenholme, 2003) they are unlikely to be sufficient models when taken only by themselves (Braun, 2002).

In summary, it was found that describing and presenting archetypes from the CLDs drawn by the groups was, in general, useful. In both the second workshops, the groups were comfortable with the relationships and found the archetypes or patterns insightful and useful for identifying and describing the key influences and helping to identify areas of intervention. This finding was stronger in the Sawyers Creek project, where the problem focus was more specific and all bar one relationship was able to be clearly labelled. A potential limitation of applying archetypes (or any follow up) relates to the amount of time that passes before the second workshop can be held and is discussed in Section 12.2.

11.11 Communication tool

This section focuses on the potential use of these as a communication tool. Comments relating to this factor were moderately prevalent across the data, being coded in around half of the data sources.

There has often been limited reporting of the impact of GMB on communication within teams, as the fact that it will occur or improve is often assumed to occur as simply part of the process (Rouwette et al., 2002). The evidence that does exist, however, tends to support the positive impact that GMB processes are believed to have on communication within groups (Rouwette et al., 2002; Scott et al., 2016b).

Participants expected the CLDs or parts there-of – for example, the identified archetypes where they were agreed – were likely to be beneficial for communication. Most often, the comments of participants referred to communication within teams or groups that they were a part of and, to a lesser extent, their use in communicating to the wider public. Examples of the teams or groups that people were referring to were the types of groups that participants were representing at the workshop, as well as people that would need to be involved further in decision-making (e.g. key stakeholders not yet identified) and decision-makers themselves, such as senior management and councillors. These examples could be defined as being those involved directly in decision-making or whose support (tacit or otherwise) may be required for a decision to be implemented, once agreed to by the stakeholder group. This is very much in the vein of Senge (1990), whose work has usually been targeted at a management audience. One participant even made a direct link between the ability of the output to be communicated and to influence further action as a measure of its success:

> *"Some of those patterns, in particular the reinforcing loops, could really be used to kind of encourage a course of action… So really there's got to be, we've got to be able to communicate it for it to be valuable." (Person P)*

A smaller number of participants thought that the diagrams would be useful to the public. One noted that literacy and overly-complicated graphs and images were often a barrier to the general public's understanding of issues, so these types of images may be a good way of communicating the complexity of situations. Another noted that the causal loop approach might be useful in Māori communities where there is both a tradition of oral communication and low levels of literacy can sometimes act as a barrier to understanding.

11.12 Summary – Building a group AND a group model

The theme discussed in this section is possibly the most important of the four identified, in addition to being the largest and most prevalent throughout the data (47% of coded extracts). The research has highlighted that the decisions being made within the case studies are significant and hold quite a lot of *creative tension* (Senge, 1990) for those involved. While the main *intended outcome* of the process in each case study was the development of a CLD, this was surpassed by the *unintended outcome* of the process constructively impacting on the *groups dynamics*. Group members generally found that they had much more in common than they thought, and the systems thinking approach was found to align with the holistic nature of the Māori world view. The contribution of the GMB process to building both a model and a group resulted in a dramatic demonstrated increase in both ownership of outcomes and shared understanding.

12 Theme 4 – Useful yet more detail required

This section will discuss the final theme, that reflects on the usefulness of some elements of the process and considers some shortcomings and possible future applications.

12.1 Uncertainty in subject matter

Decision-making is often based on limited information; some things are assumed, some are unknown and some even unknowable, all situations where SD modelling can contribute to decision-making (Sterman, 1994). In *Principles of systems*, Forrester (1968) describes the nature of systems and their behaviour with clarity and insight that has informed the discipline for decades since. While referring more to quantitative, rather than qualitative, modelling, his comments relating to model validity being a *relative* measure hold true for both:

> *"There is nothing in either the physical or social sciences about which we have perfect information. We can never prove that any model is an exact representation of 'reality.' Conversely, among those things of which we are aware, there is nothing of which we know absolutely nothing. So, we always deal with information which is of intermediate quality – it is better than nothing and short of perfection. Models are then to be judged, not on an absolute scale that condemns them for failure to be perfect, but on a relative scale that approves them if they succeed in clarifying our knowledge and our insights into systems." (Forrester, 1968, p. 3.4)*

The tensions and comments discussed in this section best relate to the two concepts of SD that Sterman (2002) notes people have the most difficulty grasping, that "all decisions are based on models, and all models are wrong."

The bulk of comments coded here, almost exclusively from the Rangitāiki workshop, indicated that many people thought that the CLD could be developed further. Comments included that it needed ‘more detail’, to be ‘developed more’ or that it could be ‘taken further’. Comments from this project also discussed the tension of getting the right level of aggregation, with several noting how much was ‘wrapped up’ in most of the factors. There were limited comments of this nature regarding the Sawyers Creek CLD for reasons that, as discussed in Section 5, are likely to reflect the fact that all variables generated by the group were incorporated and all influences (bar one) were clearly labelled.

Comments from both projects related to the challenges of making decisions with insufficient data. There was an appreciation that modelling was not reality: “modelling's great, but it doesn't always truly reflect every place that you're at” (Person A) and that attempting to model reality was difficult and there was a lack of data, particularly economic and social data. Several people highlighted the desire or need for more detail, while others recognised that this pursuit of detail would eventually have to be drawn to a close to make a decision, and that assumption was always a part of decision-making:

> *“At the end of the day though, we have to come up with a target and we have to come up with a result. And we could causal loop ad infinitum because somebody in the end has to draw a line in the sand…. at some point in time we do have to draw a line in the sand because no matter what we do there's going to be an effect - possibly positive and possibly negative - well there's going to be an effect on everyone.” (Person B)*

The tensions of the relative validity of models, as described by Forrester (1968), appear to have been experienced by both groups. The comments here highlighted that: people acknowledged that data was in some cases limited or uncertain; how some things might be measured was not clear and more detail would always be desired or useful but at some point, a decision needed to be made and there will always be some level of assumption necessary. See Section 11.1 for a discussion related to decision-making more specifically.

12.2 Time availability and efficiency

This section discusses the need for sufficient time and good time management.

The time available for considering a problem and potential actions to address it is always a key constraint, this reality is no different with GMB. In *Industrial Dynamics*, Forrester (1961) describes various likely time frames of months to years, which must be considered in the context of the limited computing power available in the 1960's, compared to what is available today. Modern time frames, however, can vary just as much and depend completely on the situation, with focused GMB processes taking anything from a few short weeks or months (Luna-Reyes et al., 2006; van den Belt, 2004; van den Belt et al., 2013) to several years in length, especially if seeking a consensus outcome (van den Belt, 2004). Key determinants of these time frames are the nature of the required regulatory response, resource scarcity, social complexity and political will.

The time required for systems thinking to become accepted by decision makers needs to be incorporated and such an attitude change may take some time (Forrester, 1961, pp. 362-363; Senge, 1990). While the use of concept models (i.e. models related to core concepts, but not richly descriptive of the system itself) can speed up the model-development process (Luna-Reyes et al., 2006; van den Belt, 2004; Vennix, 1996), their use may have the counter-intuitive effect of reducing a group's likelihood of supporting the resulting model, as Akkermans notes:

> *"Since the model is not created by the group the model might not be recognised by the group and the feeling of ownership could be quite low. Low ownership in turn leads to low commitment." (Akkermans, 1995, as cited in Vennix, 1996, p. 113)*

This again resonates with Schein's (1988) observation that people tend to not like being 'told' an answer, much preferring to develop the solution themselves in a process he describes as 'process consultation' – this is far more likely to result in a solution's support and adoption (Schein, 1988). This 'soft' benefit of spending an appropriate amount of time on GMB and developing a level of ownership among participants for the group, not just the resultant CLD, also features in other parts of this analysis. One participant described how this research process was ‘seeking’ information from, rather than ‘telling’ information to, the group (Section 10.2), while another talked about the potential issues they expected when they introduced the outcome of what they had done back to the wider group they were operating within:

> *“…It will be fun when we introduce it to the full group… [laughs] because it's just gonna bog us down! I mean I wouldn't want to sit there and think these guys decided this and this is what we thought, without having any debate on it, so why would anybody else not want to? I mean those people are all involved because they're interested and whilst we weren't making decisions on behalf of the group once they hear what we've come up with, they're going to want to debate it.” (Person B)*

The need for more time was overwhelmingly the strongest suggestion for improving the process and was prevalent across most data sources; several people also noted that they felt that they had run out of time in the first project – which likely reflects the lack of problem focus and the consequently ambitious nature of the discussion in that project (see Section 0). There was, however, an acknowledgement of the limited cognitive capacity and productivity that was possible from a group of people in a one-day workshop, and some interviews did discuss the mental fatigue that was felt by some towards the end of the first day on both projects.

While these comments relate to the need for as much time as possible in the process, they should also be considered in balance with evidence that the time available was used both *effectively* and *efficiently*. Involving participants in decision-making certainly takes more time, but it is considered to build better outcomes (Land and Water Forum, 2010; Salmon et al., 2005; van den Belt, 2004; Vennix, 1996) and has been described as ‘going slow to go fast’ (Twyford et al., 2012). Time has been identified as a key element of success, particularly in collaborative processes focused on New Zealand environmental issues (Cradock-Henry et al., 2017).

Various participants expressed the efficiency of the process and their satisfaction with the pace of the workshops, variously describing them as ‘quick’, ‘efficient’ and getting them ‘to a place quicker’, as well as talking about how they ‘grew’ and ‘built quickly’. One participant described it this way:

> *“And that's what I liked about this thing. We went from the stick-its to actually, you know, developing the causal loop. I was really quite amazed at how we went from stick-its to this, and it was quite easy! The ideas just flowed from the group, didn't they? You were going flat out to keep up. So, it just got those ideas flowing.” (Person F)*

While others expressed the efficiency in terms of the resulting outputs:

> *“I still think to be able to get an understanding from all the people that were there of a process as large as that and its relationships in two days is pretty good, really.” (Person P)*

> *“I'm in similar sorts of meetings where you have to come up with a plan and make compromises. Comparing it to those other experiences I've had I think that went a lot better than a lot of the other kind of meetings I've had.” (Person N)*

The spacing of the workshops differed for the two projects, being spaced further apart for the first project than for the second. It was found more beneficial to have the workshops closer together than further apart, as some people needed reminding of some of the detail from the first workshop when they were further apart (see Section 0). This should be considered in advance when planning a GMB process.

12.3 Versatility of process

SD originated from organisational research in the post-war period (Forrester, 2007) and the versatility of its application can itself be seen in the variety of ways it was applied by the discipline's founder, Jay W. Forrester. His application of SD covered management issues in industry (Forrester, 1961), urban development (Forrester, 1969) and the carrying capacity of the world (Forrester, 2007), which led to the famous attempt to assess the carrying capacity of the earth – *Limits to Growth* (Meadows et al., 1974). A variety of academic and real-life commercial applications are evident in the SD literature. Examples include petrochemical companies (de Geus, 1997); airlines and manufacturing companies (Senge, 1990); car makers (Sterman, 2000); large tonnage shipping and social housing policy (Vennix, 1996) and a range of environmental (including water management) and other public policy applications (Ghaffarzadegan et al., 2011; van den Belt, 2004; van den Belt et al., 2013).

It is therefore not surprising that participants noted the versatility and applicability of SD and causal loop modelling. Some actively saw it as useful in a variety of applications that they were involved with and endorsed it as an approach to be used in policy development more often: “I think it's been a useful process, in that I can see it being used again” (Person A).

Others described the applicability of it across a range of decision-making scenarios, both council:

> *“If you applied that system to solving some of the [other problems of local government], I believe it has quite a bit of merit going for it.” (Person M)*

> *“So, I thought it was really good and useful and I could see it being used by [council] elsewhere” (Person P)*

and corporate:

> *“And like one of the other guys… said, he's excited to use this in his own business.” (Person B)*

> *“From attending the workshop, I can see that you can apply it in different areas” (Person K)*

Comments in this regard are consistent with other work that has found the versatility of SD to be one of the key benefits of the approach (Winz et al., 2009).

12.4 Weighting of variables

While many participants thought that the process was useful, it was obvious that it did not provide all the answers. This section discusses the issue of the relative weighting of variables, a heading that was prevalent in just under one third of data sources.

CLDs are the qualitative side of SD and as such are not able to provide the rigourous and more specific insight that the quantitative methods do (Sterman, 2000; Vennix, 1996). Given the limited time available, the existence of quantitative modelling was not acknowledged with participants – they were only told about CLDs to limit the information they needed to absorb on the day. Some comments, however, indicated that some members of the group were progressing toward this natural next step of quantification anyway:

> *“I think we were always tending to drop into "how big is this specific factor?", which wasn't really the aim of the exercise.” (Person O)*

> *“...In my mind, anyway it's "How would you weight them?". As you get the weighting of them right you're probably in a position... and that'll be where the debate will happen, is around the weighting I guess, of how they would sit.” (Person I)*

> *“So, I mean we don't, I don't know necessarily how for example how weighted one of those aspects is. It might be only SLIGHTLY weighted to the effect or it might be really HEAVILY weighted to the effect and so it's the levers that we're going to be interested in, in the long run.*

What levers? If we pull this lever what happens down the road?" (Person A)

While the need to weight factors was not noticed by all participants, when it was observed, it was with reasonable *forcefulness* (Owen, 1984). This highlights the fact that when it was noticed, it tended to reflect the connection in the participant's mind between the elicitation and development of understanding as a group, and the need to apply this to decision-making as a group at a later stage. This is a demonstration of how the CLD approach lays a good foundation for the group to understand the relative complexity of a system, while at the same time beginning to consider issues of relative weighting within the system. Further, the step towards quantification arises from the group itself, in a natural form of progression. This builds ownership and reduces the risk that the group interprets the need for numerical modelling being thrust upon them. Also, the CLD provides a natural foundation for further stock and flow modelling.

A link to policy development, and more importantly policy testing, is one of the main reasons that quantitative model development and simulation is outlined as important in the literature (Maani & Cavana, 2007; Sterman, 2000; Vennix, 1996). The rigorous development and testing of policy interventions has been argued as a key benefit of SD, and a limited focus on CLDs in the discipline has been raised as limiting the ability of SD to influence decision-making (Forrester, 2007). It has also been stated that the use of simulation models may increase the chance that commitment and consensus lead towards a system change (Rouwette et al., 2002).

The development of a simulation model, according to a method described by Luna-Reyes et al. (2006), was an original objective of this research. However, this study has identified that this approach poses substantial risk in the context of constrained resources, as limited time frames challenge the capacity for stakeholders to understand key concepts in the development and application of dynamic simulation models. Indeed, it is emphasised how causal loop modelling provides an important, accessible, and pragmatic first step towards generating a shared understanding of the best ways to manage complex systems.

12.5 Future use

This final section looks at the potential future use of the CLDs or archetypes that were the outputs of the GMB process.

Several key pieces of literature stress that SD modelling is best when progressed to simulation stage to test policy options (Sterman, 2000; Vennix, 1996, 1999). However, most participants did not see this as a limitation of the process, as much as a next logical step.

Many talked about the way that the focus of future conversations would be aided by the experience of having developed a CLD. A range of ways that this could occur were identified. The most important of these were:

1. allowing groups or council staff to be proactive with issues, rather than waiting for problem symptoms to present themselves;
2. helping the groups or councils to identify key policy levers;
3. reflecting back on the linkages identified when considering such policy options and interventions; and
4. helping to identify the key variables that may need to be incorporated into any modelling that might occur as part of further policy development.

These suggestions provided good directions for how the CLD information *could* be used in the future; however, some participants did note that there was little understanding as to whether such opportunities *would* be used:

> *"At the time, I thought the penny dropped and I though yeah, kind of... but now I'm thinking will it make any difference to the whole process?" (Person A)*

It is noted that this comment was from the first project (Rangitāiki) that had a longer break between workshops and was supplementary to an already existing *NPS-FM 2014* process. This hints at the need to maintain participants' *agency* in a process – their confidence that their input will *have an impact and influence* the outcome (Cradock-Henry et al., 2017). With regards to the latter point in the above list, there was no clear promise that the output *would* influence anything and thus the case study itself was not strongly problem focused. Any of these factors may have contributed to the perspective expressed in the above comment. However, several participants thought that the process *had* already altered the type of action that would occur in the future. One noted that the understanding of issues was now more widely understood and, therefore, so were the areas where attention needed to be focussed, while another indicated that it had provided insight into the type of additional water monitoring that needed to occur. Yet another indicated that it had altered the place in the system where they had thought that an intervention was required.

Both the qualitative and quantitative data indicates that causal loop modelling has been of huge benefit to the groups and their ability to better understand their systems (Senge, 1990). Nonetheless, it also reinforces the point that there is a need to progress to simulation modelling and the testing of policy options if more specific insight is to be generated (Forrester, 2007; Sterman, 2000; Vennix, 1996, 1999).

12.6 Summary – Useful yet more detail required

While this final theme is less prevalent than *a refreshing new process* and *building a group AND a group model*, it is insightful and forceful nonetheless, with important implications for the application of GMB processes. Participants saw the versatility of the GMB process for use across a range of issues and, most importantly, there was a strong sense that the process had not only been a very *valuable* use of time, but an extremely *efficient* use of time when compared to how they had perceived or experienced similar decision-making processes in the past. Nonetheless, the complexity of freshwater systems was acknowledged, together with the understanding that numerical modelling would provide a logical next step towards developing a greater depth of understanding around how to manage them.

13 Conclusion

13.1 Conclusions

This research investigates whether the use of causal-loop diagrams (CLDs), applied in a group model building (GMB) process, increases the shared understanding of a freshwater issue by a group. The process involves the extension of the Luna Reyes et al. (2006) framework to include qualitative modelling, given that piloting found that quantitative modelling was difficult to perform adequately within the constrained resources facing the project. The process was applied across two case studies dealing with freshwater management issues – one looked holistically at the Rangitāiki River in the Bay of Plenty, while the other looked at *E. coli* contamination in Sawyers Creek, in Greymouth on the west coast of the South Island.

The geographical scale of the two projects were quite different; the Rangitāiki is one of the largest catchments managed by the BOPRC, while Sawyers Creek was a small, predominantly-urban stream on the West Coast of the South Island. However, most other factors remained consistent or comparable across the two case studies. For example, both groups were volunteers; moderately small groups and a mixture of interested or invited stakeholders. All these factors were consistent with appropriate or best practice across GMB processes (van den Belt, 2004; Vennix, 1996) and the smaller group sizes were also consistent with the exploratory nature of the research (Rouwette, 2002; Scott et al., 2016b). The only major exception to this consistency was the degree to which the GMB processes were focused on a specific problem or not. While the Rangitāiki process sought to understand a broader range of variables that (were) influenced (by) both water quality and quantity, the Sawyers Creek process sought to specifically focus on the issue of *E. coli* contamination. This difference proved to have a dramatic impact on the output of the processes.

It was found that, consistent with the general SD literature (Forrester, 1961; Richardson & Pugh, 1989; Sterman, 2000) and that specifically focused on GMB (Vennix, 2006), it was important to ensure that the use of SD/CLDs was focused on a *specific problem*. This reinforces the applicability of SD tools as a *problem structuring method* for use early in the process of investigating an issue. This manifested itself in two main ways. The CLD generated from the more focused process has virtually all its influences definitively qualified (99% compared to 56%). Also, the insights gained from the system archetypes that were identified were more definitive and less reliant on *part of an influence* that had been described.

The *level of aggregation* that each problem dealt with was itself *less* influential on the success of the process than the extent to which that process was focused on a specific problem or not. CLDs have been shown to be useful at varying scales within organisations or industries (Senge, 1990) and SD modelling has a demonstrated usefulness at all levels of (dis)aggregation, including concept models (Booth Sweeney & Sterman, 2000), parsimonious models (Ghaffarzadegan et al., 2011), firm models (Sterman, 2000; Vennix, 1996), catchment models (van den Belt, 2004), through to global models (Forrester, 1973; Meadows et al., 1974).

It was also found that the process was *successfully run* in both instances with a minimum of *only two people* (excluding the project sponsor or 'gatekeeper'). However, it is important to note that both people were experienced facilitators and/or modellers and had a high level of familiarity with the theory of facilitation and SD. This experience was also identified as a key enabler of the success of the process.

Responding to a need to gather data through methods more than self-reported outcomes (Scott et al., 2016b), mixed methods were used to gather quantitative and qualitative self-reported data in a post-workshop survey; and undertake thematic analysis on the transcripts of semi-structured follow-up interviews.

The self-reported data indicated not only very high levels of individual satisfaction with the process, but also that the process had helped the group's shared understanding of the issues and that the output (the CLD) would be useful to the group in the future. The thematic analysis identified four broad themes: that there was a *desire for a different approach* to decision-making; that the GMB process was a *refreshing change*; that the GMB process built both a *group AND a group model*; and that, while it was useful, it also did *not provide enough detail for decision-making on its own*.

The desire for a different approach was underpinned by the complexity of the decision-making process; as well as frustration from some of those involved that they either did not feel that their views were being (or had been) appreciated or from a direct sense of frustration from dealing with council (currently or in the past). It was felt that the GMB approach was a refreshing change as it was a simple and focused process, involving a small group of relevant stakeholders. More importantly, the fact that the group members were actively involved in the process, it was participant led and independently facilitated were all very positive aspects identified.

The groups were very pleased with the CLDs (and resulting system archetypes) that they produced and found them to be of value. Yet, they also viewed the resulting shared understanding of issues; the insight they gained into the extent that they had perspectives on issues and the impact that the process had on the dynamics of the group (e.g. developing relationships and building trust amongst members) to be of equal, if not greater, value. The personal interaction (again) and the visual approach of this tool were important enablers of this. While the process and outputs were beneficial and it was considered a particularly versatile, efficient (a one-day workshop) and useful expenditure of time and resources, the need for greater detail and complexity to support the large and complex decisions being made in the longer term was also a recurring theme.

13.2 Recommendations

Considering these conclusions, a range of recommendations can be drawn from this research.

Be problem focused

The most important recommendation is for any application of a GMB processes to *be problem focused* – the ***GMB process should be used to explore a problem, not to explore or test a possible scenario or solution***. This problem focus was found to be the factor that influenced the outcome of the two projects the most. While CLDs or SD may *themselves generate* possible options or solutions that can be explored, to not be problem focused is to miss an opportunity for SD to provide the insight that it was developed to provide.

Plan well and use skilled people

The GMB process produces useful results efficiently and quickly and it ***can be run with two people***. However, this should be supported with ***rigourous planning*** and the use of people/staff ***skilled in both facilitation and SD theory***. Even the use of CLDs that appear simple require a deep understanding and experience of SD theory for them to be beneficial (Richardson, 1999). The development of such skills could and should be pursued by regional councils across New Zealand.

Use CLDs early

This research has demonstrated the benefit of this approach as a ***problem structuring method*** early on in a decision-making process, particularly related to efficiency and versatility. However, these benefits arise within this application from the use of a *qualitative* model, rather than a *quantitative* one. A range of decision-making support tools exist on a continuum from simple to complex. A simple tool like CLDs can be utilised earlier on, while more complex SD approaches – those that involve dynamic simulation – remain important later in the process, through providing an avenue to explore the relative weighting of key relationships within a system. The shared understanding and social capital generated within a group during a GMB process focused on CLD development provides an important foundation for the subsequent construction of these more complicated frameworks.

If the going gets tough – keep going

Freshwater issues in New Zealand are often ‘wicked’ in nature, they are complex (both biophysically and socially), long-term, involve feedback (often little understood) and may improve or degrade from any number or combination of actions – intentional or not. Most importantly, they are highly emotive, as evidenced by the high level of constituent interest. Our fresh water is an interwoven part of our social, cultural, environmental and economic wellbeing.

While there is much progress, there are still many difficult decisions yet to make and many difficult conversations yet to be had. As is the nature of ‘wicked’ problems though, it is not possible to trial solutions first (Rittel & Webber, 1973), so we must progress as best we can. ***GMB has a place in this, as it is a method for facilitating difficult and important discussion to generate valuable insight***.

When the going gets tough – keep going. ‘Lean in’ to the challenge, embrace the differences of opinions and explore them, because these are likely to be signs of *creative tension* that groups can choose to view as either an opportunity or an impediment (Senge, 1990). If an *endogenous* SD perspective is applied to such challenges, it will highlight *where within* a group or a system the solution may lie (Richardson, 1999). Groups that actively work together have been proven to produce better results (Hall, 1973), and people are far more likely to support solutions that they have generated themselves than those that are ‘prescribed’ or ‘told’ to them (Schein, 1987, 1988). It may be difficult, but with appropriate structure, facilitation, and adequate time can make a real difference (Luft, 1969; Hall, 1971; Schein, 1987, 1988; Stanfield, 2000), achieving ‘win/win’ results through consensus driven interaction (Doyle & Strauss, 1976).

13.3 Limitations

Several limitations to this research are worth noting.

The sample size was small, with only two (of initially three potential) case studies taking place. This was further compounded by the fact that one project was more problem focused in its intent than the other, making a direct comparison of results difficult without acknowledging the possibility of an erroneous case study.

Time was limited for this research and only one GMB workshop was possible with each project. While applying the process within constrained resources (including time) was an objective of this study, the restricted time frame of the study itself limited the ability of the GMB process to be used further or tested at subsequent stages of problem definition, option generation and decision-making.

The potential impact that the CLD may have had on the decision-making process for each case study was not able to be investigated; and only the *participants* in the process were interviewed as part of the research, not those that had *observed* the process.

13.4 Further research

Further research may improve our understanding of the benefit this process would provide to freshwater decision-making processes in New Zealand, more generally.

An application of the same approach across a wider range of case studies would be beneficial. This would enable the benefits of the process to be tested across a more consistent range of projects. Factors such as group size/representation and demographic make-up, the problem focus of the GMB effort, the scheduling of workshops and its application specifically in response to prescribed needs of the *NPS-FM 2014* may then be controlled for.

Understanding the changes in participants' mental models relating to specific freshwater issues through pre-test/post-test methods would be a useful contribution to this field, as would an exploration of the extent to which the SD/systems thinking approach might align with the Māori world view.

Longitudinal research that investigated the impact that early use of GMB and CLDs had on decision-making in a stakeholder process would be of benefit to national and local government. Given the issues with objectivity of some of the measurements used in GMB studies (Scott et al., 2016), it may also be possible for future research to focus on the ability of decisions resulting from GMB processes to be assessed according to Ackoff's (1994) four decision types (absolution/ resolution/ solution/ dissolution), as at least a partial measure of their effectiveness. In relation to this, understanding the level of inherent ‘wickedness’ within a problem is currently very subjective; perhaps, future research might help develop a framework for assessing it more definitively, as a way of guiding the potential application of GMB processes in the future.

13.5 Final words

The issues facing freshwater resources across New Zealand are diverse and vary in their intensity, historic longevity and root causes; yet, all are likely to be at least moderately, if not highly, complex from both biophysical and social perspectives. As these resources come under greater pressure and more a part of public dialogue, a comprehensive variety of tools are required in the ‘toolbox’ for helping to make difficult freshwater policy decisions. GMB processes focused on system dynamics principles and CLD modelling have a key part to play within that toolbox. This research has demonstrated their pragmatic usefulness in the nascent stages of decision-making processes, both as a problem-structuring method and a way of building social capital within diverse groups that are tasked with making difficult decisions in highly-contested environments. In combination with other tools, this approach offers great potential to help address the challenges faced by one of our most critical and precious resources.

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Appendix 1 New Zealand's Regional and Unitary Councils

Below is a list of Regional Councils in New Zealand. Those that are unitary authorities are noted in brackets **(unitary)**.

North Island

- Auckland Council **(unitary)**
- Bay of Plenty Regional Council
- Gisborne District Council **(unitary)**
- Greater Wellington Regional Council
- Hawke's Bay Regional Council
- Horizons Regional Council (Manawatū-Whanganui Regional Council)
- Northland Regional Council
- Taranaki Regional Council
- Waikato Regional Council

South Island

- Chatham Islands Council **(unitary)**
- Environment Canterbury (Christchurch Regional Council)
- Environment Southland (Southland Regional Council)
- Marlborough District Council **(unitary)**
- Nelson City Council **(unitary)**
- Otago Regional Council
- Tasman District Council **(unitary)**
- West Coast Regional Council

Appendix 2 Sampling & validity

A brief discussion of issues of sampling and validity are provided in this appendix.

Sampling

Having outlined the methodology above, appropriate sampling for the research is now considered. The nature of the individuals and organisations that this research is interested in have an influence here.

Sample type and unit of analysis

In New Zealand responsibility for freshwater policy is held by the 16 Regional or Unitary Councils[16]. These organisations respond to the direction set by the Central Government through the *NPS-FM 2014* (Ministry for the Environment, 2014). Therefore, the decision-making organisations of interest in this research are Regional or Unitary Councils and this research will be interested in the views from a range of people within the structure of these organisations. Iwi organisations are stakeholders in all instances, and may in some cases also have co-management responsibilities of regional water bodies. An example of this exists in relation to co-management arrangements with five river Iwi in relation to the Waikato and Waipa Rivers (Nga Wai o Maniapoto (Waipa River) Act, 2012; Ngati Tuwharetoa, Raukawa, and Te Arawa River Iwi Waikato River Act, 2010; Waikato-Tainui Raupatu Claims (Waikato River) Settlement Act, 2010).

Many other organisations are also stakeholders in decision-making and may be involved either formally or informally. These include organisations

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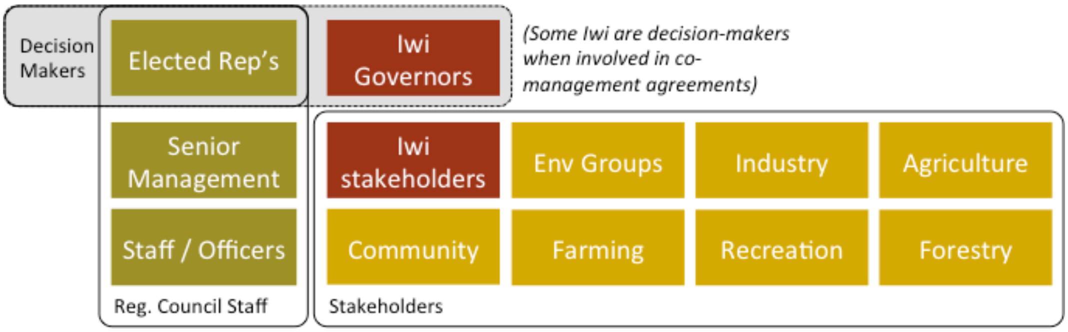
16 In New Zealand, local government is structured into 16 regions each with an elected Regional Council headed by a Chairperson. Each of these is divided into a range of smaller districts (sometimes known as cities) which also each have their own elected District (or City) Council headed by a Mayor. Certain responsibilities for both levels of government are outlined under the *RMA 1991*. In five regions, there are no district level Councils and both regional and district responsibilities are vested in the one Council. These are known as Unitary Authorities and exist in Auckland, Gisborne, The Chatham Islands, Marlborough and Tasman.

representing the interests of environmental groups, recreational water users, industry, farming, agriculture, forestry and communities. An example of potential sampling interests is shown in Appendix Figure 1.

Appendix Figure 1. Example of potential sample organisations



Because of the specific interest of this research it is impossible to select a random sample to undertake action research with – therefore purposive sampling will be undertaken (Bryman & Bell, 2015).

The unit of analysis also needs to be considered and as a variety of perspectives may be possible from those researched within a single organisation (where this is done). It is therefore considered that the unit of analysis should be at the level of the individual.

Eligibility criteria

With the organisations involved and level of analysis determined as above, the criteria for selection is now outlined. This brings in both a geographical and temporal element to the development of freshwater management policies around the country. Although the *NPS-FM 2014* has been in place since 2014, some councils are further advanced with their policy development that others. Existing personal networks within regional councils will be explored to identify a potential sponsor(s) and project(s). The eligibility criteria for an appropriate sponsor(s) and project(s) is therefore:

- They are about to or are already undertaking a freshwater management project or developing a freshwater policy. This may be in response to the *NPS-FM 2014* but is not necessary.

- They may either be responsible for the development (or the development of a portion) of such a project within their organisation or represent their organisations views in such a project.

Sample size

As this research will be action research there will not be a wide sample of projects or people involved. This will be dependent on the sponsoring regional council and the project that is identified.

Data collection

The previous section outlined the logistics of the sample, some eligibility criteria and issues relating to the sample size. This section will deal in more detail with the logistics of the data collection process including research protocols, procedures, and interview questions.

Data collection during the workshops

The researcher and will keep notes from each workshop. These may be supplemented with notes taken by supporting researchers, council staff, or recordings made of the workshops.

A survey of participants will be undertaken at the end of the workshop process.

Interview procedures and questions

The follow-up interviews will be conducted as semi-structured interviews (Bryman & Bell, 2015). This will allow for a pre-determined line of inquiry to be followed, while allowing for a flexible range of responses to be gathered from the varying participants. Interview protocols are provided in Appendix 4 and interview questions in Appendix 5.

Validity and reliability

This research may face potential issues of content and construct validity. In relation to content validity, this will need to be a cross reference of proposed semi-structured interview questions against what the research questions are and what they are intended to find out. This could be done by the researcher or may be able to be completed or reviewed by a supervisor or independent peer reviewer. This will help to ensure a ‘chain of evidence’ (Yin, 2014) is demonstrated and will be stored in a research database (see discussion of reliability below).

Construct validity presents a different challenge. Given that the number of people involved in the research will be small and identified via purposive sampling, this will not be able to be scaled up continuously as random sampling might. The information gathered from the semi-structured interviews can be reflected back to each participant (Yin, 2014) as each interview is summarised and themed, probably via a follow up telephone call. This should be sufficient to ensure that the participants agree that this is what they felt was put across in their interviews and that construct validity is maintained.

The fact that it is purposive sampling should ensure that external validity is ensured. As external validity seeks to ensure that the sample can be representative of all people that the sample is intended to represent, the fact that it is purposively sampled will ensure that this is the case.

To ensure reliability of results is to ensure that if a *different* researcher undertook the *same* study again, they would reach the same results (Yin, 2014). This will be ensured in this study by the researcher keeping a diary of their activities, maintaining and adhering to research protocols (e.g. see Appendix 4). Further, a comprehensive research database will be developed that is likely to provide a repository of both *raw* data as well as *subjective* or *reflective* data (researcher interpretations). These records may be both electronic and physical notes, so the database may be made up of both electronic and physical files (Yin, 2014) providing a detailed record that will enable to other researchers to best replicate the results.

Appendix 3 Post workshop I survey

This appendix contains a copy of the survey that participants completed at the end of the first workshop.

Workshop:	
Date:	
Participant name:	
Contact email:	
Contact telephone(s):	

1. **This process helped me better understand the perspectives of other people in the group relating to freshwater issues**

☐	☐	☐	☐	☐	☐	☐
Strongly disagree	*Moderately disagree*	*Slightly disagree*	*Neither agree or disagree*	*Slightly agree*	*Moderately agree*	*Strongly agree*

2. **This process helped has helped me to learn more about our freshwater system**

☐	☐	☐	☐	☐	☐	☐
Strongly disagree	*Moderately disagree*	*Slightly disagree*	*Neither agree or disagree*	*Slightly agree*	*Moderately agree*	*Strongly agree*

3. **I found Causal Loop Diagrams easy to understand**

☐	☐	☐	☐	☐	☐	☐
Strongly disagree	*Moderately disagree*	*Slightly disagree*	*Neither agree or disagree*	*Slightly agree*	*Moderately agree*	*Strongly agree*

4. **Using Causal Loops Diagrams has increased the agreement of the group on factors that influence our freshwater system**

☐	☐	☐	☐	☐	☐	☐
Strongly disagree	*Moderately disagree*	*Slightly disagree*	*Neither agree or disagree*	*Slightly agree*	*Moderately agree*	*Strongly agree*

5. **I believe the Causal Loop Diagram Model developed today will be useful for this project in the future**

☐	☐	☐	☐	☐	☐	☐
Strongly disagree	*Moderately disagree*	*Slightly disagree*	*Neither agree or disagree*	*Slightly agree*	*Moderately agree*	*Strongly agree*

Please turn over, more questions on the back…

6. If you agreed with the statement in Q5, why do you think the diagram developed today will useful in the future? If you disagreed, why do you not think it will be useful in the future?

7. What parts of the process worked well? Why?

8. What parts of the process did not work well? Why?

Appendix 4 Interview protocols

This interview protocol is drafted to provide an outline of detail required for the protocol of a qualitative semi-structured interview (Bryman & Bell, 2015).

<table>
<tr><td>
Interview attributes

In the first instance a face-to-face interview is the preferred method of interview.
In the second instance, where physical face-to-face interviews are not possible, a remote interview with face-to-face contact enabled by technology (e.g. Skype) is the preferred method of interview.
In the third instance, failing the first two options, a telephone interview can be undertaken, however every effort should be made to undertake the methods listed above.

</td></tr>
<tr><td>
Interview Details

Interviewer to record:

Interviewer name and details of the interview (location, date, time and length (noted at the end)).
Interviewee name, position, organisation and location
Region(s) that interviewee work(s) in
Freshwater policy project(s) that interviewee is, has been or expects to be involved in
How the interview was undertaken (in person face-to-face, via Skype, over the telephone).

</td></tr>
<tr><td>
Interviewer instructions

Ensure that interview is digitally recorded per a pre-determined format (yet to be determined). This file will need to be saved to a central project repository and saved at the soonest convenience.
Interviewer to also take notes in the interview, in case there are issues with the recording. These should be separated into two columns on the notes page as below:
<table>
<tr><td>Descriptive notes
Notes about what was discussed, any quotes, the location, description of the interviewee, the physical setting etc.</td><td>Reflective notes
Personal notes of the interviewer, including subjective observations, lines of inquiry to follow up, impressions, ideas, prejudices etc.</td></tr>
</table>

Interviewer to use standard welcome and completion scripts to open and close interviews.

</td></tr>
</table>

Interview completion After the end of each interview the interviewer will summarise their impressions, thoughts, and any notes that are worth recording about the interview. If multiple interviews are being carried out in one day, then time should be scheduled for this in between each interview.
Information privacy concerns Information privacy guidelines will be developed for the entire project and outlined before each survey is undertaken. Participants will be asked to sign a privacy permission form/statement.

Appendix 5 Semi-structured follow-up interview questions

No.	Question	What questions is seeking to understand
1	How did you **become a part of the group** and what **perspectives do you bring**?	Background
2	**Why were you interested** in the additional causal loop workshops? What were you **expecting**?	Motivation for involvement
3	**How did you find the group experience** of building a causal loop diagram?	Experience of involvement
4	How do you think this approach **improved your <u>personal understanding</u> of the overall system**, of which freshwater is a part?	Increased personal understanding
5	How do you think this approach **improved the <u>groups shared understanding</u> of the overall system**, of which freshwater is a part?	Increased group understanding
6	What parts of the process (if any) were the **easiest to understand**?	Easy parts
7	What parts of the process (if any) were the **hardest to understand**?	Difficult parts
8	**How useful were the <u>'common patterns'</u>** (archetypes) that Justin identified?	Experience of archetypes
9	In what ways do you think **the causal loop diagram and the 'common patterns' will be useful** to the project moving forward?	How might CLDs influence the project moving forward?
10	What has been the **main benefit of this process** for you? And how might this be **improved**?	Main benefit
11	What have been the **limitations of this process**? And how might this be **improved**?	Main limitations
12	Is there **anything else** that you would like to ask or comment on?	Anything else?

Appendix 6 Example briefing for participants

Overview and purpose of project
You have been invited to be part of the Causal Loop Diagram Workshops. This research that is being undertaken in conjunction with the [Council] in relation to the identification of [project].

The purpose of this project is to understand the impact that building a Causal Loop Diagram as a group might have on a group's shared understanding of the freshwater issue or problem that they are seeking to address.

Causal Loop Diagrams use systems thinking to improve participants understanding of the overall economic system of which freshwater management is a part. This approach will focus on the s*ynthesis* rather than *analysis* of an overall system. This is expected to increase participants understanding of the wider economic context of this system.

This project will be using an approach to SD modelling will is being researched by a Master degree student at the University of Waikato. The title of that research is *[Research title].*

What is this research project about?
This research is investigating how the application of Causal Loop Diagrams might be used in freshwater management to increase the understanding of the wider economic system of which it (freshwater) is a part.

Who is doing the research
This research is being undertaken by Justin Connolly. Justin is a Master of Management Studies student at the University of Waikato. This research forms a partial requirement for his degree.

The researcher is working in conjunction with [Council] to undertake this research. They are seeking to identify [project nature]

What will you have to do and how long will it take?
As a participant, you will be required to attend 1-2 workshops (each no longer than 1 day). This will be a deliberative process involving [group]. This group will develop a coordinated understanding of the factors impacting freshwater quality and quantity in the [catchment]. This will be expressed in the form of a Causal Loop Diagram.

You will also be required to be available for the researcher to undertake a follow-up interview with you at a time that is expected to be arranged within 2 weeks of the completion of the final workshop.

What will happen to the information collected?
The knowledge generated in the decision conferences will be used by [Council] as they seek to [project].

The knowledge generated and information collected by the researcher will be used to write a research thesis for the credit of a specific paper as part of their Master of Management Studies degree.

It is possible that academic articles, presentations and conference papers may be the outcome of the research. While the workshop notes and outcomes will be available to the researcher and the [Council], only the researcher and their supervisor will be privy to the specific research notes, documents and recordings made by them for research purposes during the research.

However, the thesis itself may be available to the public, unless there is a publication restriction placed on it by the university of Waikato.

Afterwards, the researcher will keep all notes, transcriptions and recordings and a copy of the thesis, and will treat them with the strictest confidentiality. Participants may be named in the publications unless they expressly request not to be. This is separate to the record of their attendance that will be kept by Council.

Declaration to participants
If you take part in the study, you have the right to:

Ask any further questions about the study that occurs to you during your participation;

Be given access to a summary of findings from the study when it is concluded, if you request one; and

Withdraw from the Causal Loop workshop(s) and hence the research at any time before the commencement of the workshop(s).

Who's responsible?
If you have any questions or concerns about the project, either now or in the future, please feel free to contact either:

Primary contact	**Secondary contact**
Researcher:	**Supervisor:**
[name]	[name]
[contact details]	[contact details]

Appendix 7 Consent form

Research title:	[Research title]

I have read the **Participant Information Sheet** for this study and have had the details of the study explained to me. I understand that this research is being carried out in conjunction with the [Council] in relation to [project]

My questions about the study have been answered to my satisfaction, and I understand that I may ask further questions at any time.

I also understand that I am free to withdraw from the study before the workshop [date]. I am also free to decline to answer any questions in the follow-up interviews of the research.

I agree to participate in this study under the conditions set out in the **Participant Information Sheet**.

I agree to my responses in the follow-up interview being recorded.

Name:	
Date:	Signed:

Additional Consent

I AGREE / DO NOT AGREE (circle one) to my images being used in the research or presentations that may result from the research.

Name:	
Date:	Signed:

Researcher (primary contact):

[Researcher details]

Supervisor (secondary contact):

[Supervisor details]

Appendix 8 Ethical considerations

Some ethical considerations are outlined here.

Potential health risk

The personal safety of research participants is of primary concern to the researcher. Fortunately, the nature of the research does not mean that any participants are likely to be in situations or involved in processes that pose any threat to their personal safety. Therefore, the level of risk here is considered low to non-existent.

Potential social and psychological risk

The research is closely involved with participants' professional experience, opinions and views. This does involve a low level of risk that participants may suffer some social embarrassment and/or reputational or psychological damage if their responses were shared with others. This may also occur if it is possible to infer from research results whom certain views might be attributed to. This is particularly a risk given that there will be a large amount of purposive sampling in this research, and many participants are likely to be able to determine who other participants are (or they may even share this information with each other).

Other risks

It is also noted that as this research will be purposively sampled, there is no risk of the research being from a set of information that has been collected for a different reason. While a sampling database will be built up during this research it will be from public information sources, self-selection or referrals.

No rewards for participation (e.g. payment) are planned for participants, so it is not considered that this poses a risk requiring ethical attention. It will however be protocol that all participants are thanked for their involvement, both in person and at the end of the research process.

Mitigation and minimisation of risks

Personal safety concerns are unlikely to occur during the survey research. However, during the interview research the personal safety of participants will be ensured by interviews being undertaken at a location that the participants are comfortable with. This is likely to be at their place of work to ensure they are in comfortable surroundings, and if this is not possible then it will be suggested at a place where there is passive observation from other people (e.g. a café), to ensure that the interviewee does not feel isolated.

A permission form will be developed for participants to sign before qualitative research commences. Any data collected will only be used for the purposes of the research and the agreement will outline that the researcher (and supervisors) will be the only people who can view the information. The researcher will only use the data for this research. Only broad statistical inferences will be drawn from the data relating to participants (e.g. demographics) and research results will only be disaggregated to a level where there are more than 5 units within each category that is reported. This will ensure that the anonymity of participants is retained and may not be inferred from a reading of the results. The researcher will also use the data to contact the participants and undertake purposive sampling of them to determine who should be in the interview sub-sample.

Strict confidentiality will apply with participant personal details and the research data. All information will be kept on a secure electronic server and access to this will be limited to the researcher (and the supervisors via the researcher). Participants will be able to access and/or update/correct their personal data at any time via the researcher. Procedures will also be developed by the researcher and shared with participants that will outline concerns such as the following:

- How people agree (or not) to be involved in the research
- How to access/update personal information
- How long personal information will be kept and what will happen to it afterwards
- How to make a complaint (either to the researcher, their supervisor or the university)

Cultural considerations

As some of this research is likely to involve surveying and interviewing of Iwi participants, these interviews will be initiated with a brief pepeha[17] of the researcher and an opportunity for the interviewee to provide their own pepeha. The researcher will provide the interviewee with the opportunity to share in an opening karakia (prayer). This is considered an acknowledgement of the cultural protocols of the participant and seeks to honour Maori tikanga (protocol). The researcher will then explain that the balance of the interview will be undertaken in English.

17 A pepeha is a Maori introduction that outlines the identity of the speaker, their tribal affiliations – iwi – and acknowledges the important components of their physical tribal area - ancestral mountain, river, canoe or other landmarks.

Appendix 9 Potential limitations

This section will summarise potential limitations that have been identified for the study. Two main areas of limitation are identified and these relate to sampling and the potential confusion around the understanding of SD before the action research begins.

Firstly, potential sampling issues are discussed. The need for purposive sampling has been discussed in Appendix 2, yet as this will be an action research process, the sample size of project(s) will be one or two. This may create some potential limitations relating to a range of biases, however this is seen as inherent in this form of research.

There is also a risk that people may be unwilling to take part in the research and it is hoped that a high level of individualised contact with possible participants will encourage as strong a response as possible.

Secondly, the results of the research may be affected by participants' confusion around what SD is – certainly at least at the early stage of the research, before the decision conferencing has been undertaken.

While this is of course the interest of this research, it may pose potential reliability issues with the research given that people will have such diverse experience. Participants' exposure to concepts such as SD modelling may be impacted by the course of significant projects in that region – i.e. if that approach has not been used on a similar project already in that region it is unlikely that people may have been exposed to it.

Appendix 10 Detailed description and analysis of the pilot workshops

Detailed discussion of pilot workshops

After selecting the SD GMB process described Luna-Reyes et al. (2006) and before applying it to the case studies in this research, it was piloted twice. Both pilot workshops were incredibly valuable opportunities for learning and proved to be a critical part of this research, having a dramatic influence on the overall application of the GMB process. So as to capture the value of these lessons, the two pilot workshops have been described in detail here.

This is an expanded version of the discussion contained in Section 4.2.

Pilot workshop I – Waikato

To practice the methodology, the GMB process was run with a group of four for an abridged period of 3.5 hours.

The profile of this group were two staff members from a Regional Council and two people without subject matter experience in the field of freshwater. The two staff from council were senior strategy staff members – one was a senior strategy advisor and the other the principal economist. Both were very familiar with the types of freshwater challenges faced by regions at a macro-level, and the economist was at least partially familiar with SD. Of the two non-experienced people, one was a specialist in the medical field, while the other was undertaking Masters level economic research at the university. Neither of these two had any concept of the technical difficulties being faced with water resources in the regions and neither were familiar with SD.

A varied cross-section of participants was deliberate as it provided an opportunity to test how different people reacted to the methodology, as well as how well people with both high and low levels of technical knowledge might contribute to the process. This approximated the dynamics that such a process might well be expected to have (Ministry for the Environment, 2012a, 2012b, 2014; Salmon, 2012) and provide useful insights.

Structure of the process

The process was run in accordance with the Luna-Reyes et al. (2006) process, albeit within a truncated time frame of half a day instead of 1-2 days. The objective of the trial was not to build a working simulation model, but rather to determine how well participants might respond to each script that was planned for use. The length of the trial run was therefore considered appropriate. The structure of the workshop is outlined in Appendix Table 1 and detailed versions of the scripts are available in (Appendix 11).

Appendix Table 1. Structure of pilot workshop I

Session	Description
Introduction	Researcher introduces himself and outline what the day hopes to achieve and how it will be structured.
Script i - hopes and fears (divergent)	A warm up activity is undertaken to 'break the ice' and to help introduce participants to each other.
Script ii - SD and the concept model (instructive/convergent)	A brief presentation and explanation of what SD is and how it can be used.
Focus question	Focus question is introduced
Script iii - variable elicitation (divergent)	Identifying the 'parts' (variables)
Script iv - reference modes elicitation (divergent/convergent)	Identifying the 'behaviours' (reference modes)
Script v - model structure elicitation (convergent)	Identifying the system structure
Script vi - reflect and confirm model structure (convergent)	The final script is to reflect the model as developed back to the group and confirm it reflects what they have developed together.

Each section of the workshop is now described in detail and assessed.

Introduction

The researcher introduced himself with a pepeha (a Māori introduction broadly establishing the identity and heritage of the speaker) and provided an overview of what the day hoped to achieve and how it would be structured. He made a point of expressing a very warm welcome to all the people that were attending, making the point that both those with experience in freshwater management, as well as those that had none, were making valuable contributions to the day.

Hopes & Fears exercise

A hopes and fears exercise was run, as described by Luna-Reyes et al. (2006) and listed in Sciptapedia[18] (Hovmand et al., 2013). Only slight procedural modifications were made. Firstly, the facilitator used different coloured paper for people to write their hopes (green paper) and fears (red paper) down on. Secondly, he invited all participants to gather around a 'sticky'[19] wall and place their own hopes and fears on the wall, rather than the facilitator collecting them off the participants. This was intended to inject some physical activity into the beginning of the day and ensure people were physically mixing when they introduced themselves rather than only being seated. It was found that this process worked well for 'setting the scene' for the morning and 'breaking the ice'. It allowed the participants to introduce themselves to each other and provided an opportunity for participants to observe each other. This was found to be useful within a group where some members had never met before.

What is System Dynamics? (concept model)

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18 'Scriptapedia' is a creative commons collection of GMB 'scripts' collated by some of the founders of this approach – Hovmand et al. (2013).

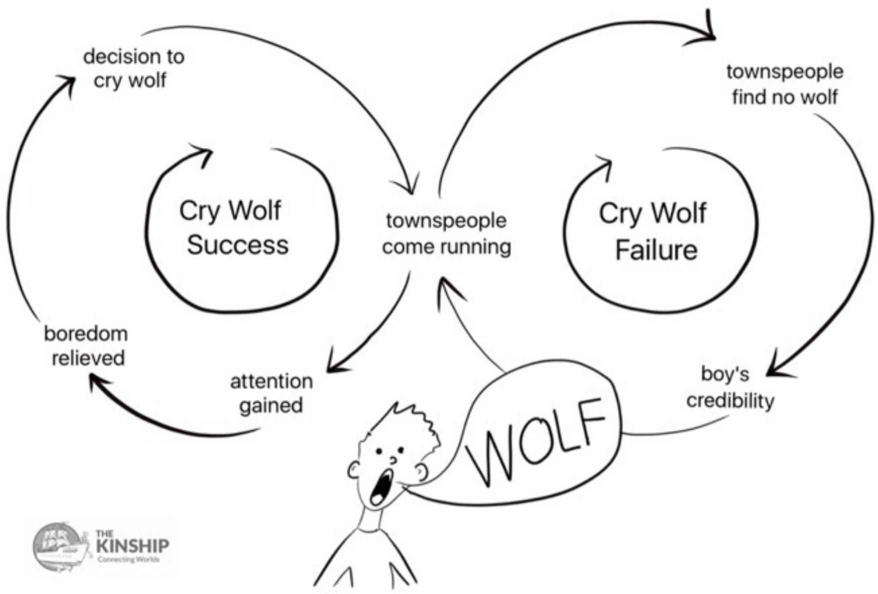
19 A 'sticky' wall is a facilitation tool that enables paper to be placed on a wall and stick to the surface –the paper can be repositioned on it without the need for tape or drawing pins. It is simply a length of polyester cloth with spray adhesive applied to it. A sticky wall can be reused many times and only occasionally requires a 'top up' of spray adhesive.

Following the Hopes and Fears session, the researcher gave a presentation on what the research was about and what SD was. This presentation went on for approximately 20 minutes and talked about a range of things as outlined below.

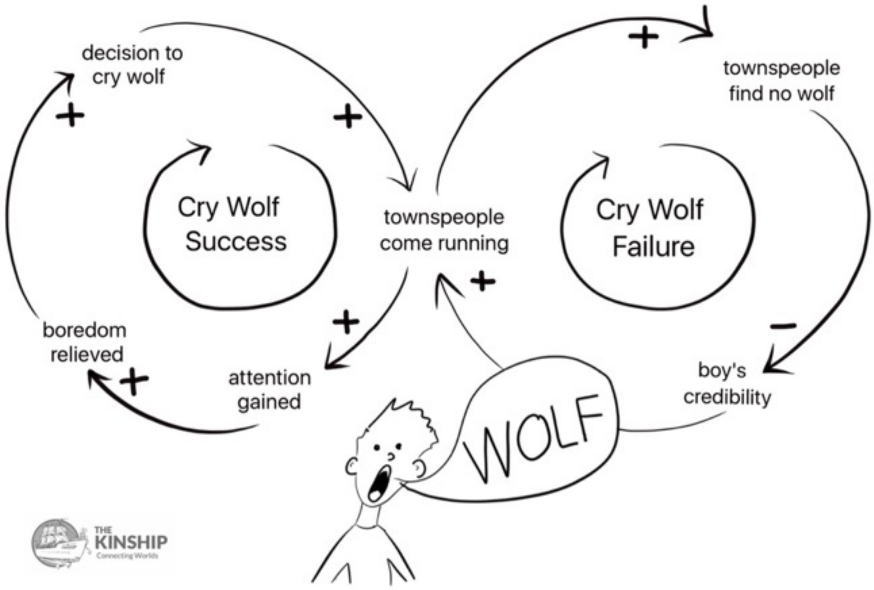
It started with a brief description of the research being undertaken and how this would work alongside a live project being undertaken by a sponsor council. This was followed by a brief outline of what economics was from the point of view of the researcher. Whilst this was a summary, it made the point that while many people thought that economics was solely about money, or the pursuit of profit, actually, it was the study of behaviours and incentives for dealing with scarce resources and the trade-offs that resulted from this.

The concept of CLDs was then introduced to the group and a simple example was presented and described in the style of Peter Senge (1990). This was presented in two forms, firstly only with connectors/links, and secondly with the connectors/links annotated as being either positive or negative relationships. The CLDs presented as examples are shown in Appendix Figure 2 and Appendix Figure 3.

Appendix Figure 2. Example CLD without annotation



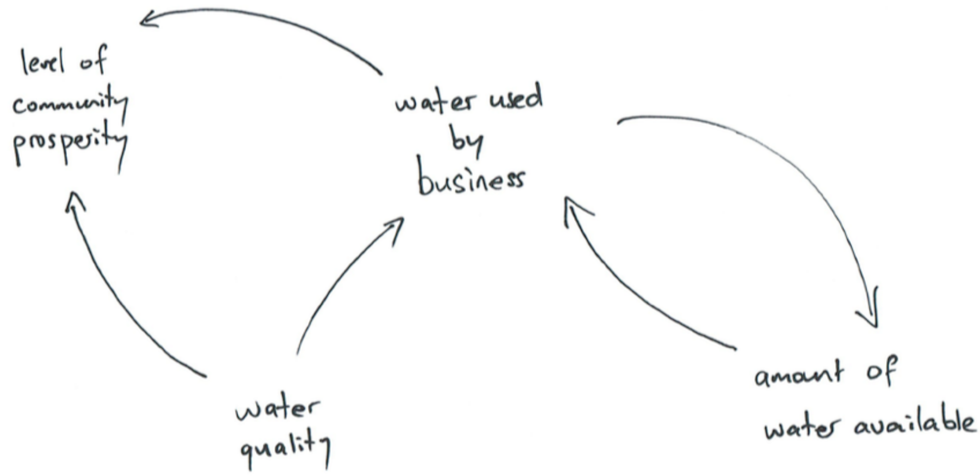
Appendix Figure 3. Example CLD with annotation



Following this, the characteristics of problems that suit a SD approach were presented to the group. These characteristics were grouped into two parts. Firstly – that systems are complex, non-linear, have feedback loops, often have time delays/lags, and there is often a lack of detailed data (Sterman, 1994; 2000). Secondly, time was specifically devoted to describing the concept of stocks and flows – as this is considered a key concept in the SD approach (Sterman, 1994) and the researcher wanted to ensure that the participants were comfortable with it. The latter is particularly important given that the Luna-Reyes et al. (2006) framework is based on the development of a quantitative stock-and-flow model.

A concept model relating to the problem that the group was there to consider was then presented as a way of initiating discussion in the form of SD models. The concept model was developed by the researcher and is shown below. Luna-Reyes et al. (2006) recommends the action of providing an incomplete, and even deliberately incorrect diagram, because this is more likely to initiate interjections and corrections from participants. However, in contrast to the recommendation of Luna-Reyes et al. (2006), this concept model was presented in the style of a CLD, rather than in stock and flow model architecture. The motivation of this was the desire to avoid any pre-determined variables at all in the GMB process, thus ensuring that *all* variables were purely participant generated. The effectiveness of this adaptation is discussed below.

Appendix Figure 4. Concept model for pilot workshop I



The primary lesson from this section was that it took a lot longer to complete this introduction to SD theory than expected. This was primarily due to there being many concepts that participants were being introduced to for the first time and they needed sufficient time to absorb and understand them.

The presentation in this section was constructed to build up the participants' understanding of the necessary concepts in sequence from least to most difficult, from CLDs through to simulation model structure. What this pilot workshop identified, however, was that while all participants could absorb the concept of CLDs, the concept of the polarity of the links/relationships (being either positive or negative) took a little explaining for all participants to understand. The participant who was from a highly-technical, medical background struggled for some time with the concept of positive and negative relationships in CLDs. This would appear to be because in the scientific world a positive relationship is qualitative in relation to the result achieved (a certain type of result may be desirable and therefore a *good* thing and therefore a *positive* relationship), whereas in the mathematical sense it is in relation to the trend of the variables (if variable A *increases* then this will mean that variable B *also increases*, therefore this is a *positive* relationship). This is consistent with the researcher's professional experience of working with groups to understand the concept of CLDs.[20]

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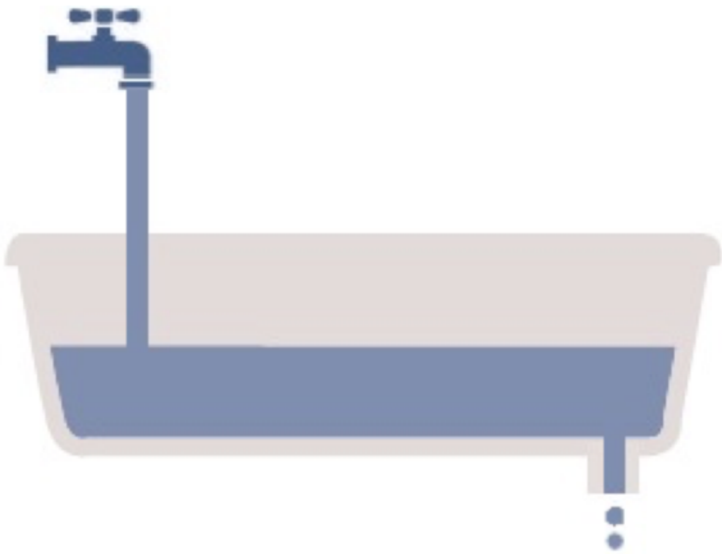
20 The researcher was professionally involved with a government ministry in the development of a workshop for introducing people to economics and benefit-cost analysis. Part of this workshop introduced participants to the

After explaining the CLD, the researcher talked about the structure of simulation models and how these differed slightly from CLDs. For example, a variable that might only require a single node to be represented adequately in a CLD might require one stock, one flow and at least one connector in a SD model. Participants responded well to explanations of the individual SD model components – for example, stocks and flows. The bathtub analogy (Richardson & Pugh, 1989; Sterman, 2001) was used to help explain stocks and flows, with the level of water in the bathtub being the stock, and the flows of water both in and out being the flows (Appendix Figure 5), and during discussions with each participant the researcher found that all had clearly understood these concepts.

Appendix Figure 5. Images of the 'bathtub' analogy used to demonstrate the concept of stocks and flows



When preparing for the pilot workshop, it had been considered that the step explaining CLDs would provide a useful stepping stone to explaining the architecture of a stock and flow simulation model. However, in practice it was found that the subtle differences between the structure of CLDs and

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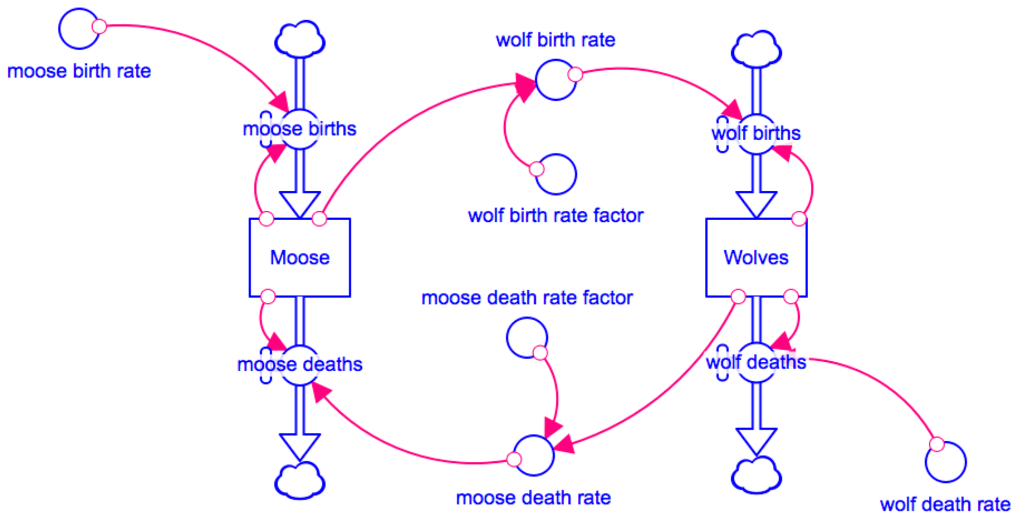
concept of CLDs. The researcher co-delivered this workshop across the country many times and at every workshop there was usually at least one person whom had challenges with understanding the polarity of relationships in a CLD. It is thought that this is because usually the audiences involved some people from a technical background, for whom positive and negative relationships usually imply a qualitative relationship, rather than a quantitative one.

stock and flow models required virtually immediate further explanation and discussion, which proved to be confusing for the participants. The explanation of both concepts was too ambitious and confusing for participants within the limited time available.

The next step was to introduce an example stock and flow simulation model and an example output (See Appendix Figure 6 and Appendix 7). An example 'predator/prey' model was used that had was based on a simple example based on real data on the Insightmaker website (Fortmann-Roe, 2016). It was found by this stage though that most of the workshop time had been taken up explaining CLDs and then stock and flow models. This meant that there was little time to talk about the example model and it was therefore rushed. In hindsight, this model was too complex as an introductory model for participants and a simpler model should be used in future.

Appendix Figure 6. Example simulation model – workshop I[21]



Predator-prey model based Fortmann-Roe (2016)

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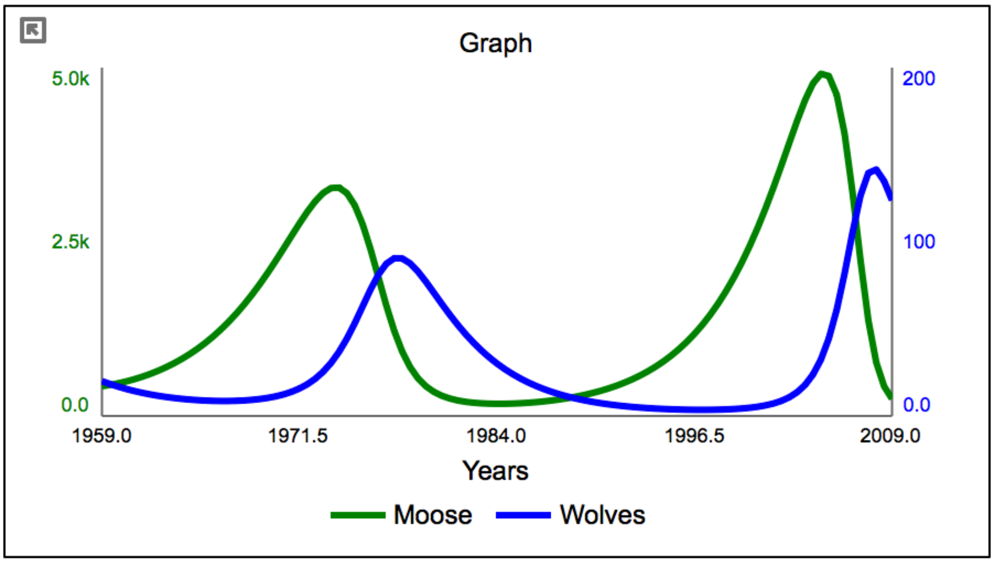
21 This model was constructed by the researcher in STELLA software and is based on one sourced from an example on the web. This was accessed at the following URL on 15 November 2016: https://insightmaker.com/insight/2068/Isle-Royale-Predator-Prey-Interactions

Appendix Figure 7. Example simulation model output – workshop II



Predator-prey model based Fortmann-Roe (2016)

As the group progressed into using the scripts generated for eliciting a simulation model, they had a good understanding of the concepts of simulation models, as discussed. However, they were more familiar with CLDs as that was the concept they were introduced to first, they had received more information on this and these tools are conceptually simpler to understand than stock and flow models. This highlighted the potential to remove the explanation of CLDs in the future, to save time.

Focus question

The introductory sections of the workshop previously described introduced participants to the *concepts* of SD modelling, it was time to move into the model building scripts with the group. The modelling efforts of the group were to be guided by a focus question which had not been introduced until this point to avoid confusion. The focus question used for the pilot workshop is outlined below. This was used in the process of identifying variables, behaviours and the structure of their relationships. The question is:

> *What is the relationship between water availability, water quality and the use of water by business across the Waikato region?*

Variable elicitation

This script was based on that described by Luna-Reyes et al. (2006) and included in Scriptapedia 4.0.6 (Hovmand, et al., 2013) with minor modification. Participants were given 5 minutes to list as many variables that they could think of. The term ‘parts’ was deliberately used with participants, instead of ‘variables’, to make this more accessible to the non-technical members of the audience.

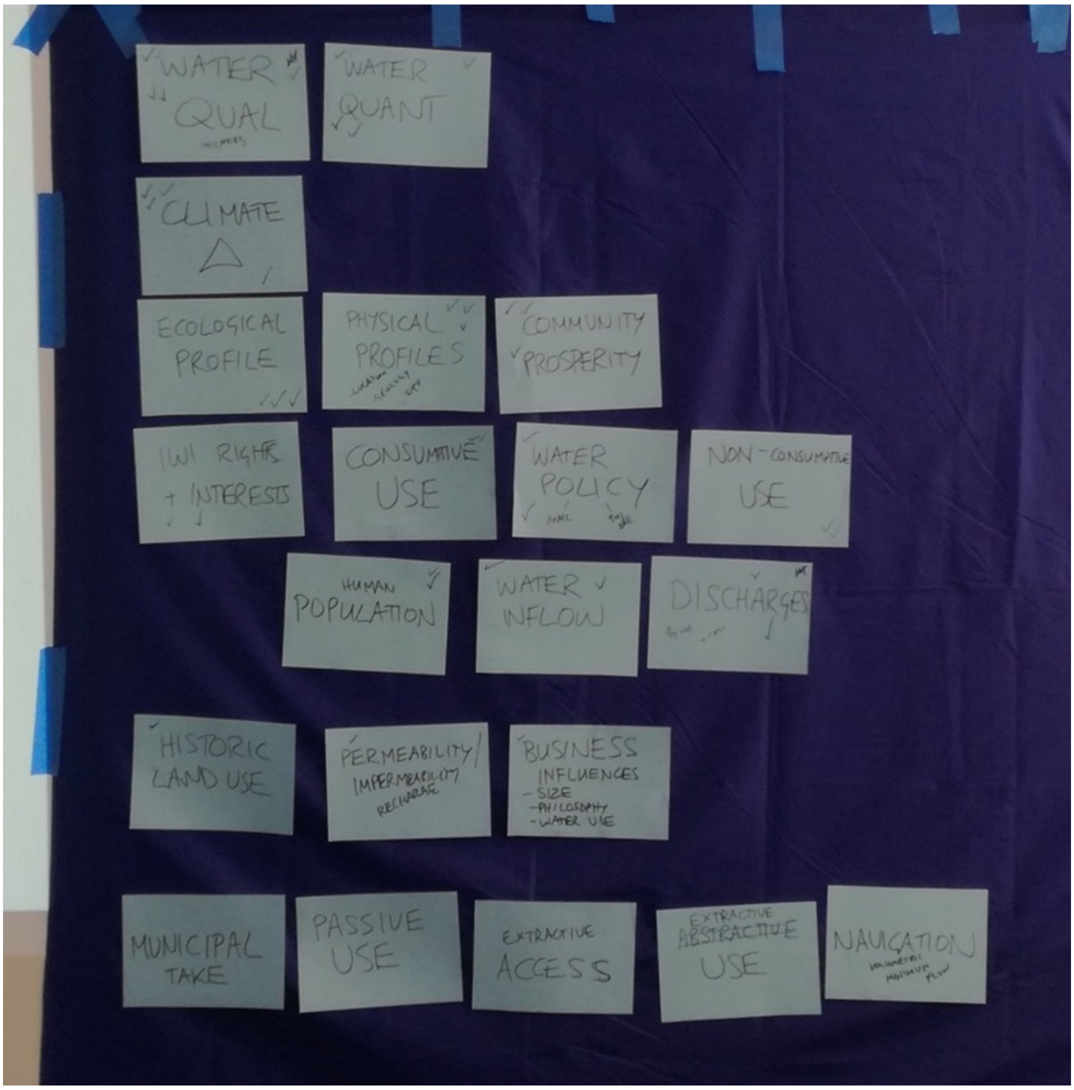
Participants then took turns sharing **three ‘parts’** (variables) that they felt were most important while the facilitator wrote these down on pieces of paper and collected them on a piece of material to which an adhesive had been applied and that had been placed on a wall (i.e. a “sticky wall”). In the Luna-Reyes et al. (2006) script, one variable was shared at a time from each participant in turn so that those that were most important could be identified. For reasons of expediency, in this pilot workshop each participant took turns sharing three variables (instead of one-by-one) until all participants felt that all the main variables they had identified had been shared. While some people ended up providing more variables, the process of sharing three in turn did still ensure that all participants had contributed at least one new variable to the communal list.

Once all participants felt that all their variables had been shared (either by themselves or others), a vote was taken to identify the most-important variables. This was done by providing 5 votes to each participant initially to allocate around any of the variables that the participants saw fit. The facilitator noted that more sets of 5 votes would be allocated in turn until the group felt that there was a clear indication of what the most-important variables were. Overall, this process required two sets of 5 votes to be allocated before the group judged the most-important variables to have been elicited. The results are tabulated in Appendix Table 2 and photographed in Appendix Figure 8.

Appendix Table 2. Most important variables elicited for the Waikato pilot workshop (table).

# votes	'part' or variable(s)	
5	Water quality	Water quantity
4	Climate change	
3	Physical profile	Ecological profile
	Community prosperity	
2	Iwi rights & interests	Human population
	Consumptive use	Water inflow
	Water policy	Discharges
	Non-consumptive use	
1	Historic land use	Permeability/impermeability (recharge)
	Business influences	
0	Municipal take	Extractive use
	Passive use	Navigation
	Extractive access	

Appendix Figure 8. **Most important variables elicited for the Waikato region pilot workshop (photograph). Note the presence of the sticky wall in the background.**



This script resulted in the two top-ranked variables being water quality and quantity. These variables were two of the three main components of the focus question, the third being the use of water by business. One lesson could be that variables assumed within a focus question – in this case water quantity and quality – should be assumed as variables within any model being built. This will allow people to focus their attention on other variables that will then *explain the behaviours* seen in these variables.

Further, these main variables may lend themselves to being possible ‘sectors’ within a model structure, the dynamics of each being able to be developed in turn. The key benefit of representing sectors in such models is that a rich CLD can be generated for each micro-unit, while allowing a focus on macro-level relationships in a higher, more-parsimonious diagram. While sectors were not part of the Luna-Reyes et al. (2006) approach, this has been advocated previously by Marjan van den Belt (2004) in *Mediated modelling: A systems dynamics approach to environmental consensus building*. However, this sectoral approach may also detract from the integrated way in which this modelling seeks to view the interdependency of these two components of water management.

The variable with the second largest number of votes was Climate Change and it was also discussed that this could also be made up of many variables, possibly lending itself to being a sector of its own. Examples of the types of variables that could be included in a sector like this include temperature and rainfall.

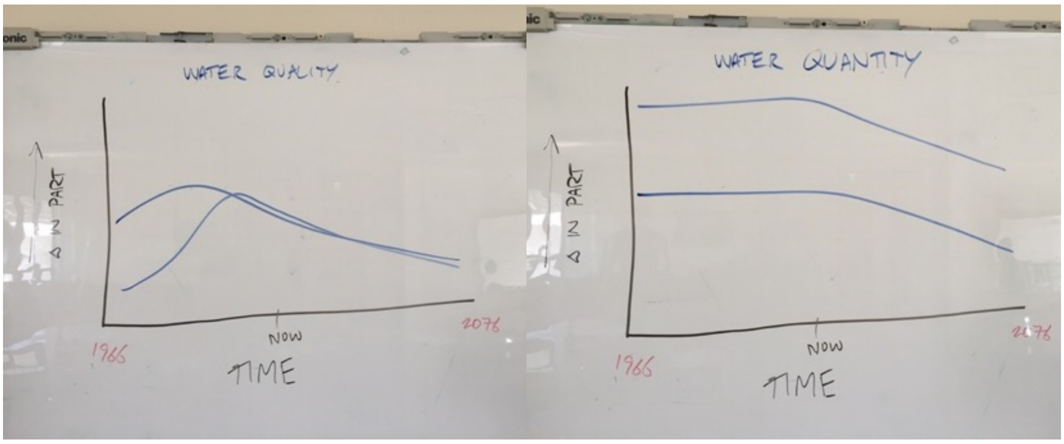
When undertaking *ex-post* analysis of the variables, the researcher found that better definitions of the variables could have been captured. While there was a clear understanding of the variables that emerged from discussion, establishing clearer definitions could have helped to reduce confusion in the future.

'Behaviour'/reference mode elicitation

This script took the most-important variables in turn and sought to identify a reference mode (or behaviour-over-time graph) for each. Rather than doing this as individuals as described in Luna-Reyes et al. (2006), this was carried out in *pairs*. This allowed the group to learn from each other, continuing to develop familiarity as a pathway to developing appreciation and trust of other participants' views (van den Belt, 2004).

Participants were given a graph template with time on the x-axis and change on the y-axis. A 50-year window either side of the present was assumed (1966-2066) and participants were asked to sketch the relationship that they thought had occurred over the last 50 years and how that might change over the coming 50 years, given current practice. At this stage in the pilot, time was becoming limited and so reference modes were only identified for 3-4 of the key variables. This provided some insight into the behaviour of the key variables as well as giving insight into how well participants responded to this script.

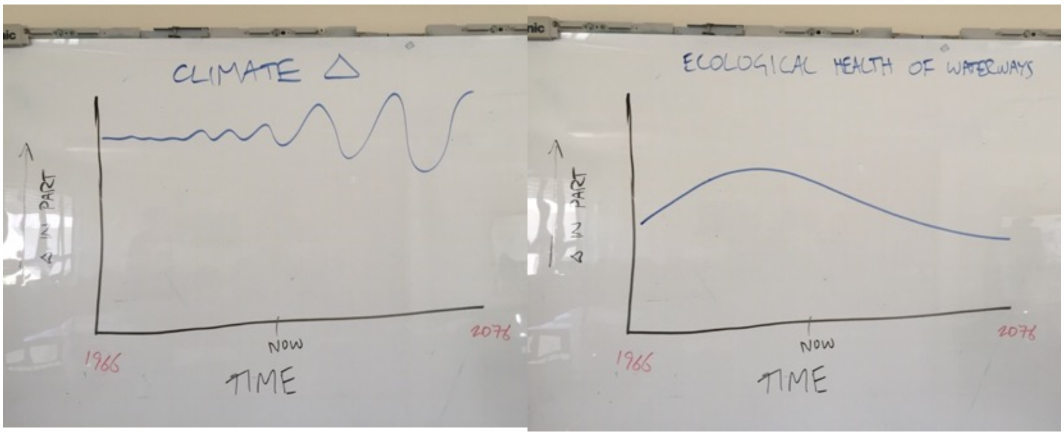
Appendix Figure 9. Example successful reference modes – note the similarity between groups.



Positive outcomes that were observed from this script were that the two groups produced similar reference modes for some of the variables (Appendix Figure 9). It is worth noting, however, that these were usually formed in relation to variables ('water quality' and 'water quantity') where there is likely to already have been an aligned level of knowledge between the two technical attendees from council – who were in separate pairs.

It was also difficult to determine reference modes for some variables, as shown in Appendix Figure 10. This was due to the variable containing many sub-variables – many of which were unknown or difficult to predict (e.g. climate change) – and/or the variable demonstrating different behaviours across the defined geographic region (e.g. ecological health of waterways). This demonstrated the challenge, probably quite common in environmental systems, that while all variables were connected in a system, the behaviours they present can be quite variable spatially within that system. One way of addressing this might be to draw the system with greater disaggregation; however, this would seem to be at odds with the main objective of seeking to build a shared, high-level understanding of a complex system in the limited time frames that are often available.

Appendix Figure 10. Example challenging reference modes.



As time was limited only these four behaviours were explored and the group then moved on to system structure elicitation.

System structure elicitation

The final session of the day attempted to elicit the structure of the system that would explain the relationships that had started to be determined. Up until this script, the workshop had been run by the *facilitator* only. In contrast, this was the script in which the *modellers* role became most prominent, in accordance with Luna-Reyes et al. (2006).

Using a document projector[22], the modeller drew the system as it was developed by the group. This graphic was projected onto the screen from where the facilitator coordinated the discussion. Starting with the most-important variables identified by the voting undertaken earlier, a given process was followed:

4. Each variable was drawn on the system diagram.
5. The variable was identified as a stock, flow, or other influencing variable.
6. Connections were drawn between it and other variables.

As this script progressed, a picture of the system was gradually built up Appendix Figure 11. The final model is shown in Appendix Figure 12.

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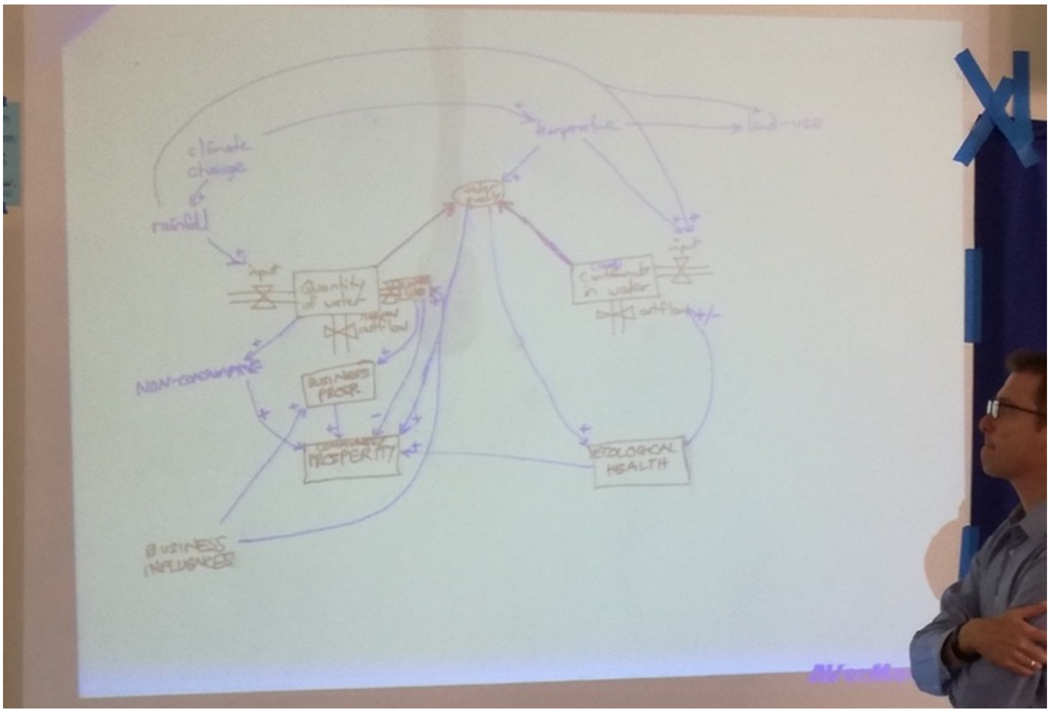
22 A document project is the modern version of an overhead projector, which is what was used by Luna-Reyes et al. (2006).

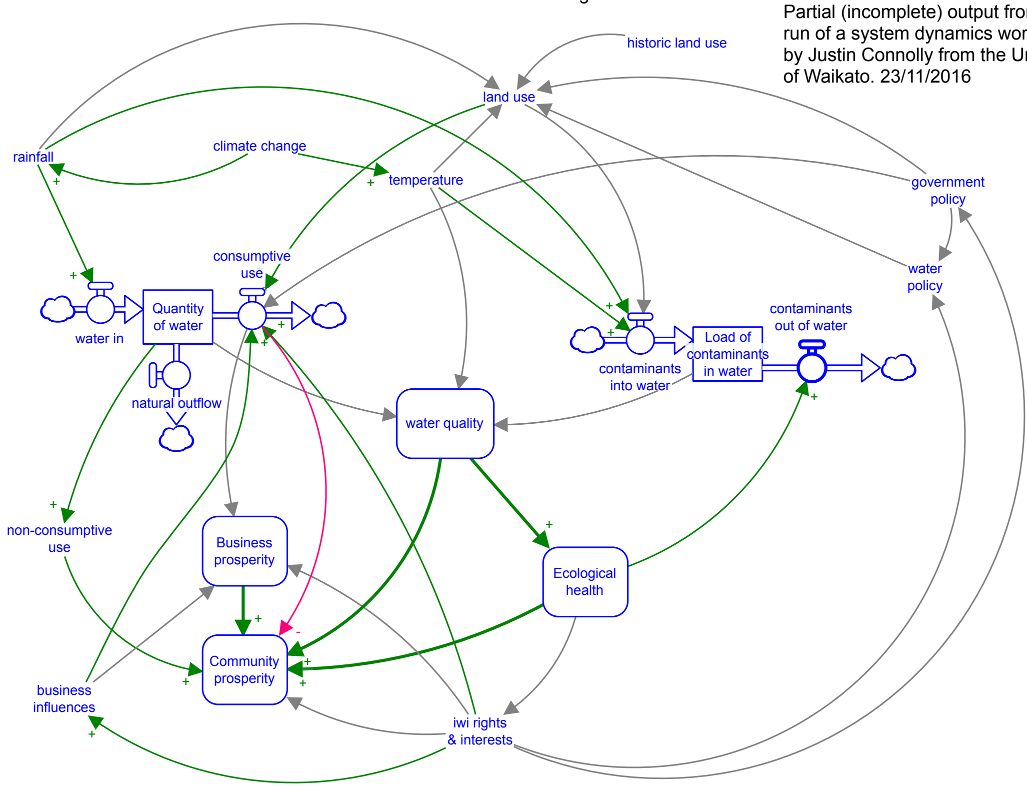
Appendix Figure 11. Using the document projector to draw the system.



Appendix Figure 12. Test-workshop I – output model

What is the relationship between water availability, water quality and the use of water by business across the Waikato region?

Partial (incomplete) output from a trial run of a system dynamics workshop run by Justin Connolly from the University of Waikato. 23/11/2016



Within this process, the researcher (an experienced facilitator) acted as the facilitator and was assisted by an experienced modeller. Both found this session to be highly fluid and as the system evolved and changes were made, corrections often had to be made as new variables were introduced or connections modified. Overall, this was a successful part of the day and it was found that there were two important parts to it.

Firstly, there was the documentation of the system that was produced by the modeller in response to discussion by the group and this would be the tangible output that was produced by the script. Secondly, the generation of the diagram led to an ongoing discussion with regards to the interdependency of various elements within the system. This was much more difficult to document and would only have been possible if it was recorded or someone was present to transcribe – like the 'recorder' role described in Richardson and Andersen (1995). Nevertheless, it was highly valuable in terms of promoting group learning, given that people from a range of backgrounds discussed their individual thoughts in a constructive way that did not lead to any level of obvious conflict. Overall, the communication between both technical and non-technical participants was good and all views were appreciated. The researcher observed that both groups of people learned something from the other, and this appeared to be consistent with the high-quality group communication that is intended in GMB (van den Belt, 2004) and has been reported in previous GMB processes (Scott et al., 2016b). This is likely to be a result of the type of double-loop communication described by Argyris (1994) that the process enabled, which allowed a dialogue around issues and increased participants understanding (Doyle & Strauss, 1976).

From a practical point of view, the use of clear acetate layers to gradually build up more detail of the model – as described in Luna-Reyes et al. (2006) – was trialled here. As the model was not built up in strict 'sectors', as suggested by van den Belt (2004), it was difficult to know when new layers should be added. The modeller found this challenging to work with given the tendency for wet ink to run when an acetate layer was added on top of another. Additionally, a connection drawn earlier was sometimes found to need modification and layers of the acetate would have to be removed to access it, impacting on the flow of the conversation. The use of the acetate layers tended to make drawing the model more difficult.

Summary of lessons from pilot workshop I

The process has been described in detail and assessed above. Below is a summary of the lessons from this first pilot workshop.

- Overall, **time was a challenge**. While this was only a trial of the workshop and not expected to produce a complete system model, it demonstrated how challenging that would be within a single day. One day is approximately half of that time required in the process used by Luna-Reyes et al. (2006). However, even achieving this in practice – as discussed below in the context of the case studies – is ambitious given the cost this imposed on the host organisations and participants.
- **Both technical and non-technical participants** demonstrated an ability to **grasp the concepts of SD**, becoming familiar with CLDs as well as stocks, flows and connections.
- **Understanding the polarity of relationships in CLDs** as quantitative and not qualitative **was difficult**. Sterman (2000) has noted the alternate use of 'same' (positive) and 'opposite' (negative) terminology to indicate the polarity of relationships and this terminology may be less confusing than the '+' or '-' signs, as used here and in many previous causal-loop applications.
- The **key variables** defined in the focus question **should be assumed** as variables in the model. In this workshop, they were identified as the two top variables during the variable elicitation script – this would seem obvious and may have come at the cost of prioritising other important variables.
- The use of the **document projector was a success** while the use of **acetate layers for drawing the model in layers was unsuccessful**, they were found to be confusing and cumbersome for the modeller. The use of both were described in Luna-Reyes et al. (2006).

- Participants struggled with the concept and act of determining **reference modes**. Not all variables identified were necessarily variables that HAD a reference mode, or were made up of many variables with different reference modes, or the same variable presented differently in different geographic areas within the area included in the focus question. Examples of these were climate change and the ecological health of waterways. As 'behaviours over time', reference modes are a key part of what the system is trying to explain. Hence, perhaps this phase can be simplified through limiting it to the identification of reference modes to a limited number of key variables. More focus can then be applied to developing an understanding of the rest of the system in attempting to explain these behaviours.
- **When brainstorming** variables, it is necessary to ensure people **focus at as high a level of aggregation** as possible. This will help to ensure that a succinct number of variables is attained. This is important because time constraints will limit the opportunity to explore a high number of variables, as observed in this pilot.
- **Too many concepts were introduced to the participants** for them to understand in the introduction session. It was difficult for participants with no prior knowledge of SD to learn the language of BOTH CLD and stock and flow model architecture. Further, two example models were introduced – an *example model* that was not related to freshwater and a *concept model* that was. The process described by Luna-Reyes et al. (2006) only had *one* concept model and so my use of two likely confused the participants who were trying to absorb two different technical subjects and understand the differences in technical language between CLD and stock and flow simulation modelling.
- **The region-wide approach was problematic** for this example. Participants struggled with generalised 'behaviours' or generalisations for variables that demonstrated huge geographic diversity – even though they were the same variable. This is a major limitation, as the relationship between core variables could change in polarity depending on their spatial location. This suggested that a

higher level of geographic disaggregation may be required in freshwater applications, highlighting potential issues with determining the boundary of the system being modelled and may reflect the iterative nature of the learning process that is likely to be required, as described by Schein (1988) and Sterman (1994).

Pilot workshop II – Bay of Plenty

Towards the end of 2016, the BOPRC confirmed that they would like to test the GMB process in the Rangitāiki catchment, where they were working through an *NPS-FM 2014* process to identify values and set objectives for water quality and limits for contaminant loss from point and non-point sources. An initial meeting with BOPRC staff was undertaken to explain the SD approach and to develop a concept model for presentation, as was required within the selected methodology (Luna-Reyes et al., 2006).

This session with staff – some of whom had a basic understanding of causal loop mapping and some of whom did not – was used to run a second pilot workshop. One benefit of this approach was that it would ensure that support staff were more aware of what was going to happen on the day.

This was mainly the same as the first pilot application, but with some minor modifications. Building on the experience of the first pilot workshop, the following amendments were made and sought to be tested:

- **The entire workshop would be run by only one person**, alternating between the roles of facilitator and modeller, as opposed to them being separate people – as described by Richardson and Andersen (1995).
- **A sticky wall and paper was to be used to build the model**, instead of an overhead projector.
- **A whiteboard would be used to collate the variables** instead of a sticky wall. This was consistent with how Luna-Reyes et al. (2006) described their process.
- **No explanation of a CLD would be provided** in the introduction. Rather the concepts of stocks and flows would be introduced, the example model would be explained and a concept model introduced.

This process was run with a group of eight people in November 2016 – again running for around 3.5 hours. The group consisted of eight staff members, all of whom were experienced in dealing with freshwater issues from different perspectives. The participants varied depending on whether their work primarily involved policy development, science provision, engagement, and/or communications.

Structure of the process

Once again, the process was run in accordance with the structure described by Luna-Reyes et al. (2006) and in a similarly constrained time frame. As with the first pilot, the objective was not to build a working simulation model but to determine how participants responded to the scripts that were to be used. The structure of the workshop is outlined in Appendix Table 3.

Appendix Table 3. Structure of pilot workshop II

Session	Description
Introduction	Researcher introduces himself and outline what he hopes to achieve in the day and how the process will be structured.
Script i - hopes and fears (divergent)	A warm-up activity is undertaken to 'break the ice' and to help introduce participants to each other.
Script ii - SD and the concept model (instructive/convergent)	A brief presentation and explanation of what SD is and how it can be used.
Focus question	Focus question is introduced.
Script iii - variable elicitation (divergent)	Identifying the 'parts' (variables).
Script iv - reference modes elicitation (divergent)	Identifying the 'behaviours' (reference modes).
Script v - model structure elicitation (convergent)	Identifying the system structure.
Script vi - reflect and confirm model structure (convergent)	The final script is to reflect the model as developed back to the group and confirm it reflects what they have developed together.

Each section of this second workshop is now described and assessed.

Introduction

The researcher began the workshop by introducing himself, his professional background and his current post-graduate research interests. Objectives for the research were outlined. The researchers' objectives were focused on how systems dynamics can contribute to the learning environment for those involved in freshwater decision-making, and the council's objectives were an opportunity to trial a possible tool to assist in freshwater decision-making. The focus question was outlined in the introduction, but was also reiterated later in the presentation.

Hopes & Fears exercise

The hopes and fears exercise was run the same way as in the first test. Participants were asked to provide one hope and one fear, each colour-coded to a green (hope) or red (fear) piece of paper respectively. These were collectively placed on the sticky wall and the participants briefly explained what their hopes and fears were.

This exercise was a good opportunity for the participants to learn more about each other, as well as an opportunity for the facilitator to learn about the group. Once again, it also provided a physical and interactive way of beginning the session.

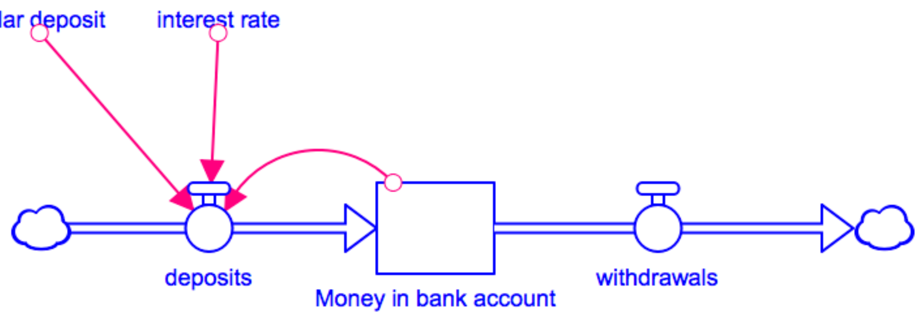
What is System Dynamics? (concept model)

While this script remained the same, the content of the presentation was changed from the first pilot workshop. A brief description of the holistic nature of economics as the study of trade-offs was retained (Tietenberg & Lewis, 2015), and the presentation then focused on introducing the group to the conditions that lend themselves to simulation models and the main parts of simulation models (e.g. stocks and flows, as per Sterman (1994)). An explanation and example of a CLD was *excluded*.

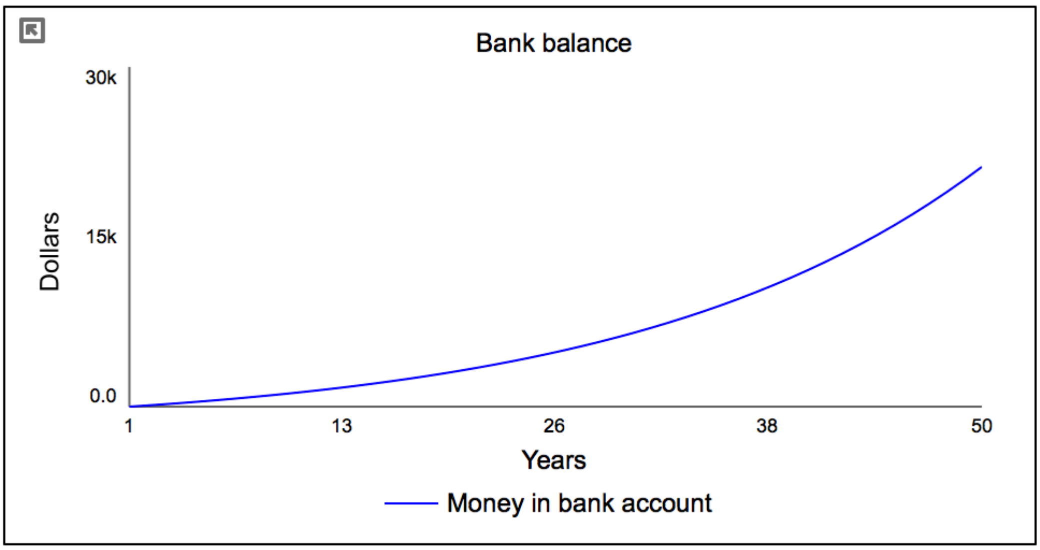
As in the first pilot, the analogy of a bath being filled with water Sterman (1994) was used to describe stocks and flows and this was well received.

A simple example of a SD model was then explained. This was the example of a bank account with a regular deposit being made into it and no withdrawals. The model architecture was described and explained (Appendix Figure 13) then an example of a model output graph was provided and explained (Appendix Figure 14).

Appendix Figure 13. Example model structure – bank account



Appendix Figure 14. Example model output – bank account



This example was well received as it was simple and accessible (everybody has a bank account) and clearly demonstrated how the system worked. It was also non-controversial and avoided the subject matter of freshwater and therefore any potential controversy around this.

After this simple example, the predator-prey model as described in the first pilot workshop was also explained as an example of the style of output that could potentially be taken from the first and second workshops (see Appendix Figure 6 and 0). As this was slightly more complex than the first example (the bank-account formalism), it took a little more effort to explain and again this added substantial time pressure given the time constraints of the workshop. Unlike the first workshop, it was found that the participants found the concept and structures of stock and flow models accessible and able to be understood with some discussion. Like the first pilot workshop, participants struggled to absorb and understand two disparate examples (cf. bank account and predator-prey dynamics), leading to increased time pressure for the workshop and confusion of the participants.

Focus question

The focus question for the session was developed in conjunction with the gatekeeper and the facilitator in preparation for the workshop. The gatekeeper was keen to explore participants' understandings of how they saw different parts of a system being connected. Initially outlined in the introduction, this was now restated more clearly as:

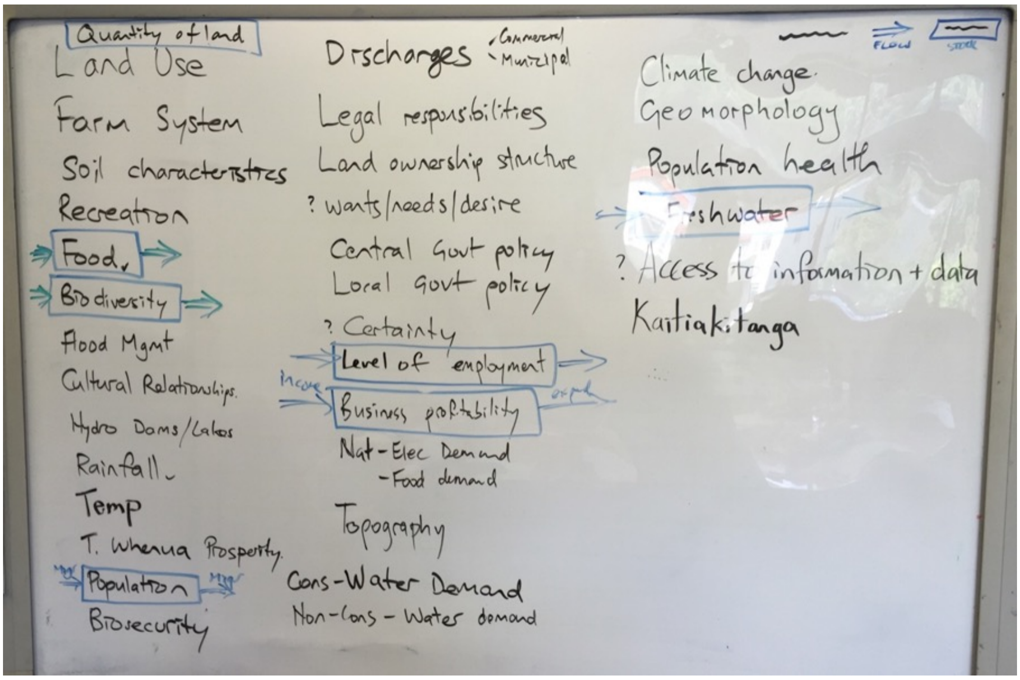
> *What variables and relationships influence and are influenced by freshwater in the Rangitāiki catchment?*

Variable elicitation

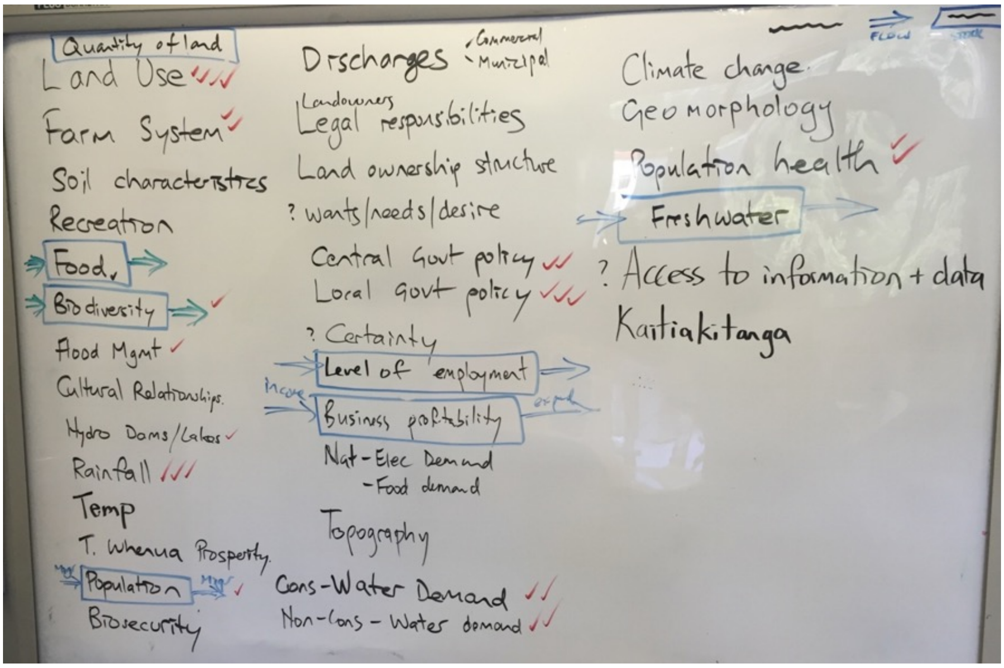
This script was run as in the first pilot workshop and in accordance with the Luna-Reyes et al. (2006) process. Participants were asked to brainstorm as many factors as they could think of and then they were shared with the group three at a time, gradually building up a total list of parts. The difference with how this was done, compared to the first script, was that instead of using the sticky wall, the variables were collated on a whiteboard.

A larger number of variables were elicited relative to the first pilot, a total of 35 variables were identified with some containing sub-sets. Some discussion was then held and those 'parts' (variables) that could be clearly agreed as stocks were identified – a total of seven were identified. A voting exercise was then undertaken to identify those parts that participants thought had the greatest impact. These would form the basis of the model (for the results of this exercise, refer to Appendix Figure 13, Appendix Figure 16 and Appendix Table 4).

Appendix Figure 15. Variables with stocks identified (photograph).



Appendix Figure 16. Variables with stocks identified and ranked (photograph).



Appendix Table 4. Variables with stocks identified and ranked (table). The number of ticks next to each item dictates their relative importance, as voted by the group.

	'part' or variable		
Stocks	**<u>Biodiversity</u>**	✓	**Level of employment**
	<u>Population</u>	✓	**Business profitability**
	Quantity of land		**Freshwater**
	Food		
Other 'parts'/variables	<u>Land use</u>		Recreation
		✓✓	Cultural relationships
	✓✓		
			Temperature
	<u>Local government policy</u>		
		✓✓	Tangata whenua prosperity
	✓		
	<u>Rainfall</u>		Biosecurity
		✓✓	Wants/needs/desires
	✓		
			Certainty
	<u>Central government policy</u>	✓✓	National electricity demand
	<u>Farm system</u>	✓✓	
	<u>Consumptive water demand</u>	✓✓	National food demand
	<u>Non-consumptive water demand</u>	✓✓	Topography
	<u>Population health</u>	✓✓	Climate change
	<u>Flood management</u>	✓	Geomorphology
	<u>Hydro dams/lakes</u>	✓	Access to information & data
	Soil characteristics		
	Discharges (commercial and municipal)		Kaitiakitanga
	Legal responsibilities		
	Land ownership structure		

Those voted most important are <u>underlined</u>, the number of votes they received with is indicated by the number of ticks (✓)

When assessing the success of this script, it is notable that a much larger number of variables were elicited, which is to be expected from a larger group. Yet, the number did not directly correlate to the increase in group size – the group was twice the size, while the list of variables was only one-and-a-half times larger. This suggests that while participant numbers may increase the collective knowledge of a system contained within a given system boundary, it need not proportionally increase the number of elements therein. Accordingly, while there may be some enrichment of the diagram through the development of complementary ideas, there may also be some crowding-out whereby the ideas of one individual are identical to those of another. This inefficiency may be expected to increase with the number of participants, for a given system boundary.

However, what was noticeable was the level of detail that these variables were identified at. For example, national electricity and food demand, legal responsibilities (in relation to land) and land ownership structures. This was different from what was identified in the first pilot, in that the examples were much more specific given the localised nature of the case study. The participants were also greater in number (nearly twice as many as the first pilot) and were entirely experienced staff – so their understanding of the issues was much more detailed and reflected their professional knowledge. Other variables remained unclear and would benefit from further discussion and definition which the time frame of the pilot workshop did not allow. Examples of this included 'certainty' – understood to have related to the certainty of the legal and policy environments, and 'wants/needs/desires' – understood to have described how the community might describe their social and economic drivers.

While this process of eliciting as many variables as the participants could think of was useful, it appeared to overwhelm the participants with the complexity of the situation. While they could be seen to be developing an appreciation for the complexity of the system that they were operating within, it became obvious that it would be difficult to achieve a workable SD model from the variables generated within the time frame.

Ex-post feedback from the group regarding this session also indicated that the facilitator tried to *reinterpret and change the words* of the suggested variables, rather than *capture the words as they were provided*. This was considered necessary by the facilitator given the need to capture diverse ideas and evolve those suggestions into variables that would work well in a stock and flow model, yet feedback indicated that it had the *unintended consequence* of disengaging some participants who felt that their suggestions were not being heard and captured correctly, or that they were somehow 'incorrect'. This was a valuable lesson from this pilot workshop and the need for independence when facilitating has been highlighted by both Doyle and Strauss (1976) and Hunter (1994) who note the role of the facilitator is to guide the *process*, the role of the participants is the *content*. The perceived need to modify and interpret these variables was partly due to having only one person filling the roles of both facilitator and modeller. It highlighted the challenge of introducing a group to SD and attempting to achieve a workable dynamic model of a complex system within such a limited time frame.

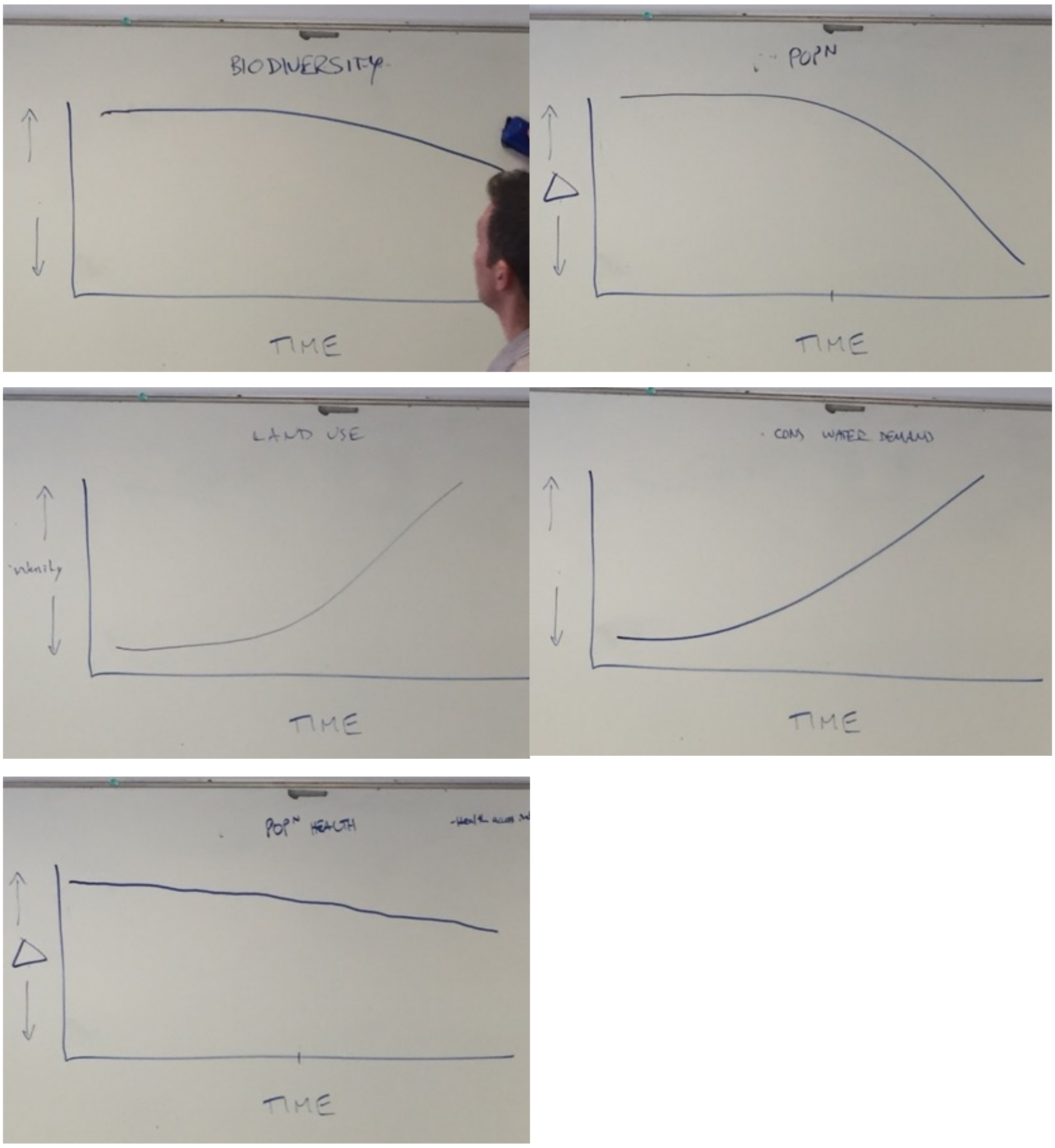
This activity also highlighted the need to attempt to limit the number of variables elicited, at least to begin with. This was considered necessary to be able to achieve a workable model within the constrained time frame and would focus participants on the variables that are most relevant. Marjan van den Belt (2004) quotes Antoine de Saint-Exupéry to demonstrate the need for ensuring models are as simplistic as possible:

> *Perfection is attained not when there is no longer anything to add, but when there is no longer anything to take away. (Antoine de Saint-Exupéry, as cited in van den Belt, 2004, p. 90)*

‘Behaviour’/reference mode elicitation

In the first pilot workshop, the group worked in pairs to develop reference modes and then discussed these as a group. Given time constraints and seeking to test an alternative group approach, this session sought to develop reference modes through group discussion. This was performed on a whiteboard, while the group discussed how they perceived certain variables had and would continue to ‘behave’ and this was sketched on a graph until there was a high level of agreement amongst the group. This was attempted for two of the identified stocks and three of the other variables (Appendix Figure 17).

Appendix Figure 17. Example reference modes elicited. Clockwise from top left: biodiversity; population; consumptive water demand; population health; land use.



As with the first pilot workshop, some variables were seen to have many other variables contained within them and these proved challenging to describe behaviours for. One example of this was land use, where it was not possible to describe how the variety of land uses present in the catchment had and may continue to evolve. So, this behaviour was instead tied to the general variable of *intensity* of land use. Another example was population health that was agreed would be made up of a wide range of indicators, some of which would already be available from health statistics and others that would not.

While there was some good discussion about the behaviours of variables, the facilitator observed that it was difficult to achieve broad consensus on how these should be defined and represented. It also became clear that some participants were struggling to see how this exercise would fit into the overall model that was being developed. In effect, they were beginning to become overwhelmed with technical detail and the complexity of the system, and were not able to envisage how this was contributing to the model building.

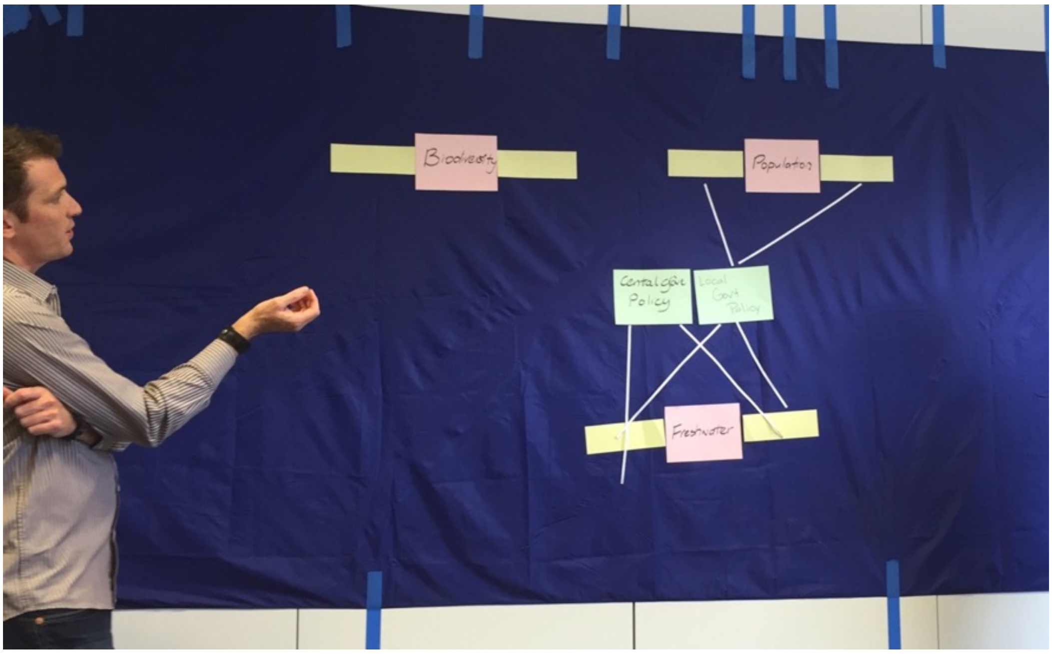
Given time constraints, this session was only partially completed in this pilot workshop.

System structure elicitation

This script was structurally the same as when run in the first pilot workshop and as described by Luna-Reyes et al. (2006); however, the technology used to support it was different.

Firstly, it was only run by one person, so the researcher was filling the role of both facilitator and modeller. Secondly, a sticky wall was used to collate the model, rather than the document-projector system. This was to test the ability of using colour-coded paper and strips of paper or string to map out the variables and connections (see Appendix Figure 18). Red paper was used for stocks, yellow for flows and green for other influencing factors. Shredded paper or string was used to draw the connections. This method was drawn from the perceived positive response that respondents in the first pilot had to the interactive nature of the sticky wall when brain storming variables, the physically interactive nature of this tool appeared to keep them engaged in the process.

Appendix Figure 18. Using a sticky wall to build the model. Red paper was used for stocks, yellow for flows and green for other influencing factors. Shredded paper or string was used to draw the connections.

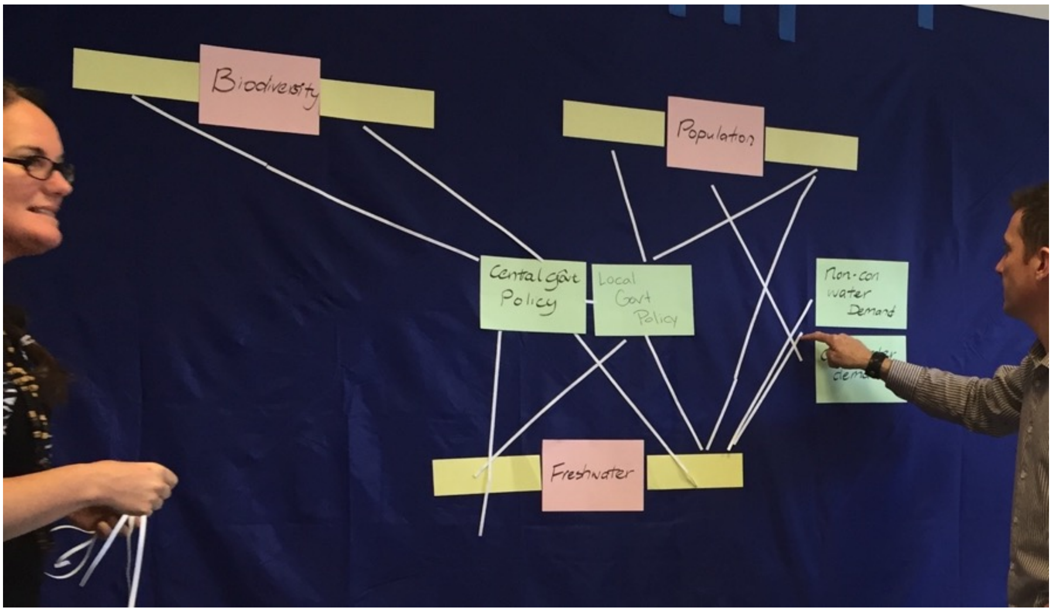


The sticky wall was found to be highly interactive, but also highly problematic. While the colour-coding of the paper was useful, the physical need to place the paper on the wall detracted from the facilitators ability to moderate the discussion. Part way through the exercise, one of the participants began helping the researcher by placing the paper and connections, effectively taking the role of the modeller. While this was useful in freeing up the facilitator to focus on the discussion, it created some logistical challenges as there were now two people operating in the limited physical space in front of the wall – they kept getting in each other's way, which impacted the flow of the discussion.

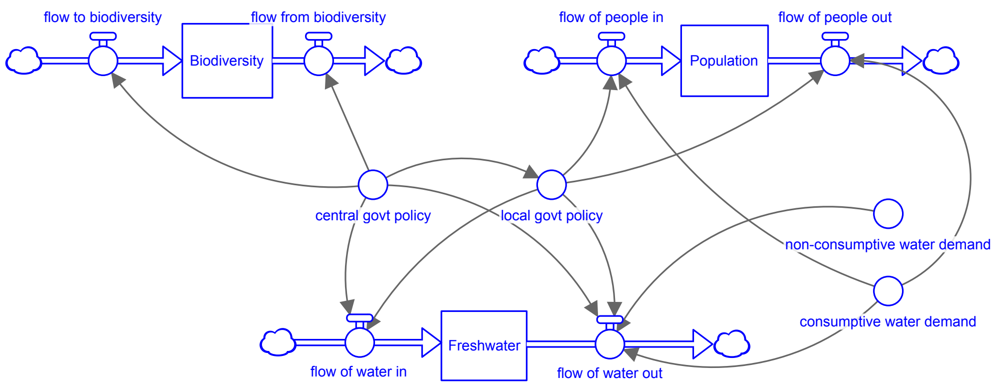
This approach was also found to take more time, as it was physically more difficult to place paper and string on the wall than to draw them under a document projector. This was further complicated by the fact that while the paper adhered well to the sticky wall, the shredded paper or string did not and kept falling off.

While this session enjoyed some robust discussion, it was also drawn to a close early due to time constraints and before any robust model had been developed. The final model architecture as it was developed is shown as a photograph (Appendix Figure 19) and as a STELLA Software model drawn *ex-post* (Appendix Figure 20).

Appendix Figure 19. Final unfinished model architecture (photograph)



Appendix Figure 20. Final unfinished model architecture (STELLA)



Summary of lessons from pilot workshop II

The process has been described and considered in detail above. Below is a summary of the lessons from the second workshop.

- **Time continued to be a challenge**. This was still only a pilot of the workshop and was not expected to produce a complete system model. Yet, with a larger number of participants, it became obvious that achieving the desired output – architecture of a stock and flow model – would be a challenge.

- **NOT explaining CLDs made it easier to explain stock and flow models,** as the two were not inadvertently confused by participants. However, it was still found that while the components of a stock and flow model were easily grasped by participants, understanding how they worked as a system was harder for participants to grasp. Research has shown that while the concepts of stocks and flows are easy to grasp, translating this conceptual understanding into an accurate understanding of the dynamic relationships between stocks and flows is surprisingly uncommon – even among research subjects highly articulate in mathematics (Booth Sweeney & Sterman, 2000).
- **Having two SD examples (i.e. the bank account and predator-prey examples) remained confusing** for participants. The example of the bank account was easily grasped but the predator-prey model was more difficult. Also, neither of these were freshwater examples and so by the end of the workshop, once freshwater had been introduced, there were three diverse topics that participants were required to reflect on the dynamic behaviour of.
- Participants found it **difficult to identify 'behaviours'/reference modes** for the variables that had been identified. Usually, this was because each variable was made up of many other variables that might present differing behaviours. Again, this indicated that the level of aggregation and geographic diversity were key issues that complicate applying this particular process in the context of freshwater.
- The **sticky wall was not an effective tool for building the model** with participants. This was found to be cumbersome and slower than the document-camera approach, which was an important constraint given the time limits faced within the workshop.
- At least **two people were required to run the workshop**. Results from this pilot indicate that these responsibilities are best allocated to the facilitator and modeller roles (Richardson & Andersen, 1995). It was not possible for one person to do both jobs within the limited time frame available. While this might be possible with the luxury of

more time, the act of being the modeller detracted from the focus that was able to be given to facilitating the discussion.

- A huge number of variables were elicited at varying levels of resolution. Only **allowing participants a limited number of variables when generating ideas** might help manage this, while ensuring participants also focus on those most important to them. The literature does not provide guidance on the most efficient or effective number of variables that should be generated as this is heavily dependent on the number of participants involved and the exact nature of the problem being modelled. However, it is noted that when a group is left with the option to generate an open number of stocks they tend to generate all that they can think of and, "analyse details rather than select the most important ones and synthesise the broad lines" (van den Belt, 2004, p. 86).

Appendix 11 Original scripts used in Luna-Reyes et al. (2006)

This appendix includes the original scripts used in the GMB process described by Luna-Reyes et al. (2006). These are:

- Hopes and fears
- Concept model
- Variable elicitation
- Graphs over time
- Structure elicitation
- Reflector feedback

All scripts are reproduced from those listed in *Scriptapedia 4.0.6.* (Hovmand et al., 2013).

Hopes and fears script

<table>
<tr><th colspan="3">Hopes and fears script</th></tr>
<tr><td>Context:</td><td colspan="2">At the start of a GMB project.</td></tr>
<tr><td>Purpose:</td><td colspan="2">To elicit and establish group expectations for a GMB session or project.</td></tr>
<tr><td colspan="2">Primary nature of group task:</td><td>Divergent</td></tr>
<tr><td colspan="3">Materials needed:</td></tr>
<tr><td colspan="3">Two different colours of office paper (8.5 x 11) for each participant
Thick markers
Blue "painters" masking tape</td></tr>
<tr><td>Inputs:</td><td colspan="2">None</td></tr>
<tr><td>Outputs:</td><td colspan="2">List of participants’ hopes and fears.</td></tr>
<tr><td colspan="3">Roles:</td></tr>
<tr><td colspan="3">Facilitator with good group facilitation skills and knowledge of the local language and topic
Recorder to document the session</td></tr>
<tr><td colspan="3">Steps:</td></tr>
<tr><td colspan="3">Participants are given several sheets of paper in each colour the facilitator explains that they will be writing their hopes and fears for the project and then sharing them with the group.
The facilitator states which colour represents hopes and which represents fears.
In a round-robin fashion, each participant then reads one fear and one hope. The facilitator takes each hope and fear that the participant has read and posts it on the wall. After each participant has had a chance to share once, the facilitator may open the floor to participants to offer hopes and fears or may go around the room until everyone has shared all their hopes and fears.
The facilitator then tries to identify some of the themes of the hopes and fears.
Recorders write down the hopes and fears in the session notes.</td></tr>
<tr><td>Evaluation criteria:</td><td colspan="2">Participants have shared both their hopes and fears for the upcoming project; participants understand the overall themes of the hopes and fears.</td></tr>
</table>

Concept model script

<table>
<tr><th colspan="3">Concept model script</th></tr>
<tr><td>Context:</td><td colspan="2">Early at the start of a GMB project</td></tr>
<tr><td>Purpose:</td><td colspan="2">To introduce the process of modelling and symbolism of a model to participants</td></tr>
<tr><td colspan="2">Primary nature of group task:</td><td>Presentation</td></tr>
<tr><td colspan="3">Materials needed:</td></tr>
<tr><td colspan="3">Whiteboard and markers
Computer and projector</td></tr>
<tr><td>Inputs:</td><td colspan="2">None</td></tr>
<tr><td>Outputs:</td><td colspan="2">Familiarity with stock and flow and causal icons
Understanding that maps can be created for the groups’ problem(s)
Understanding that the model is owned by the group and can be repeatedly modified and improved</td></tr>
<tr><td colspan="3">Roles:</td></tr>
<tr><td colspan="3">Experienced modeller to design the Concept Model
Experienced helper to show and run the formal model</td></tr>
<tr><td colspan="3">Steps:</td></tr>
<tr><td colspan="3">The experienced modeller draws by hand the first version of the concept model on the whiteboard. Demonstrate/draw the tub with faucet and drain to explain stock & flow icons.
The experienced modeller then projects the first quantified version of the concept model from the computer. The first quantified version of the concept model is identical to the first version drawn on the white board. Then, simulate and trace the behaviour produced by the model.
On the whiteboard add one or more elements to the first version to get an amended Concept Model (second version). The added elements are elicited by the experienced modeller from the participants. Project the second version of the concept model and trace its behaviour over time. The behaviour should be different so as to demonstrate that “behaviour is a consequence of structure”.
Repeat step 3 one more time.
The experienced modeller summarises the lessons as follows: the icons that will be used, maps can be quantified and simulated, behaviour can be generated endogenously, changing structure changes behaviour, maps and models can be repeatedly refined, and groups can own the models they create.</td></tr>
</table>

Concept model script	
Evaluation criteria:	• Participants are talkative, wanting to tell the modeller how the model is wrong and can be improved. • Participants can use the symbolism of SD to express their own ideas.

Variable elicitation script

Variable elicitation script		
Context:	Early in the modelling process	
Purpose:	To facilitate consensus-based group discussion about the model problem and boundaries. It elicits key variables that become the input for other activities.	
Primary nature of group task:		Divergent
Materials needed:		
• Markers • Stacks of plain paper • Chalk/whiteboard markers		
Inputs:	None	
Outputs:	Prioritized list of variables	
Roles:		
• Facilitator with moderate expertise in SD and small group facilitation • Modeller with moderate expertise in SD		
Steps:		
Part I 1. The facilitator gives each participant sheets of blank paper and markers. 2. The facilitator writes a task focusing question on the whiteboard or flipchart, such as, “What are the key variables affecting the process and outcomes of the [project name] project?” 3. The facilitator asks participants to write as many problem-related variables as they can on the sheets of paper. Participants are given a few minutes to work individually on their lists. 4. Once they have finished the individual exercise, the facilitator uses the same process used in the hopes and fears script to put all individual variables on the board. When a variable name is open to several interpretations, the facilitator asks for a brief description or		

Variable elicitation script	
definition of the variable, including the units in which the variable can be measured. 5. The facilitator writes the variable name on the board, including any additional information in parenthesis. Part II 6. The facilitator asks the participants to prioritize the variables by simple voting mechanisms. Individuals can vote for as many variables as they want. The number of votes for each variable is also written down on the board. 7. The facilitator makes a summary of the variables on the board, while the recorder captures the products of the process either photographically or in a word processor. 8. The facilitator suggests which variables can be considered stocks as they are mentioned. If the participants agree, the facilitator can add the words "level of" to these variables.	
Evaluation criteria:	Identification of key variables and stocks.

Graphs over time script

Graphs over time script	
Context:	At the beginning of a GMB session as it is a springboard for discussion about the problem to be modelled.
Purpose:	To engage participants in a GMB session in framing the problem, initiating mapping, eliciting variables and gathering input in deciding the reference modes for the study.
Primary nature of group task:	Divergent
Materials needed:	
• Camera or other method to capture the graphs • Stacks of 8.5x11 white paper with X and Y axes drawn on them • Large blank wall (8'x10') • Thick markers • Glue sticks, Tacks or painters tape	
Inputs:	None
Outputs:	Candidate variables for the dynamics model or the map
Roles:	
• Facilitator works with the group and has some experience with SD	

Graphs over time script

- Modeller listens to what is being graphed and the way people are talking about the graphs. They must also be able to conceptualise early seeds of system structure
- Wall builder to cluster graphs and talk about themes with little or no experience in SD
- Runner (optional) to bring the graphs from the community facilitator if the group is large
- Recorder to document the session and photograph the clustered graphs

Steps:

1. Based on group size, decide whether to break participants into subgroups. In smaller groups N<10, allow individuals to work and present independently. I larger groups N>10, divide participants into groups of roughly 10. Ask the subgroups to sit together.
2. The modelling team hands out sheets of white paper to each participant group.
3. The facilitator gives an example of how to draw a graph over time, carefully labelling X-axis "Time" with start time, end time, and now indicated with a vertical dashed line. The Y-axis is labelled with a variable name. The facilitator then sketches the behaviour over time.
4. The facilitator then asks participants to draw one variable over time per piece of paper. The participants should be given the option of including hoped for behaviour, expected behaviour, and feared behaviour on the same graph.
5. The facilitator and wall-builder walk around and help participants with the task if they need it. Allow 15 minutes or until the group runs out of steam to complete the task.
6. Reconvene as a large group.

   A: If N<10, the facilitator takes one graph at a time from each participant, holds it up in front of entire group and asks him/her to talk about it. Ask for participants to share the "best stuff" first. Clarify timescale, variable names, etc.

   B: If N>10, instruct subgroups to share their graphs with each other and choose the ones they think are most important. The facilitator then goes to each subgroup and holds the first graph they have selected in front of entire group. The subgroup spokesperson talks about the graph. Ask subgroups to share the "best stuff" first. Clarify timescale, variable names, etc.
7. The facilitator then hands the graph to the wall-builder.
8. The facilitator repeats steps 6 and 7 with each participant or subgroup, taking one graph at a time until all graphs are shown or

Graphs over time script	
	time has run out. Finish by asking if any participant has something else that really ought to be shown. 9. During steps 7-8, each graph is posted on the wall. The wall builder tries to cluster the graphs meaningfully on the fly based on themes and variables. 10. The facilitator asks the wall builder to explain the clusters of graphs on the wall. The wall builder tries to summarise dynamics that help to characterise the problem that emerges from the participants graphs. 11. The facilitator enables the participants to talk about the clusters and the characterisation of the problem they imply. 12. Consider labelling the clusters based on themes or related variables. There is potential for the modeller to close by highlighting the beginnings of feedback thinking in the dynamic problem.
Evaluation criteria:	• Interesting, self-sustaining group discussion after clusters described by the wall builder. • Meaningful clusters identified. • Graphs tend to converge to a clear dynamic problem. • Some key dynamic variables emerge from reflecting on the graphs and thematic clusters. • Modelling team can begin to see key stocks and perhaps important feedback loops. • Members of the group appear to have better understanding

Structure elicitation script

Structure elicitation script		
Context:	This script fits after exercises to elicit reference modes and a break have been completed.	
Purpose:	To capture the key endogenous mechanisms elicited during a discussion that have the potential to explain the observed behaviours or dynamic hypotheses.	
Primary nature of group task:		Convergent
Materials needed:		
• Chalk/whiteboard markers • Flip chart/whiteboard		
Inputs:	• Prioritised list of variables	

Structure elicitation script	
	• Behaviour over time graphs (reference modes)
Outputs:	Basic stock and flow structure
Roles:	
• Facilitator • Modeller	
Steps:	
1. During the break after the reference mode elicitation script, the modelling team selects a couple of key behaviours from the reference mode elicitation exercise. 2. The facilitator starts the structure elicitation by suggesting two stocks. The facilitator explains that these stocks are initial simplifications of the system. 3. The facilitator asks the group to identify the variables that help to open or close the faucet of these two stocks. Participants suggest causal relations linked to these two initial stocks and their corresponding rates. 4. The facilitator clarifies the nature of the causal relationships with the group while drawing them on the board. 5. After adding a couple of variables and causal relations, the facilitator summarises by telling the story embedded in the model so far and asks the group to add further causal explanations, stressing the importance of selective thinking about causality with the purpose of reaching a powerful and parsimonious explanation of the project success.	
Evaluation criteria:	A basic stock and flow structure has been provided.

Reflector feedback script

Reflector feedback script	
Context:	After each iteration of structure elicitation
Purpose:	To summarise dynamic insights and stories told by the group. It also allows for clarification of fuzzy ideas or capturing additional information about model structure needed to formulate the model
Primary nature of group task:	Convergent
Materials needed:	
• Chalk/whiteboard markers	

<table>
<tr><th colspan="2">Reflector feedback script</th></tr>
<tr><td colspan="2">Flip chart/whiteboard
Overhead transparencies
Overhead projector</td></tr>
<tr><td>Inputs:</td><td>Prioritised list of variables
Behaviour over time graphs (reference modes)</td></tr>
<tr><td>Outputs:</td><td>None</td></tr>
<tr><td colspan="2">Roles:</td></tr>
<tr><td colspan="2">Reflector</td></tr>
<tr><td colspan="2">Steps:</td></tr>
<tr><td colspan="2">The reflector presents a series of diagrams created during the group discussion. Diagrams and nots are usually captured in overhead transparencies using markers of different colours.
The diagram is presented in the simplest form of a transparency. More complex versions with additional variables are progressively layered on top of the first diagram. As the reflector places each layer on the projector, he/she presents the story behind the diagram.
The presentation includes comments about how a more operational version of the diagram helps to clarify causal relations and important feedback, and continuous confirmation of the adequacy of the diagram as a representation of the group thinking.
The reflector may add variables to the diagram at the group’s request.</td></tr>
<tr><td>Evaluation criteria:</td><td>Unclear ideas have been clarified.
The group has a better sense of variables and causal relations needed to complete a model.</td></tr>
</table>

Appendix 12 Scripts used in revised GMB process

The scripts listed in this appendix are those that were applied in the final process in this research. Some are as originally described in Luna-Reyes et al. (2006) while others have been modified, often in only the minutiae such as process detail, simple supporting tools (e.g. document projector instead of overhead transparencies) or the number of items participants are requested to generate (some have been limited instead of being left open-ended).

While all scripts are based on those listed in *Scriptapedia 4.0.6* (Hovmand et al., 2013), any minor amendments have been noted as appropriate. The originals of all scripts amended here are provided in Appendix 11, except for *Initiating and elaborating a causal loop diagram* which is a new addition and did not feature in the Luna-Reyes et al. (2006) process. It was used here as it was described in *Scriptapedia 4.0.6* (Hovmand et al., 2013).

The scripts included in this appendix are:

- Hopes and fears (amended)
- Concept CLD (amended)
- CLD variable elicitation (amended)
- Initiating and elaborating a causal-loop diagram

Scripts marked as *amended* are based on those listed in *Scriptapedia 4.0.6.* (Hovmand et al., 2013) but have been amended specifically for this research. The *Initiating and elaborating a causal-loop diagram* script is the only script used as described in *Scriptapedia 4.0.6.* (Hovmand et al., 2013).

The Hopes and Fears Script (amended)

This script has been amended in the following ways:

1. The script has been **combined with participant introductions** themselves, to reduce time.
2. Participants have been **limited to the one hope and one fear each**, to reduce time.
3. A **sticky wall has been used** to affix paper to the wall instead of blue painter's tape, and participants stand around it to discuss the themes. This is intended to make the session more interactive.
4. The paper colours have been specified (this is optional but preferred) as **green for hopes and red for fears**.
5. The facilitator **actively involves the group** in the identification of themes in the hopes and fears, both by encouraging them to **physically stand around the sticky wall** when placing items on it, and by actively **eliciting the groups help in observing** what hopes and fears may be grouped in the same themes.

Hopes and fears script (amended)		
Context:	At the start of a GMB project.	
Purpose:	To elicit and establish group expectations for a GMB session or project.	
Primary nature of group task:		Divergent
Materials needed:		
• sticky wall • One piece of green paper and red paper (A5 or A6) for each participant • Thick markers • Tape recorder (optional)		
Inputs:	None	
Outputs:	List of participants' hopes and fears.	
Roles:		
• Facilitator with good group facilitation skills and knowledge of the local language and topic. • Recorder to document the session.		

Hopes and fears script (amended)	
Steps:	
1. Participants are given one piece of paper in each colour. The facilitator explains that they each will be writing down one hope and one fear for the project and then sharing them with the group. 2. The facilitator states which colour represents hopes (green) and which represents fears (red). 3. The group then stands around the sticky wall and – in a round-robin fashion – each participant then introduces themselves, reads their one fear and one hope and places them anywhere on the sticky wall. 4. Once all participants have contributed their paper to the wall, the facilitator actively works with the group to try and identify some of the themes of the hopes and fears. Those with similar themes are grouped together. 5. Recorders write down the hopes and fears in the session notes, photographs are taken, or the conversation is recorded for transcription afterwards (or several/all).	
Evaluation criteria:	Participants have shared both their hopes and fears for the upcoming project; participants understand the overall themes of the hopes and fears.

Adapted from Scriptapedia 4.0.6 (Hovmand et al., 2013)

Concept CLD script

This script was previously the *concept model script* and has been amended in the following ways:

1. This is **no longer an interactive demonstration** of both model architecture AND **dynamic behaviour** that elicits additional structure, but only a demonstration of CLD architecture.
2. This is **only a presentation** and does actively seed the structure elicitation session.

Concept CLD script (amended)		
Context:	Early at the start of a GMB project	
Purpose:	To introduce the process of modelling and symbolism of a model to participants	
Primary nature of group task:		Presentation

Concept CLD script (amended)	
Materials needed:	
• Whiteboard and markers • Computer and projector	
Inputs:	None
Outputs:	• Familiarity with variables and feedback loops in CLDs • Understanding that maps can be created for the groups' problem(s) • Understanding that the model is owned by the group and can be repeatedly modified and improved
Roles:	
• Facilitator to present the Concept CLD	
Steps:	
1. The presenter draws on a whiteboard or builds up in successive presentation slides the concept CLD, demonstrating the two elements of *variables and links*. 2. The concept of feedback loops is explained as the model is built up. Ideally the Concept CLD provides an example of the counter-intuitive behaviour of systems. For example, an increase in variable A has a positive effect on both variables B and C, yet variables B and C both respectively have a positive and negative effect on variable D.	
Evaluation criteria:	• Participants are talkative and contemplative, wanting to question the presenter or tell them how the model is wrong and can be improved. • Participants can use the symbolism of SD to express their own ideas.

Variable elicitation (amended)

This script has been amended in the following ways:

1. Participants have been **limited to generating no more than six variables**, to reduce time.
2. A **sticky wall has been used** to affix paper to the wall instead of blue painter's tape, and participants stand around it to discuss the themes. This is intended to make the session more interactive.
3. Participants are asked to **group their six variables into two groups** – one of <u>**higher**</u> **importance** and the other of <u>**lesser**</u> **importance**.

4. The facilitator **actively involves the group** in the identification of clusters of variables identified, both by encouraging them to **physically stand around the sticky wall** when placing items on it, and by actively **eliciting the groups help in observing** what variables may be grouped in the same clusters.
5. **Clustered variables are then labelled** after being grouped. If variables are common enough and able to be described by the group this label becomes the variable name.

<table>
<tr><th colspan="2">Variable elicitation script (amended)</th></tr>
<tr><td>Context:</td><td>Early in the modelling process</td></tr>
<tr><td>Purpose:</td><td>To facilitate consensus-based group discussion about the model problem and boundaries. It elicits key variables that become the input for CLD development.</td></tr>
<tr><td colspan="2">Materials needed:</td></tr>
<tr><td colspan="2">Markers
Stacks of plain paper (A5 or A6)
Small stack of coloured paper (A5 or A6)
sticky wall
Tape recorder (optional)</td></tr>
<tr><td>Inputs:</td><td>None</td></tr>
<tr><td>Outputs:</td><td>Prioritised list of variables</td></tr>
<tr><td colspan="2">Roles:</td></tr>
<tr><td colspan="2">Facilitator with moderate expertise in SD and small group facilitation
Modeller with moderate expertise in SD (optional)</td></tr>
<tr><td colspan="2">Steps:</td></tr>
<tr><td colspan="2">Part I
The facilitator gives each participant sheets of blank paper and markers.
The facilitator writes/projects the focus question on the screen/ flipchart. e.g. “What factors influence or are influenced by….?”
The facilitator asks participants to write <u>no more than</u> six problem-related variables on the sheets of paper. Participants are given a few minutes to work individually on their lists.
Once they have finished the individual exercise, the facilitator asks participants to discuss their list in pairs or threes.</td></tr>
</table>

5. After discussing their lists with each other, the group is given several minutes as individuals to prioritise their factors into two groups, the first of <u>highest</u> importance, the second of <u>lesser</u> importance. Participants are asked to mark all three of their 'higher' importance factors with the number "1" in the top corner and all three of the 'lesser' importance factors with the number "2" in the top corner.
6. The facilitator asks the group to take their 'top three' factors and as a group, all at once, put them anywhere on the sticky wall. The facilitator then works with the group to identify which factors should be clustered together. It is important that this is an *inductive* process and that the factors are clustered by the similarity of their *content*, no *labels* are applied to any of the clusters of factors yet.
7. Once participants feel that the factors have been logically clustered, a piece of <u>coloured paper</u> is added to each cluster of factors. The facilitator then works with the group to develop a *label or name* for each cluster. When a variable name is open to several interpretations, the facilitator works with the group to develop a brief description or definition of the variable. If there are units that the group agrees that the variable might be measured by, this is also noted (but is not necessary). *These cluster names will now become the variables that are prioritised in Part II.*

   Note before progressing to Part II

   The above process can be repeated with the <u>remaining</u> variables (marked with a number '2'). The decision on whether to do this now or at a later stage in the workshop depends on how confident the facilitator is that the group will be able to work through the number of variables listed in the structure elicitation script.

Part II

8. The facilitator asks the participants to prioritise the variables on the wall using a simple voting mechanism. The facilitator can decide whether the number of votes can be limited (e.g. 5 per person) or unlimited. The number of votes for each variable is also written down on the variable name.
9. The facilitator makes a summary of the variables on the wall while the recorder captures the products of the process either photographically or in a word processor.

Evaluation criteria:	Identification of key variables.

Initiating and elaborating a causal-loop diagram script

The following script is from *Scripatpedia 4.0.6* (Hovamund et al. (2012)) and is reproduced here with only a minor adjustment for the supporting technology used on the day.

Initiating and elaborating a causal-loop diagram	
Context:	This script may be used at the beginning of a project to get an initial idea of central concepts and their relationships. If the aim of the project is to construct a formal simulation model, it is recommended to build a stock and flow model. In addition, when accumulation is an important aspect of the problem, a stock and flow model is recommended.
Purpose:	• Initiating mapping • Eliciting relations • Eliciting feedback loops
Materials needed:	
• A projector and a document projector over a whiteboard, at which a modeller sits and draws the diagram as described by the group. *	
Inputs:	A list of variables.
Outputs:	Deliverable: a causal-loop diagram which may be described in a report (in the case studies, only a qualitative model is built) or be used as a dynamic hypothesis on the basis of which formal modelling starts. Interim output/product: increased consensus on dynamic hypothesis, or a possible structural explanation for observed behaviour.
Roles:	
• Facilitator/ modeller with experience in drawing causal-loop diagrams, preferably with experience in building formal models as well. Facilitator/modeller and participants.	
Steps:	
6. Remind the group of the problem variable, preferably sketched as a reference mode of behaviour. Remind the group of the list of variables elicited before. Place the list of variables in such a way that it is visible to the group of participants. Write the problem variable in the centre of a white board or blackboard. 7. Build the model by steps a, b and c below (cf. Vennix, 1996: 120). a. Ask participants which variable from the collected list cause changes in the problem variable. When someone makes a suggestion, include this in the drawing of the model to visualise what is meant. Then, check to see if everyone agrees with the	

	proposed relation. If someone disagrees, ask for clarification and try to determine what the group thinks the relationship should be. If a discussion goes on too long, you can choose to temporarily 'park' this item and continue with another part of the model. Hopefully, there will not only be variables that have a direct relationship with the problem variable, but you will also be able to build a few logical chains of reasoning (via intermediate variables) into the model. In addition, check the polarity (positive or negative) of the relationship. b. After spending some time doing this, proceed to the identification of consequences of changes in the problem variable. c. At the point where a feedback chain becomes closed, check with the entire group to see if the chain as a whole is correct. Check again to see if a loop is positive or negative. 8. In the last part of the session, analyse the model by checking the feedback loops one more time. Before you close the group session, make sure you do the following activities. If there is a list of parked issues, go through them. State once more what has been done and what will happen with the final products. Formulate a few concise conclusions. As Andersen and Richardson (1997) say: 'end with a bang!' Make sure that all the information that is necessary for the report has been noted.
Evaluation criteria:	Improvement in quality of communication, insight, consensus on the problem and commitment with regard to resulting actions.

*** The *Scriptapedia 4.0.6* entry refers to manual (paper-based) and software (e.g. VenSim) tools required to support this script. The only modification made to this script is the listing of a projector and a document camera over a whiteboard for the modeller to draw the CLD on.**

Appendix 13 Detailed information on the two projects

This appendix contains more detailed information on the following aspects of the two case studies for this research:

- Information about the catchments and the projects.
- Information about the participants.
- Information about the scheduling of the workshop.

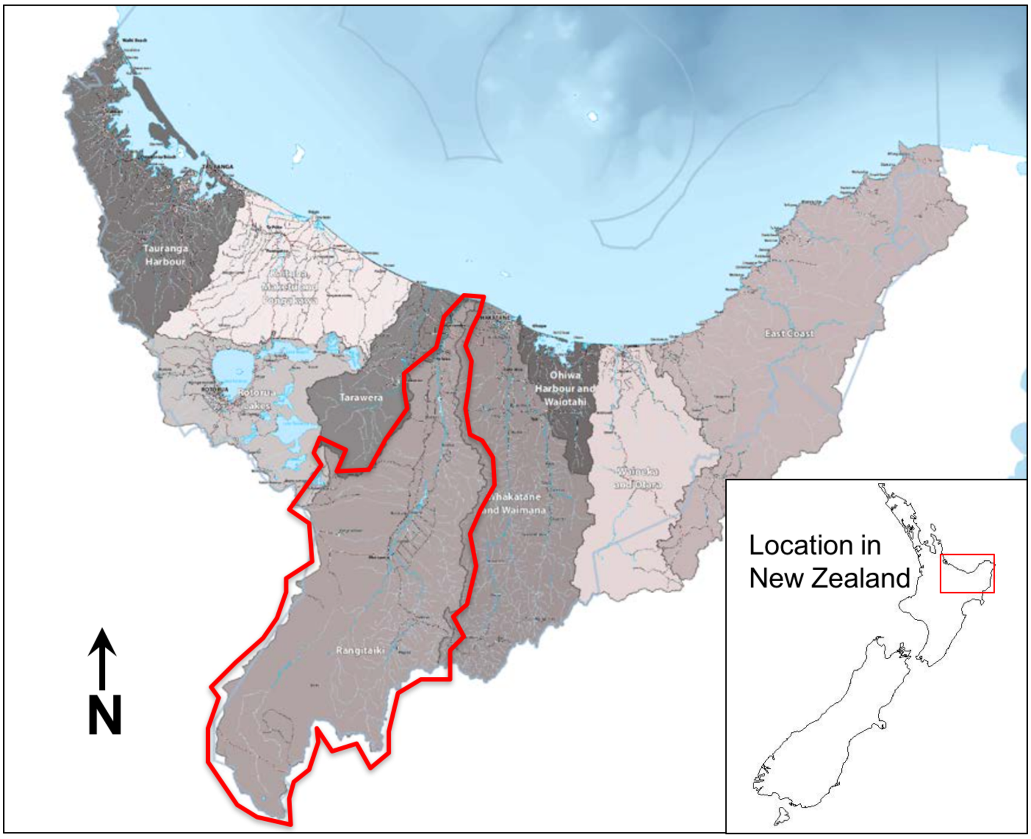
The projects

Project I: Rangitāiki catchment, Bay of Plenty

The first of the two projects were run in the Rangitāiki catchment in the Bay of Plenty Region of the North Island.

The Rangitāiki catchment is one of nine Water Management Areas (WMAs) that the Bay of Plenty Regional Council has divided its region into for the purposes of freshwater management. It is in the central Bay of Plenty, with the Rangitāiki river entering the Bay of Plenty to the west of Whakatāne. The major town within the catchment is Murupara, with a large farming community also at Galatea. A map of the Bay of Plenty WMAs, with the Rangitāiki catchment highlighted, is provided in Appendix Figure 21.

Appendix Figure 21. Indicative map of Bay of Plenty Water Management Areas with Rangitāiki catchment highlighted.



This map is adapted from one provided in the BOPRC technical document Rangitāiki Water Management Area: Current State and Gap Analysis (Bay of Plenty Regional Council, 2016)

The BOPRC were keen to be involved in the research, as in previous years they had sought to explore how CLDs might be incorporated into their freshwater-management work. Further, when contacted by the researcher, they had not long started a process that was to develop values, objectives and limits for freshwater in the Rangitāiki catchment in response to the *National Policy Statement for Freshwater Management 2014* (*NPS-FM 2014*) (Ministry for the Environment, 2014).

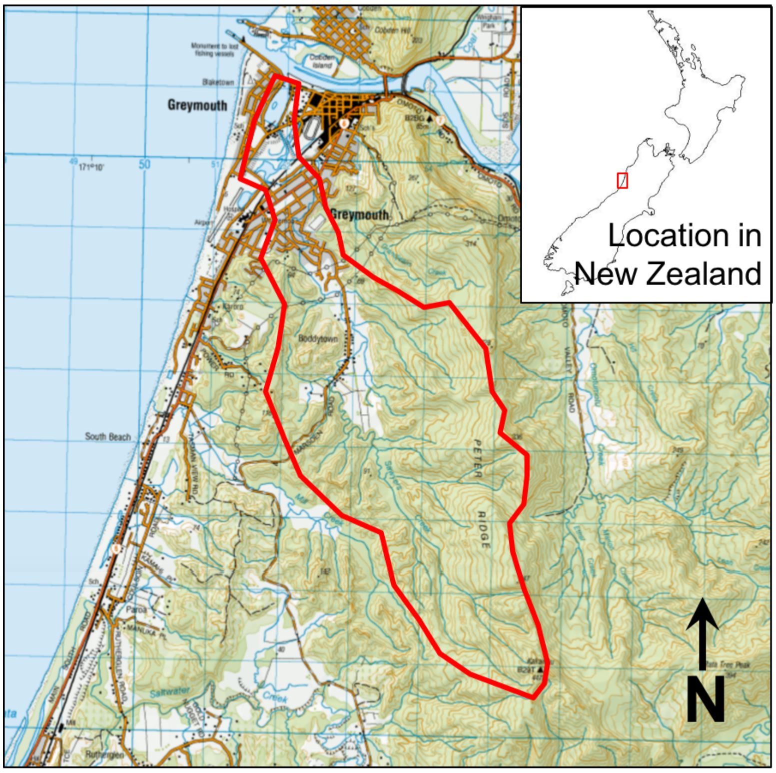
BOPRC agreed to work with the researcher to run a series of workshops. It was stressed to participants that these workshops were ***experimental*** and would be run ***in parallel*** to the ongoing *NPS-FM 2014* process not ***as a part of it***.

Project II: Sawyers Creek catchment, West Coast

The second of the two projects were run in the Sawyers Creek catchment in the West Coast Region of the South Island.

Sawyers Creek is a small stream that passes though the southern urban areas of Boddytown and Greymouth before joining the Grey River a few hundred metres before is discharges into the Tasman Sea. The headwaters of Sawyers Creek are characterised by steep hill country covered in indigenous forest. Dry stock farming and plantation forestry occurs in the middle of the catchment, giving way to urban residential land use towards the bottom of the catchment (Appendix Figure 22).

Appendix Figure 22. Indicative map of Sawyers Creek catchment



The approximate area of the Sawyers Creek catchment is shown on the above topographical from https://www.topomap.co.nz. Accessed on 29 May 2017.

The West Coast Regional Council (WCRC) were keen use the research process to help understand the issue of *E. coli* contamination in Sawyers Creek. As the *E. coli* levels in that creek fail the National Bottom Lines for *E. coli* outlined in the *National Policy Statement for Freshwater Management 2014* (*NPS-FM 2014*) (Ministry for the Environment, 2014), action will be required to address this in the future, and this research was a useful first step to help with understanding the problem. This was a good example of the applied use of the workshop approach. The council were at the early stages of investigating the *E. coli* issue in this catchment and there was not yet any existing strategy or programme of work developed to address it. This provided an excellent opportunity to apply the GMB approach.

The workshop groups

The previous section provided an overview of the two projects in the research. This section provides an overview of the two groups involved in the workshops.

Purposive sampling was used, which is non-randomised sampling that seeks to directly sample participants based on their relevance to the research question or objectives (Bryman & Bell, 2015). This is discussed in (appendix cross reference).

Group representation: Project I –Rangitāiki River

To help develop and implement the values, objectives and limits for the *NPS-FM 2014* in the Rangitāiki catchment, the BOPRC established Rangitāiki Freshwater Futures Community Group in November 2015. This group was made up of 27 members of the local community and was intended to help council with recommendations to develop and implement the *NPS-FM 2014*.

The full group was too large a sample of participants for the researcher to run the deliberative-conference with. Therefore, a brief explanation of the research and several possible dates were provided to all group members, and any that were interested were invited to indicate: a) their interest, and b) what date they would be able to attend the first workshop. BOPRC managed the invitations that were sent to all attendees, coordinated the responses and chose a date where a good cross section of people from the group could attend. They organised all logistics (e.g. coordinating responses, booking venues and catering, organising support staff).

During planning for the workshop, it was obvious that they took care to ensure that they chose a date that ensured attendance from people that were representative of the cross-section of broader views and values within the stakeholder group. This is considered consistent with the principles of purposive sampling and therefore is not considered to be a key risk to the research, in terms of increasing bias.

A total of 10 people attended the workshop; four women and 6 men. They represented a broad cross-section of the people involved in the wider group and included people who provided the following perspectives: dairy farmers, orchardists, local iwi, conservationists, iwi landowners (commercial) and commercial power generation. Estimates for the number of people that can be involved in a GMB process range from 5-25 (van den Belt, 2004; Vennix, 1996), indicating that 10 is an appropriate and intermediate amount.

Group representation: Project II –Sawyers Creek

To help explore the issue of *E. coli* contamination in waterways, WCRC gathered a collection of representative stakeholders together for the workshop. No existing group had yet been formed and so WCRC staff identified stakeholders of interest who they believed would better help them understand the problem, and whose support may be required to implement any solution identified. This approach is seen to be consistent with purposive sampling (Bryman & Bell, 2015). Again, the council took responsibility for identifying and coordinating all stakeholders, although the profile of participants was discussed with the researcher to establish its suitability.

A total of six participants attended the first workshop. This group was made up of two regional-council staff members, one district-council staff member, one district councillor, one district health-board staff member, and a resident from the catchment who was also a part-time farm manager for small landholdings in the catchment. While this number is around the minimum suggested for a GMB process (van den Belt, 2004; Vennix, 1996), comments analysed in the thematic analysis (Section 10.3) indicated that while greater representation could have been beneficial; overall, there seemed to be adequate representation in the group and it generally worked well.

Scheduling of workshops

Having outlined each case study and the representation in the groups, this section outlines the similarities and differences evident in the scheduling of the workshops in the two projects.

While a consistent GMB method was applied, some disparity between the case studies is evident because the summer holidays occurred between the first and second workshop of the Rangitāiki case study, the researcher was less aware of the time required to analyse the CLD in between the workshops and it was a slightly larger group to coordinate and therefore finding a suitable date for the second workshop took a little longer.

Scheduling: Project I – Rangitāiki River

The first workshop was held on 15 December 2016 and the second was held on 23 February 2017. Both were approximately five hours long. The 2-month gap between workshops was primarily due to the first workshop occurring before the main summer holiday period (Christmas), which meant that it was difficult getting all people back together again until February.

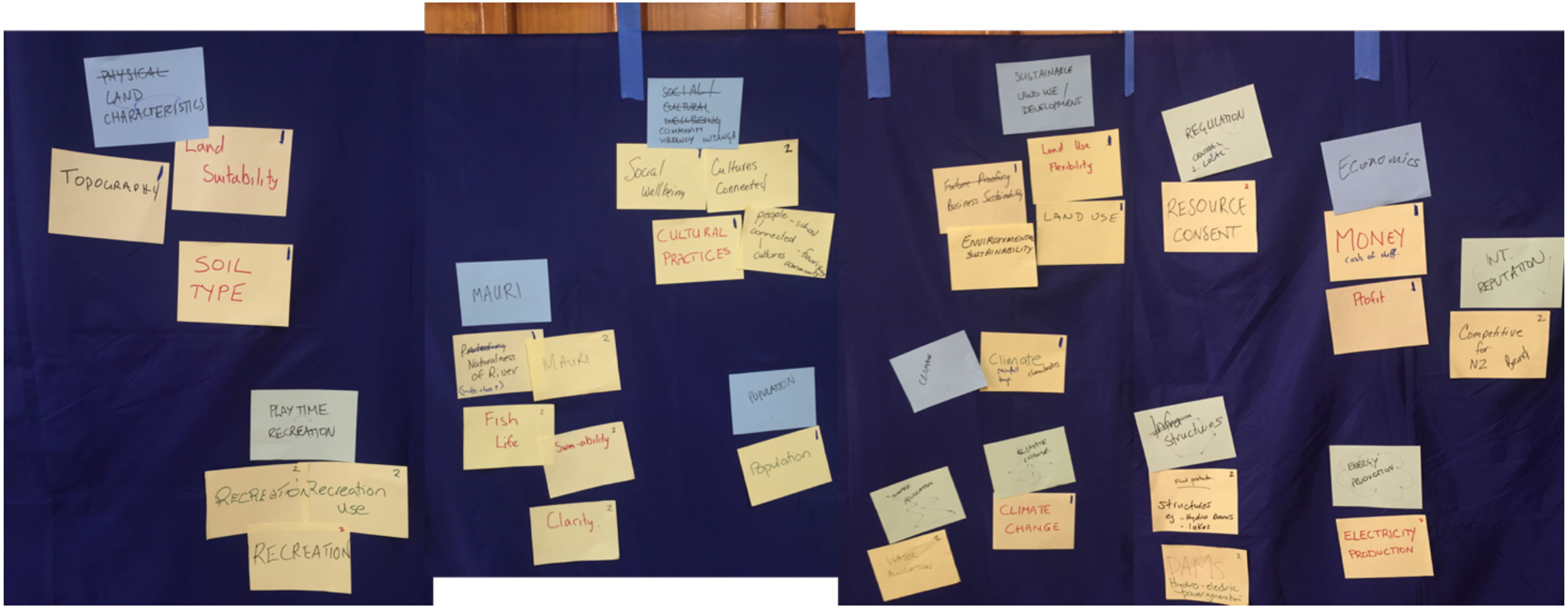
Scheduling: Project II – Sawyers Creek

The first workshop for Sawyers Creek was held on 09 March 2017 and the second was on 23 March 2017. Both were approximately 5 hours long.

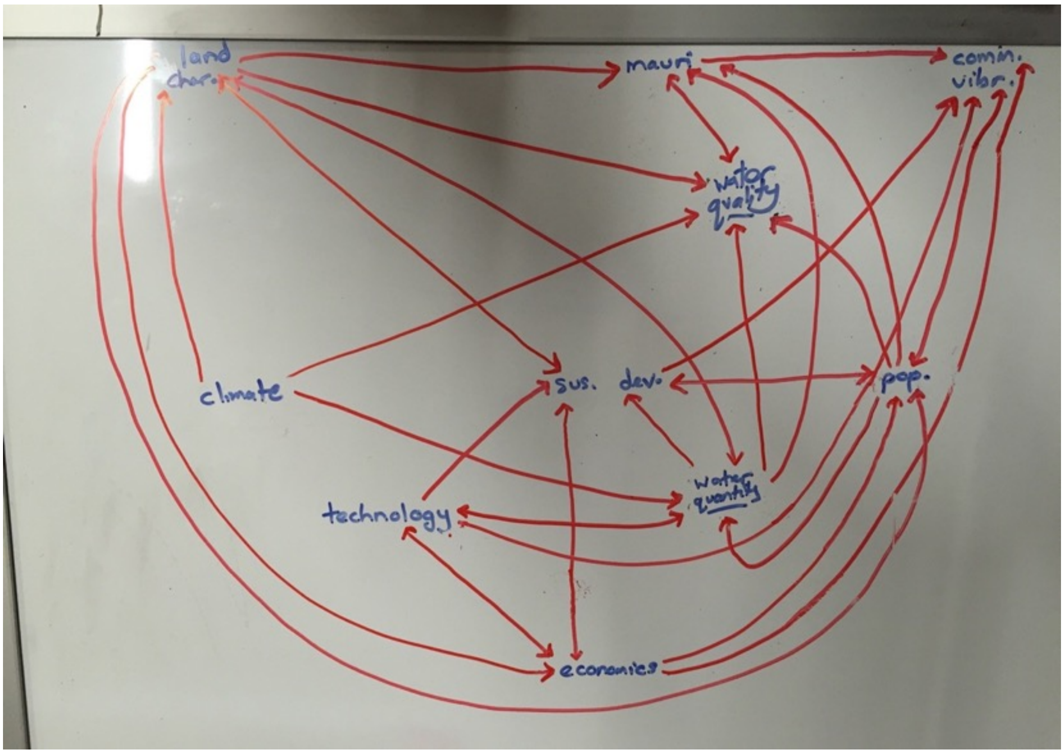
There was only a two-week gap between workshops because they were both scheduled at the same time. This was because the researcher had a better idea of the time required to analyse the CLD between workshops. The smaller group was also easier to organise.

Appendix 14 Rangitāiki River workshop 1: Photographs

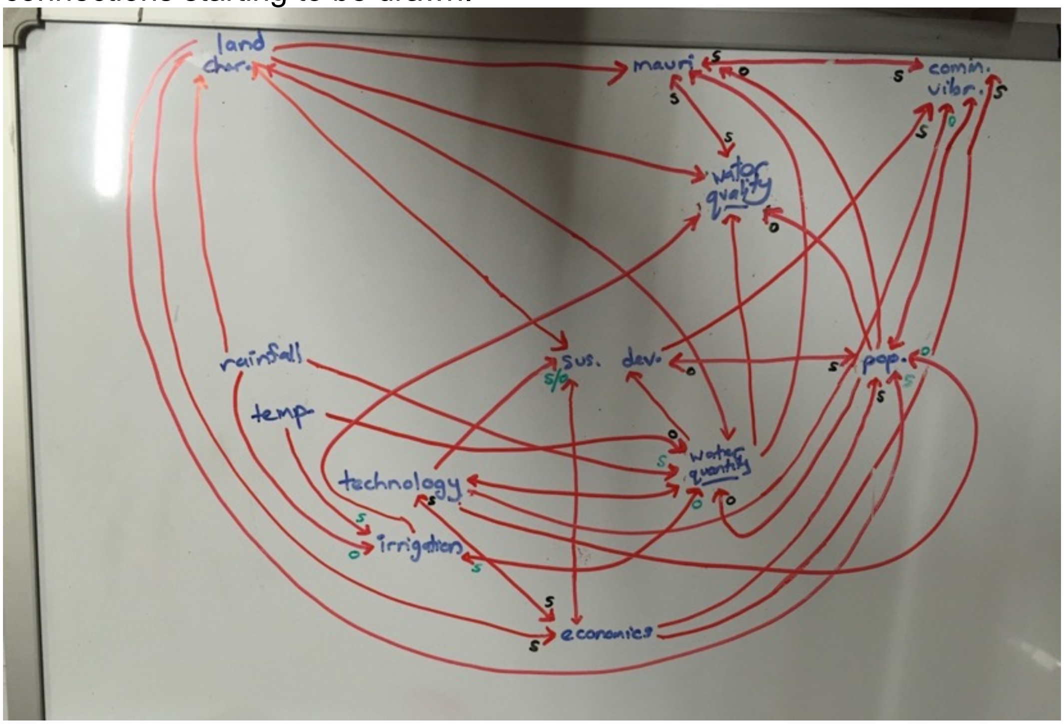
Appendix Figure 23. **Photo 1 (collage): All factors on the sticky wall after two rounds of the group identifying factors, sorting and labelling them.**



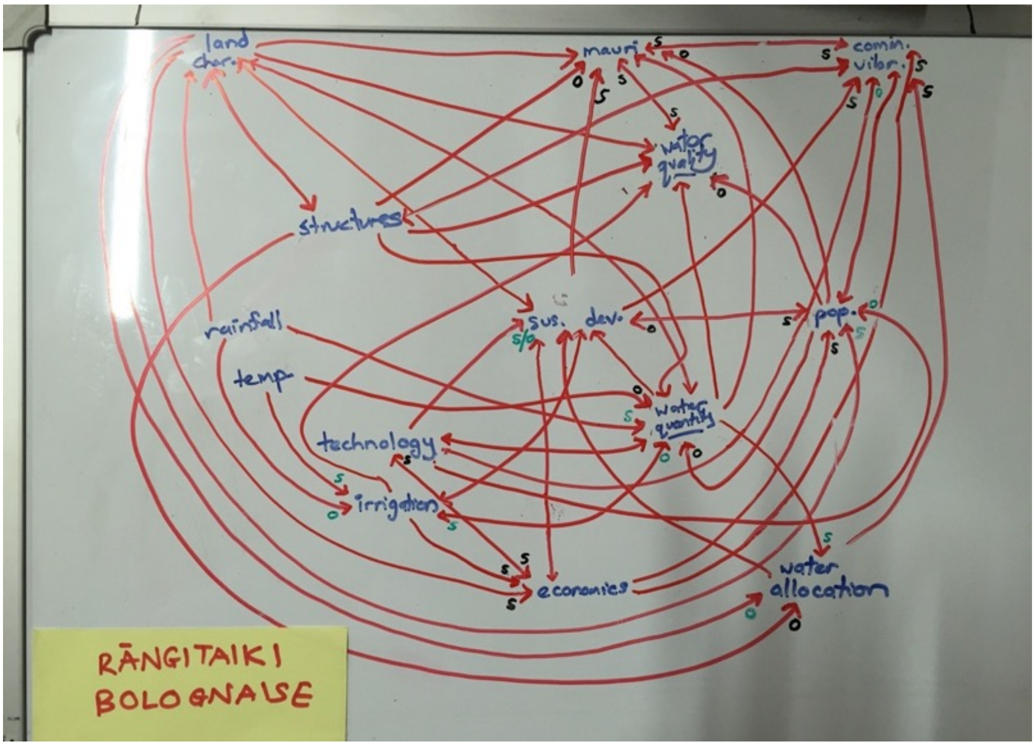
Appendix Figure 24. **Photos 2-4: Photos showing the development of the CLD by the Rangitāiki group.**



A photograph from early in the conference showing some of the connections starting to be drawn.



A photograph mid-way through the conference, some complexity developing.

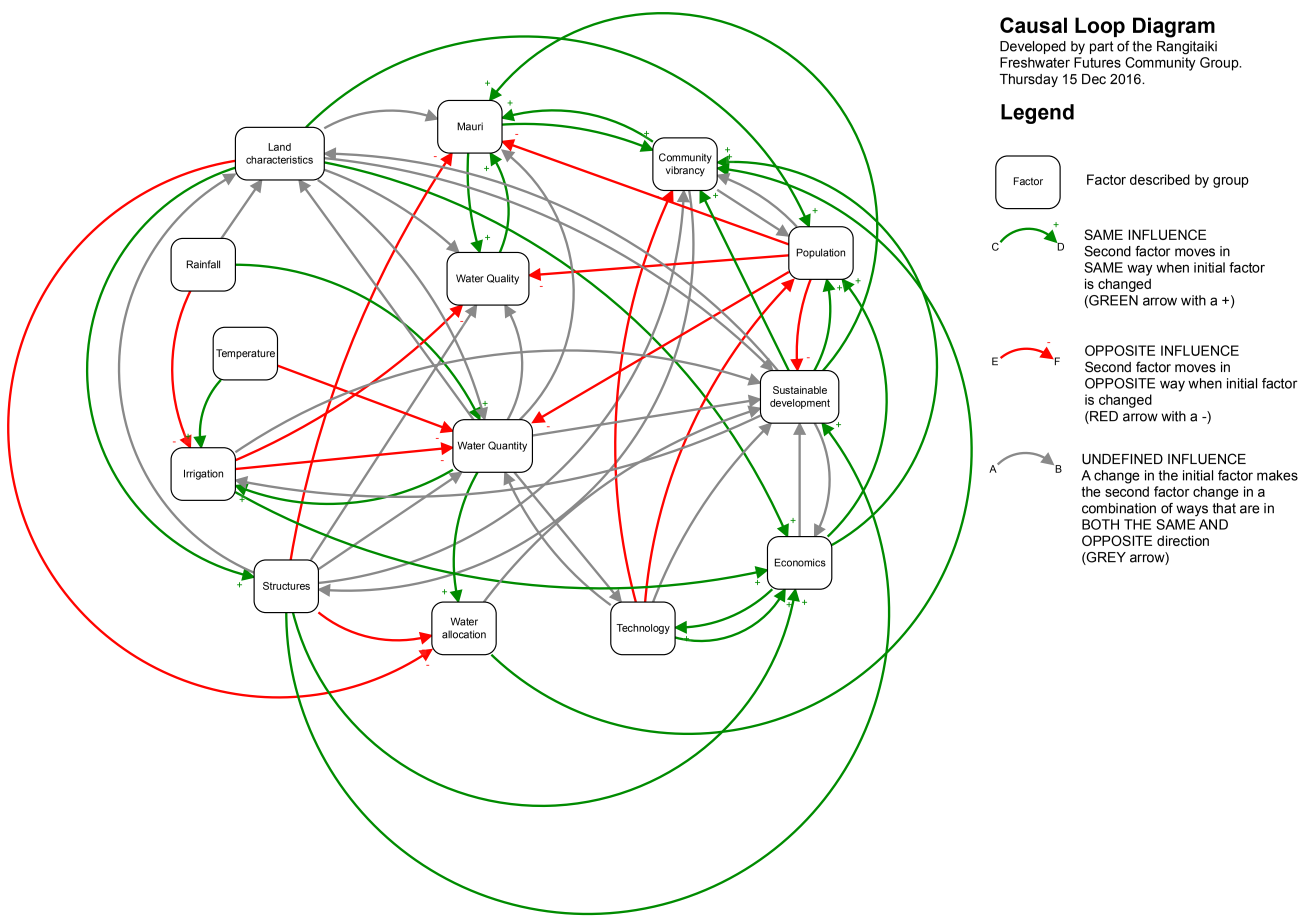


The final result, labelled ‘Rangitāiki bolognaise’ to reflect the complexity discussed.

Appendix 15 Rangitāiki River CLD

This appendix includes the draft version of the CLD after the first workshop and the final version of the CLD after the second workshop.

Appendix Figure 25. Rangitāiki catchment – Draft CLD after first workshop[23]

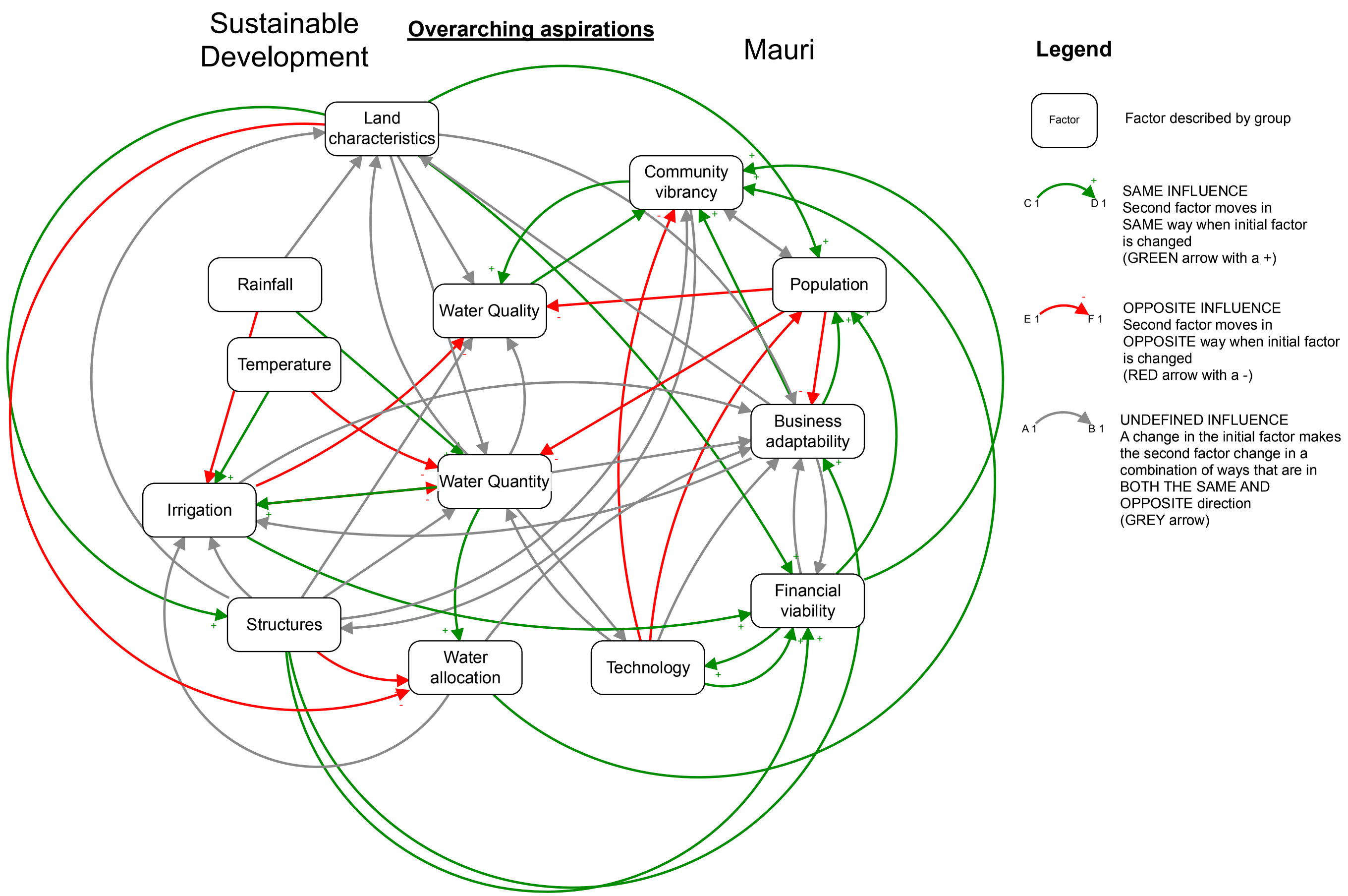


In this diagram, the 12 factors identified by the group are shown with the two factors of water quality and water quantity (both were part of the focus question for this case study) in the middle of the diagram.

*The influences described by the group have been drawn. Those in green are **Same (positive)**, those in red are **Opposite (negative)**, while those in grey are undefined, as they are likely to be a combination of both.*

23 This diagram has been drawn using STELLA Software. STELLA Software is specialised SD modelling software from ISEE Systems Inc. (www.iseesystems.com). Other types of software exist including brands like Vensim (www.vensim.com) and Insight Maker (www.insightmaker.com).

Appendix Figure 26. Rangitāiki catchment – Final CLD after second workshop



Appendix 16 Rangitāiki River variables and influences in the CLD

Appendix Table 5. Final list of variables elicited in the Rangitāiki GMB process.

Final list of variables and their descriptions included in the CLD for the Rangitāiki River.

Variable	Description
Mauri (overarching variable)	Mauri was the term used to describe the 'naturalness' of the river. It is a Maori term used broadly to describe the 'life force' of the river, which is diminished when the river is modified and its 'naturalness' is diminished. Every living thing is considered to have a 'Mauri', or a spiritual life force. Broadly, this was a factor that included the natural characteristics of the water, including things like swimmability, the quantity and quality of fish life, clarity of the water, etc. The general concept of 'Mauri' was also discussed at length and it was agreed that this best encompassed the elements that the group thought this represented. Mauri as a cultural concept related to The point was made that it might be impossible to recover the original level of Mauri in the river (or all living things) due to human modification. However, it was acknowledged that some progress has been made and parts of the system can be made to return to a higher level of Mauri. *This factor was the subject of sustained discussion and much is considered to be involved in this high-level factor.*
Sustainable Development (overarching variable)	Sustainable development was a term used by the group to describe the generally agreed concept of development that maximised an increase in wellbeing across four broad areas – social, cultural, environmental and economic wellbeing. Recording impacts or reporting progress according to these areas of wellbeing is usually referred to as 'quadruple bottom line reporting'. *This factor was the subject of sustained discussion and much is considered to be involved in this high-level factor.*

Variable	Description
Water Quality	A high-level acknowledgement of the **quality of the water** within the Rangitāiki WMA. *This factor was assumed as part of the CLD given that it is a primary part of the research and was not generated by the group.*
Water Quantity	A high-level acknowledgement of the **quantity of water** within the Rangitāiki WMA. *This factor was assumed as part of the CLD given that it is a primary part of the research and was not generated by the group.*
Community Vibrancy	This factor describes and captures the social components of the wider community in relation to the system and evolved from a discussion around social wellbeing and cultural practices. The broad connection here were 'people' and their wellbeing. This is a very broad factor that incorporates many considerations. After some initial discussion about whether 'cultural' and 'social' needed to be kept separate, they were all included in this factor to reflect the connectedness and overlap of these elements within the wider community. *This factor was the subject of sustained discussion and much is considered to be involved in this high-level factor.*
Financial viability	This factor was based on a grouping of the suggested areas of *money* and *profit*. This indicates a specific focus on financial costs and benefits and was labelled economics in the first workshop, but changed to *financial viability* in the second to reflect this narrower focus. This term was applicable to individuals and households, not just businesses.

Variable	Description
Irrigation	The act of abstracting water from a natural source or storage and applying it to productive farmland and horticulture. *This factor was added to the CLD during discussion to identify all the links between factors and was not one of the originally identified factors.*
Land Characteristics	This factor described the features of the land that the area is naturally endowed with. This involved a discussion of things like topography, soils and the suitability of the soils for varying activity. This was separate to the characteristics of climate which were discussed and categorised as a separate factor. It is acknowledged that there are many land characteristics that are included within this factor. Depending on the influence being described, different characteristics are considered from this factor. Often, when considering influences relating to, for example 'structures' or 'economics', it is the *suitability* of the land characteristics being considered that are considered to increase or decrease. In original discussions 'land use' formed part of this definition but was later separated out as 'human use' of land and included in a separate factor, as distinct from the physical characteristics of the land itself.
Population	The population factor is a distinct and clear representation of the *number* of people in the area represented by the system. Any description of the qualitative aspect of the people involved is represented by the broad category of **Community Vibrancy**.
Rainfall	Rainfall relates to the pattern of rainfall in the area. This was originally part of an earlier factor called *climate* that was separated into two parts (with *temperature*), as these two parts were considered distinct factors in themselves. However, it is noted that their joint influence will have an impact on other factors - i.e. a hot, dry summer is different to a hot, wet summer.

Variable	Description
Structures	Structures is a factor that describes all *river related* infrastructure in the WMA. This takes many forms and covers many uses. For example, dams are a major feature in the WMA and may be used to generate electricity and store water for other uses. There is also a large network of flood-protection structures that feature in the WMA, such as stopbanks. During discussion, this factor included an element of the 'appropriateness' of structures as well as the number. This is a concept that is difficult to describe in detail, as it will depend on what it is being considered as a counter factual. Broadly, the number of structures can be considered to increase or decrease; however, it remains unclear if further discussion would be useful to determine if the increase in structures should be considered from the perspective of the associated level of water retention/take that goes with it.
Business adaptability	Originally labelled sustainable development, *business adaptability* was a term used to capture a wide range of elements that originated from elements of *land use*, *land use flexibility* and *business sustainability* that were suggested by members of the group. The original discussion relating to this factor centred around the resilience of businesses, their ability to be adaptable and flexible in response to drivers in the business environment. The group described this as the cultural drivers underpinning business practices in the area. An original title that was suggested here was *sustainable land use*. This factor seemed to evolve during the day. As discussion progressed, this factor seemed to be considered more and more from the classical interpretation of sustainable development - e.g. a quadruple bottom-line perspective. Because of this, the title was revised in the second workshop. *This factor was the subject of sustained discussion and much is involved in this high-level factor. While re-labelled in the second workshop, the various influences were not and should be reconsidered at some point.*

Variable	Description
Technology	This factor describes advances and/or changes in physical and economic technology. Physical technology is mechanical advances, automation etc. This may include elements of water related technology or not - for example, it might refer to the automation of a milking practice on a dairy farm, or the development of more water efficient irrigation technology for a land use. Economic technology could be described as how people are engaged for work (e.g. wages vs contracting). Although quite different things were both described as technological factors by the group. *This factor was added to the CLD during discussion to identify all the links between factors and was not one of the originally identified factors.*
Temperature	Temperature relates to the patterns of temperature in the area. This was originally part of an earlier factor called *climate* that was separated into two parts (with *rainfall*), as these two parts were considered distinct factors in themselves. However, it is noted that their joint influence will have an impact on other factors - i.e. a hot, dry summer is different to a hot, wet summer.
Water Allocation	The act of determining access to, and the distribution of, water amongst users in the WMA. This covers all uses, including agriculture, industry, and municipal demand.

Appendix Table 6. Final list of influences elicited in the Rangitāiki GMB process.

Final list of influences and their descriptions included in the CLD for the Rangitāiki River.

No.	From variable	To variable	Status	Description
1	**Land Characteristics**	**Business Adaptability**	Undefined (?)	**Land characteristics** can influence **Business Adaptability**. The land characteristics will in part determine how sustainable any development of the land might be, or how adaptable various uses of the land might be. This is because the land use will respond to the types of land available. It was noted that much of the land soil type was ash as a result of the Tarawera eruption.
2	**Business Adaptability**	**Land Characteristics**	Undefined (?)	**Business Adaptability** can influence **Land characteristics**. As one of the main components of sustainable development was land use, this describes how the use of land may impact on the characteristics of the land. For example, in the development of residential housing land contours may be reshaped, therefore influencing the characteristics of the land. Similarly flood protection of pastoral land might reform the shape of land with regards to development of stopbanks and removal of shingle from riverbeds etc.
3	**Financial Viability**	**Business Adaptability**	Undefined (?)	**Financial Viability** can influence **Business Adaptability**. This describes the influence that profitability has on the various uses of land. The group described that generally only profitable uses of land would drive a change in the use of land.
4	**Business Adaptability**	**Financial Viability**	Undefined (?)	**Business Adaptability** can influence **Financial Viability**. The type of land use that is pursued in the WMA will impact on the amount of money that is made by businesses in the catchment.

No.	From variable	To variable	Status	Description
5	**Land Characteristics**	**Financial Viability**	Same (+ve)	**Land characteristics** can influence **Financial Viability**. As described the more suitable the characteristics of the land for productive use will increase the potential for money to be made from that land. Therefore, this has been described as a *same (positive)* relationship.
6	**Land Characteristics**	**Water Quality**	Undefined (?)	**Land characteristics** can influence **Water quality**. Land characteristics (topography and soil type etc.) make land more prone to erosion in some places, which would affect water quality by increasing the amount of sediment in the streams/river.
7	**Land Characteristics**	**Water Quantity**	Undefined (?)	**Land characteristics** can influence **Water quantity**. The group described how they had already learned that there were a range of different aquifers and groundwater that were a natural feature of the land characteristics. Therefore, land characteristics (including subsurface geology) would influence water quantity.
8	**Water Quantity**	**Land Characteristics**	Undefined (?)	**Water quantity** can influence **Land characteristics**. The amount of water in the catchment will impact on the land characteristics as this might influence the shape of the land through erosion. While the focus of discussions around water quantity related to both surface and groundwater, the surface water could include overland flow before it reaches a stream or river.
9	**Water Quantity**	**Business Adaptability**	Undefined (?)	**Water quantity** can influence **Business Adaptability**. The amount of water in the catchment will have an influence on the way the land may be used, the focus of the factor 'sustainable development' was originally the adaptability and flexibility of land use and how business can adapt and respond to changes.

No.	From variable	To variable	Status	Description
10	**Rainfall**	**Water Quantity**	Same (+ve)	**Rainfall** can influence **Water Quantity**. The more water there is in terms of rainfall the greater the level of water available in the catchment.
11	**Temperature**	**Water Quantity**	Opposite (-ve)	**Temperature** can influence **Water quantity**. A higher temperature the lead to an evaporation effect, therefore leading to less water in the catchment. Higher temperatures would also lead to increase demand from human and animal consumption.
12	**Land Characteristics**	**Population**	Same (+ve)	**Land characteristics** can influence **Population**. The desirability of the land by people for recreation will impact on the number of people that live in the catchment. This is also considered to include the amenity value that residents get from living in an attractive area.
13	**Business Adaptability**	**Population**	Same (+ve)	**Business Adaptability** can influence **Population**. Described as the relationship between business drivers and types of business operations and the number of people that live in the catchment. This recognises a relationship between the number of jobs and the availability of labour.
14	**Financial Viability**	**Population**	Same (+ve)	**Financial Viability** can influence **Population**. The greater the financial benefit from work for people living in the catchment, the greater the number of people that are likely to live there.
15	**Population**	**Community Vibrancy**	Undefined (?)	**Population** can influence **Community vibrancy**. The level of the population will impact on the community vibrancy, although they are not necessarily volumetrically related. That is, a larger population does not necessarily result in a more vibrant community, and a small community might be a very vibrant one.

No.	From variable	To variable	Status	Description
16	**Community Vibrancy**	**Population**	Undefined (?)	**Community vibrancy** can influence **Population**. The vibrancy of a community is likely to impact on the level of the population, although this again is not necessarily likely to be linear.
17	**Technology**	**Population**	Opposite (-ve)	**Technology** can influence **population.** Increases in-production technology would generally mean less people involved with work and so therefore would have an opposite effect on the number of people in the catchment. Technology may also influence via the ability of people to work remotely, therefore potentially increasing the number of people.
18	**Technology**	**Community Vibrancy**	Opposite (-ve)	**Technology** can influence **community vibrancy** through increases in production technology that generally mean less people involved with work. This would generally have an opposite effect on the vibrancy of the community in the catchment by reducing the opportunity for jobs. Conversely, community vibrancy might be increased by a higher need for skilled employees to help operate or develop technological solutions for productive land use. It was also noted that there were other industries and could contribute via these connections that were not only farming and horticulture. These many influences indicate the number of elements included in 'community vibrancy'. ** There was some debate as to whether this link was direct or via the factor of business drivers and 'sustainable development'*

No.	From variable	To variable	Status	Description
19	**Technology**	**Business Adaptability**	Undefined (?)	**Technology** can influence **Business Adaptability**. Changes in technology will have an impact on the type of land use that is utilised in the catchment and the types of businesses that occur. This also includes advances in innovation that are related to both production and environmental technology. This may be both a same and opposite influence, and so therefore is overall determined as undefined. For example, increased production technology such as improved machinery or improved contracting practices may increase sustainable development. While increased environmental innovation such as genetically modified organisms may decrease sustainable development.
20	**Technology**	**Financial Viability**	Same (+ve)	**Technology** can influence **Financial Viability**. The higher the level of technology the greater profitability for business tends to be.
21	**Financial Viability**	**Technology**	Same (+ve)	**Financial Viability** can influence **Technology**. Higher levels of profitability are likely to mean a greater amount of money to invest in technology or innovation. Therefore, this is described as a Same (+ve) influence.
22	**Technology**	**Water Quantity**	Undefined (?)	**Technology** can influence **Water Quantity** Improved water efficiency technology may increase the amount of water available in the catchment. It may also increase demand for water and so therefore not create any more available water. Therefore, this influence was described as undefined.

No.	From variable	To variable	Status	Description
23	**Water Quantity**	**Technology**	Undefined (?)	**Water quantity** can influence **Technology.** The amount of water available may impact on the demand for water efficient technologies - the more water there is the less the demand and incentive to invest in water efficient technologies. It is acknowledged that this focuses on a component of the technology factor and that some influences may operate the opposite way.
24	**Water Quality**	**Community Vibrancy**	Same (+ve)	**Water Quality** can influence **Community vibrancy**. The higher the level of water quality the better the quality of life in relation to water activities (e.g. recreation, drinking etc.), therefore the higher the community vibrancy.
25	**Population**	**Business Adaptability**	Opposite (-ve)	**Population** can influence **Business Adaptability**. The higher the number of people then the greater the pressure on businesses ability to be sustainable.
26	**Population**	**Water Quantity**	Opposite (-ve)	**Population** can influence **Water quantity**. The greater the number of people in the catchment then the greater demand on water resources for consumption. Therefore, the less water there will be available.
27	**Population**	**Water Quality**	Opposite (-ve)	**Population** can influence **Water quality**. The greater the number of people in the catchment then the greater impact on water quality through pollution.
28	**Irrigation**	**Water Quality**	Opposite (-ve)	**Irrigation** can influence **Water Quality** by dispersing nutrients over the land being irrigated. Adding water also has the effect of leaching nutrients and contaminants from the soil.

No.	From variable	To variable	Status	Description
29	**Temperature**	**Irrigation**	Same (+ve)	**Temperature** can influence **Irrigation** as the higher the temperature the greater the chance of water evaporation from soils, and therefore the need for irrigation. ** It was acknowledged that temperature was only one of the climatic factors influencing irrigation. While represented separately the combined impact of rainfall and temperature will have different effects on irrigation. For example, high temperatures can be had with high levels of moisture/rainfall (e.g. a hot and humid summer), and would not result in increased irrigation.*
30	**Rainfall**	**Irrigation**	Opposite (-ve)	**Rainfall** can influence **Irrigation** as the higher the level of rainfall the lower the need for irrigation. ** It was acknowledged that rainfall was only one of the climatic factors influencing irrigation. While represented separately the combined impact of rainfall and temperature will have different effects on irrigation. For example, high temperatures can be had with high levels of moisture/rainfall (e.g. a hot and humid summer), and would not result in increased irrigation.*
31	**Irrigation**	**Water Quantity**	Opposite (-ve)	**Irrigation** can influence **Water Quantity** by reducing the amount of water in the catchment. It was acknowledged by the group that this was a high-level simplification and that water for irrigation might come from the river, groundwater and/or stored water. However, it was agreed that this high-level relationship was accurate.

No.	From variable	To variable	Status	Description
32	**Water Quantity**	**Irrigation**	Same (+ve)	**Water Quantity** can influence **Irrigation** as the greater the quantity of water available, the greater the potential quantity of water available for irrigation.
33	**Rainfall**	**Land Characteristics**	Undefined (?)	**Rainfall** can influence **Land Characteristics** through the act of erosion. This relationship was left as undefined as it was difficult to determine whether the desirability of the land was increased or decreased by the level of rain. * It could be argued that this relationship could be removed to simplify the CLD.
34	**Water Quantity**	**Water Quality**	Undefined (?)	**Water Quantity** can influence **Water Quality** in both same and opposite ways. While it is a broad statement to make it is often considered the more water there is, the better the quality it might be. This is often due to the dilution effect of water quantity and this would be a same (S) relationship. However, the opposite (O) relationship can also be true. For example, water held back in a lake or a dam could contribute to lower water quality levels as there could be an increase in algae activity in stratified layers within the water body.

No.	From variable	To variable	Status	Description
35	**Community Vibrancy**	**Water Quality**	Same (+ve)	**Community vibrancy** can influence **Water quality** as increased community vibrancy in relation to a community's attitude to how water is positively and proactively managed will ensure that water is cared for and considered an important resource.
36	**Irrigation**	**Financial Viability**	Same (+ve)	**Irrigation** can influence **Financial Viability** as the higher the amount of irrigation that is undertaken, broadly the higher the productivity and yield of the land. While irrigation certainly is likely to incur a greater cost on businesses, it is argued that it would not be undertaken if it was not profitable and therefore the influence is considered to be **Same (+ve)**.
37	**Business Adaptability**	**Community Vibrancy**	Same (+ve)	**Business Adaptability** can influence **Community vibrancy** as improved sustainable development will impact on a whole range of things that might be counted as community vibrancy.
38	**Financial Viability**	**Community Vibrancy**	Same (+ve)	**Financial Viability** can influence **community vibrancy** through the provision of jobs and financial improvements.
39	**Water Quantity**	**Land Characteristics**	Undefined (?)	**Water Quantity** can influence **Land Characteristics** in much the same way as rainfall in that a greater amount of water might result in erosion and a slowly more modified landscape.
40	**Water Quantity**	**Water Allocation**	Same (+ve)	**Water Quantity** can influence **Water allocation** as generally the more water there is, the more there is available to be allocated.

No.	From variable	To variable	Status	Description
41	**Land Characteristics**	**Water Allocation**	Opposite (-ve)	**Land Characteristics** can influence **Water allocation** as the quality of certain types of land characteristics will influence whether water is required to be allocated. In this case, the lower the quality of the lands ability to retain/hold water then the higher the need for allocation. It is noted that this is an example of the many elements involved in the Land Characteristics factor and they are not all necessarily quantitative - some are qualitative.
42	**Water Allocation**	**Business Adaptability**	Undefined (?)	**Water allocation** can influence **Business Adaptability** in both same and opposite directions. Water allocation is an enabling factor of development (it was noted that much water is currently allocated to industry in the catchment), while at the same time, the allocation of water may not be sustainable in the environmental sense of the word (taking from waterways).
43	**Business Adaptability**	**Irrigation**	Undefined (?)	**Business Adaptability** can influence **Irrigation** through sustainable development meaning that water is used in the most efficient and best practice way.
44	**Irrigation**	**Business Adaptability**	Undefined (?)	**Irrigation** can influence **Business Adaptability** by enabling appropriate and sustainable development to occur.

No.	From variable	To variable	Status	Description
45	**Water Allocation**	**Community Vibrancy**	Same (+ve)	**Water allocation** can influence **Community vibrancy** because without an appropriate level of water allocated for municipal use or human consumption, there would not be sufficient water to maintain vibrant communities. ** There is also an element of certainty of water supply for businesses that affects community vibrancy via the factors of: 'water allocation' => 'sustainable development' => 'population' => 'community vibrancy'.*
46	**Structures**	**Community Vibrancy**	Undefined (?)	**Structures** can influence **Community vibrancy** as some can ensure that the conditions for a vibrant community are provided and maintained. For example flood protection structures provide the ability for the communities to safely exist at lower total risk of flood danger. It is noted that flood protection structures can encourage the level of development behind them thus increasing the CONSEQUENCE of any flooding, but the flood protection structures themselves reduce the LIKLIHOOD of flooding - thus leading to a lower OVERALL RISK profile. From a recreational point of view they also provide conditions that allow communities to recreate on man-made lakes etc. Opposite influences can occur from stopbanks that may impact on the visual amenity of an area, so overall this relationship has been left as undefined.

No.	From variable	To variable	Status	Description
47	**Community Vibrancy**	**Structures**	Undefined (?)	**Community vibrancy** can influence **structures** because in order for a community to be viable it may have a greater desire to develop and maintain appropriate flood protection structures.
48	**Structures**	**Business Adaptability**	Same (+ve)	**Structures** can influence **Business Adaptability** as ensuring a range of *appropriate* structures means that the conditions to pursue more sustainable development exists. For example this may provide the ability to use the land in different ways that are appropriate for achieving sustainable outcomes. The point was made in the workshop that this is not necessarily a Same (+ve) relationship as from an ecological point of view structures are not very good - e.g. they impeded fish passage. However, when writing up the researcher considered this to be captured under the Opposite (-ve) influence between structures and Mauri, and is therefore left out of here. Therefore, this is left as a Same (+ve) relationship. ** This is an example of two factors that both have quite a lot included in them.*
49	**Structures**	**Financial Viability**	Same (+ve)	**Structures** can influence **Financial Viability** as the range of *appropriate* structures will ensure that appropriate conditions for profitable business are provided. During discussions, this generally related to structures that related to water take or use (i.e. those that enabled water take, retention or irrigation).

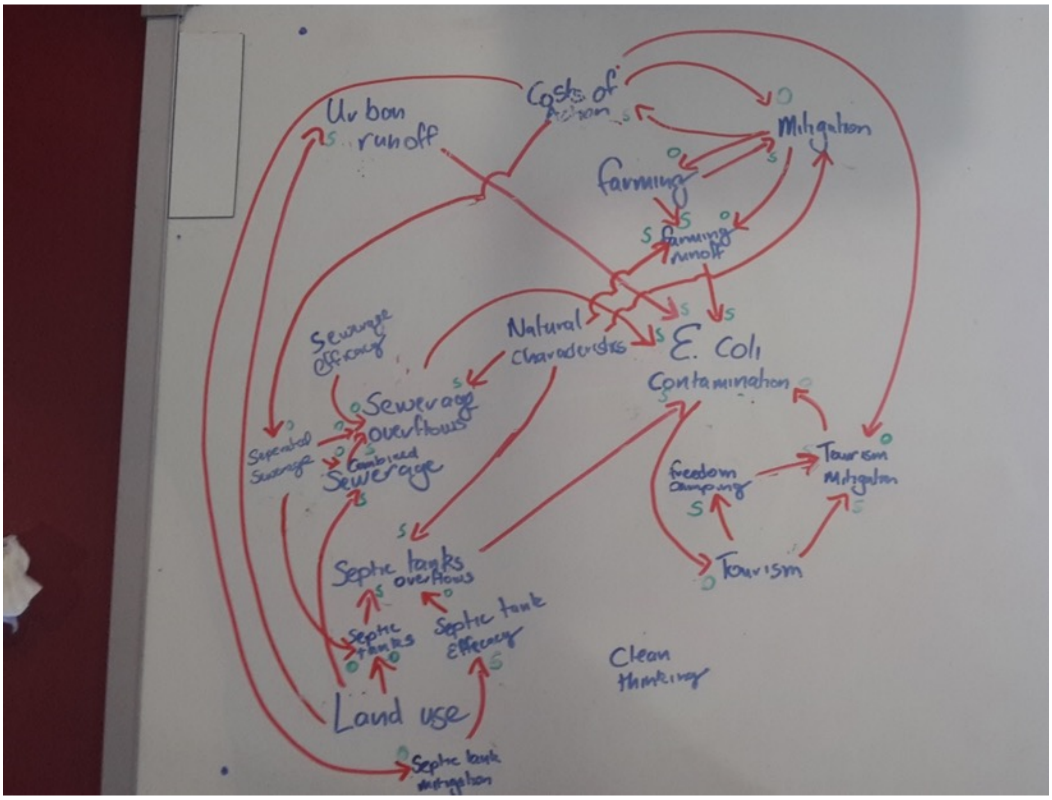
No.	From variable	To variable	Status	Description
50	**Land Characteristics**	**Structures**	Same (+ve)	**Land characteristics** can influence **Structures** as the area would need to be naturally gifted with land characteristics that enable certain structures. That is, the geography would need to lend itself to being able to provide dams and water storage. During discussions, this influence was generally taken to refer to structures that enabled water take, retention or irrigation.
51	**Structures**	**Land Characteristics**	Undefined (?)	**Structures** can influence **Land characteristics** as once a structure is in place this will impact on the flow of water and this will in turn have an impact on the land characteristics. For example, it may reduce deposition of sediment through reduced flooding, or impact on the water table through water storage, or increase erosion due to channeling of water and the development of artificial water channels. Given the variety of ways that structures may impact on land characteristics this influence has been left undefined.
52	**Structures**	**Water Allocation**	Opposite (-ve)	**Structures** can influence **Water allocation.** When discussed amongst the group it was considered that structures were or would only be built when there was confirmation of a right to access water - i.e. water allocation. Therefore, it holds that generally, the more structures that are built (already having been allocated water) then the less water allocation would then be left to distribute or allocate.

No.	From variable	To variable	Status	Description
53	**Structures**	**Water Quality**	Undefined (?)	**Structures** can influence **Water quality** by limiting the animal or human impact on a waterway. For example, culverts in streams over which stock can move, rather than having to walk directly through a stream. On the other hand larger structures in the main branch of the river retain water and therefore can impact negatively on water quality.
54	**Structures**	**Water Quantity**	Undefined (?)	**Structures** can influence **Water quantity** as the greater the number of structures then the greater the amount of water retained within these structures. However, structures may also impede the flow of water to other parts of the catchment (e.g. downstream of a dam or to areas that have been flood protected). Therefore, the group did not feel that this influence was strictly a Same (+ve) or Opposite (-ve) relationships and it has been left Undefined (?).

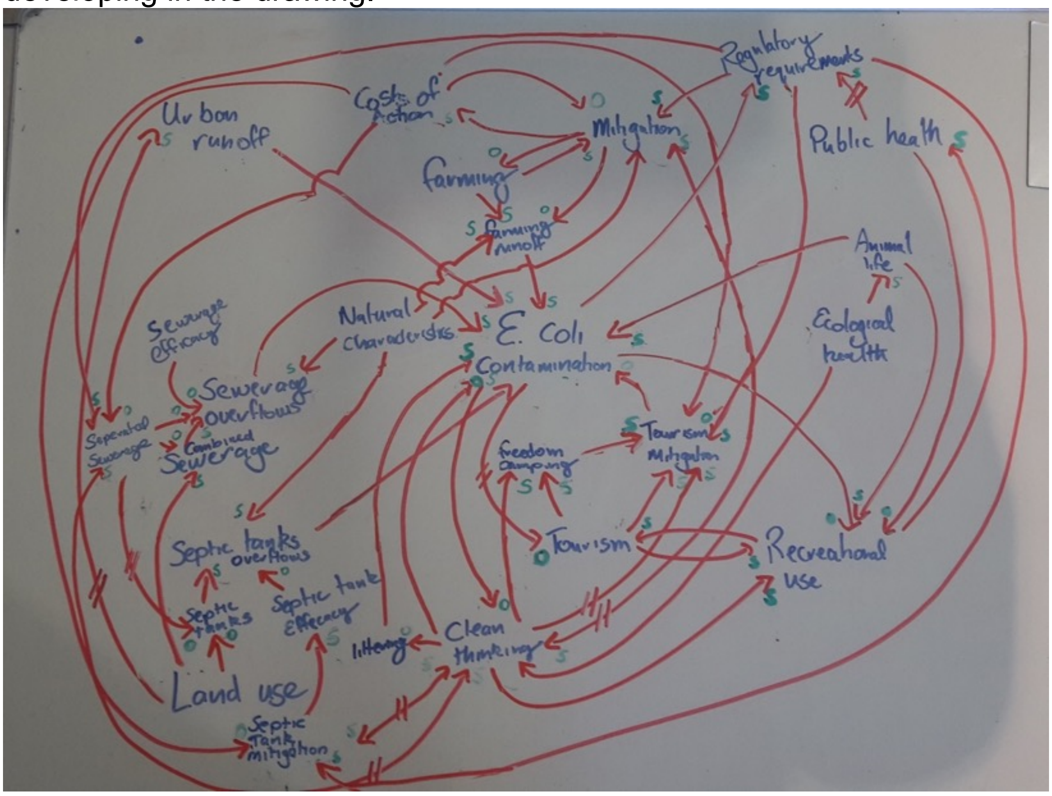
Appendix 17 Sawyers Creek Workshop 1: Photographs

Appendix Figure 27. **Photo 1 (collage): All factors on the sticky wall after two rounds of the group identifying factors, sorting and labelling them.**

Appendix Figure 28. **Photos 2-4: Photos showing the development of the CLD by the Sawyers Creek group.**



A photograph from mid-way through the conference showing complexity developing in the drawing.

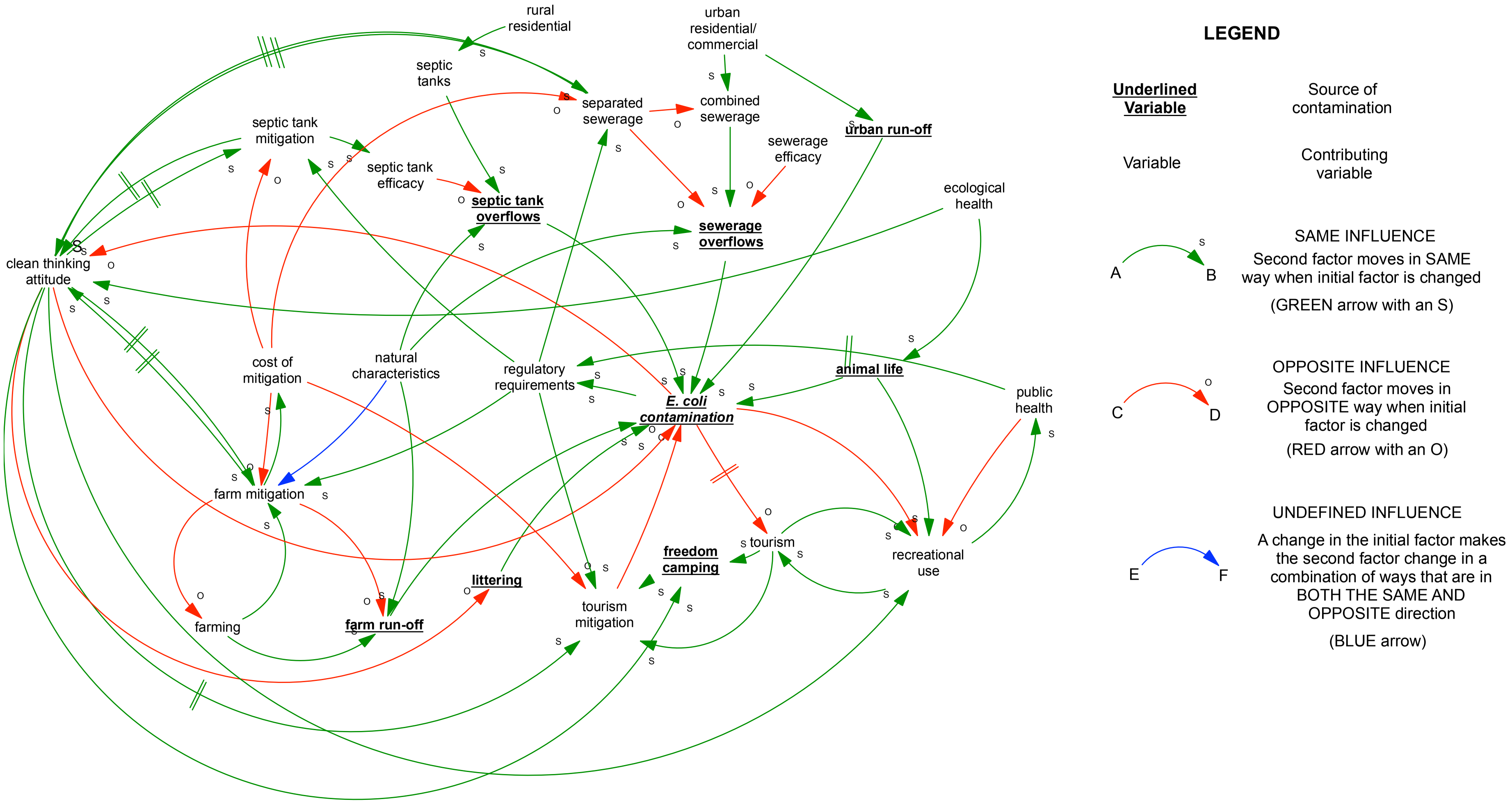


The final result demonstrating a high level of complexity.

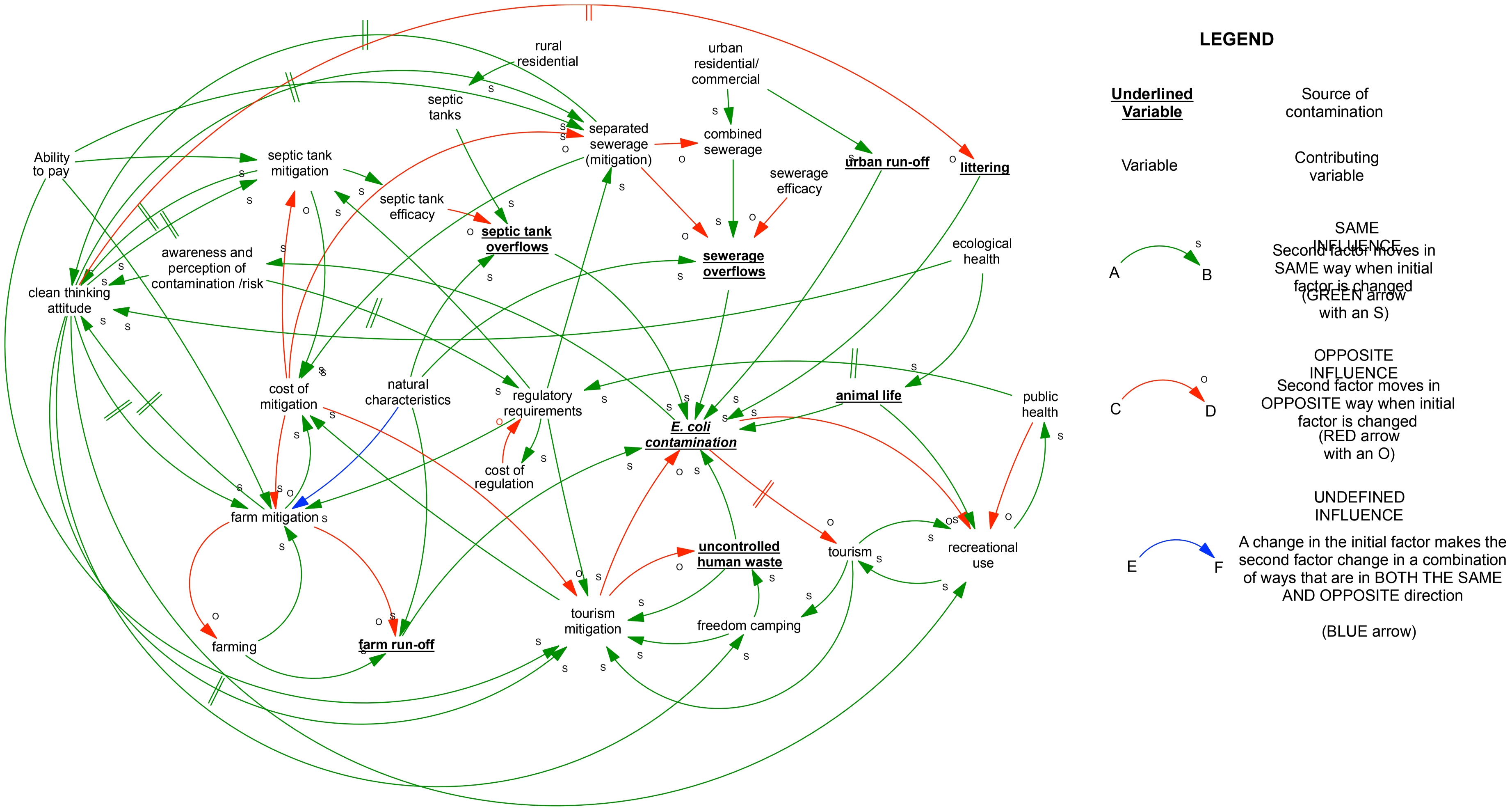
Appendix 18 Sawyers Creek CLD

This appendix includes the draft version of the CLD after the first workshop and the final version of the CLD after the second workshop.

Appendix Figure 29. Sawyers Creek catchment – Draft CLD after first workshop



Appendix Figure 30. Sawyers Creek catchment – Final CLD after second workshop



Appendix 19 Sawyers Creek catchment: variables and influences in the CLD

Appendix Table 7. Final list of variables elicited in the Sawyers Creek GMB process.

Final list of variables and their descriptions included in the CLD for Sawyers Creek.

Variables	Description
***E. coli* contamination**	This is the level of *E. coli* measured in Sawyers Creek at any one location. *E. coli* is an indicator of faecal contamination in freshwater. ** This factor was assumed as part of the CLD given that it was a primary part of the research and was not generated by the group.*
Urban residential/ commercial	This factor describes the more intensive use of land closer to town. This is characterised by higher levels of impermeable surface, more dense and intense residential and commercial use and importantly is generally characterised by connectivity to the town's main sewerage. This includes impact of the district planning land use zones of commercial, urban and residential land, as well as possible other types of zonation.
Combined sewerage	A sewerage network or system where both the stormwater and sewage from buildings are hooked up to **ONE** set of pipes to be carried away. This means that BOTH sewage and stormwater flow in the same pipe meaning flow in these pipes increases during rainfall events. As the number of buildings connected to these systems increases, their propensity to overflow during times of higher rainfall tends to increase.
Separated sewerage	A sewerage network or system where the stormwater and sewage from buildings are hooked up to **SEPARATE** sets of pipes. One pipe for stormwater and a separate one for sewage. As the capacity of these pipes should not be influenced by higher rainfall events, there should be no or minimal sewage overflow events from these systems.

Variables	Description
Sewerage efficacy	A measure of how well sewerage (both combined or separated) is deemed to be operating. If there are a high number of overflows from a combined system, the efficacy of that system will be deemed to be low. Likewise, if there is plenty of capacity in a separated system and no overflows, the efficacy of that system will be deemed to be high.
Sewerage overflows	The number and volume of overflows from combined sewerage systems. These tend to be a mixture of raw sewage and rainwater and generally occur in higher rainfall events.
Urban run-off	The run-off of stormwater from denser urban areas. These sources tend to be largely from impervious or semi-pervious surfaces given the nature of paving and roading in urban areas, and this excludes stormwater run-off connected to separated sewerage systems.
Rural residential	This factor describes the slightly less intensive use of land for residential purposes near to town. This is characterised by lifestyle type properties, which are generally characterised by a lack of connectivity to the town's main sewerage system and a reliance on their own septic tank systems. This is generally characterised by the district planning land use zone of rural-residential, as well as possibly others.
Septic tanks	An on-site wastewater treatment device that is not connected to town sewerage. Wastewater is stored in these ponds to allow solids to settle out, then the liquid is released into the surrounding ground where it dissipates through the soil.

Variables	Description
Septic tank mitigation	This is any action deemed necessary by a council to increase the use or efficacy of septic tank systems. For example, this could be compliance monitoring or septic tank subsidies.
Septic tank efficacy	A measure of how well septic tanks are deemed to be operating. If the tanks are operating in a way that that ensures overflows of raw unseparated sewage are not occurring, then the efficacy of that system will be deemed to be high. If regular overflows of a system are occurring before sewage can settle, because stormwater is able to infiltrate the septic tank or the water table is too high, then the efficacy will be deemed to be low.
Septic tank overflows	The number and volume of overflows from septic tanks.
Farming	The act of farming livestock on land in the Sawyers Creek catchment. This is predominantly dry stock farming, characterised by mostly sheep with some cattle.
Farm run-off	The run-off of contaminants, primarily in the form of animal faecal matter, from farms in the Sawyers Creek catchment into Sawyers Creek and its tributaries.
Farm mitigation	Any action taken on a farm that seeks to decrease the run-off of contaminants from farm land into Sawyers Creek. This may be fencing, riparian planting or other measures.
Littering	The act of someone littering where that litter is either directly thrown into Sawyers Creek or indirectly makes its way into the creek due to littering practices elsewhere.

Variables	Description
Tourism	The general number of visitors visiting the West Coast and Greymouth. Includes both domestic and international.
Freedom camping	While freedom camping does include vehicles with self-contained toilet facilities, this specifically relates to the vehicles that **DO NOT HAVE SELF-CONTAINED TOILET** facilities. This relates to the number of these visitors to the West Coast and Greymouth, both domestic and foreign.
Uncontrolled human waste	This is the amount of human waste that is discarded directly to the environment as a result of freedom camping in vehicle without self-contained toilet facilities.
Tourism mitigation	The infrastructure that is or may be provided to tourists and freedom campers to cater to their toilet and general waste requirements. This includes things like public toilets, camping areas, rubbish facilities etc.
Natural characteristics	The natural characteristics in Sawyers Creek catchment that may encourage or aid the leaching or run-off of faecal contaminants into Sawyers Creek. For example, this might be high rainfall or a high water table in areas where there are septic tanks, or steep slopes that encourage run-off, or lack of vegetation cover. This is quite a broad factor, but is intended to be viewed from the perspective of characteristics that aid or assist with faecal contamination.

Variables	Description
Recreational use	The use of parts of Sawyers Creek itself or parts of the catchment for recreational use. This includes passive (e.g. walking alongside) and active (e.g. paddling, kayaking) use of Sawyers Creek and its tributaries. It also includes active use of the surrounding bush for things like camping and hunting.
Public health	Public health is the amount of people that physically get sick from faecal contamination in Sawyers Creek, or the risk of people getting sick.
Ecological health	The ecological health of the upper catchment, as characterised by its cleanliness and ability to support various flora and fauna. This is separate to the level of animal life that may actually be supported by this system.
Animal life	The volume of animal life in the bush areas of Sawyers Creek. This excludes farm animals which are covered in the 'farming' factor, unless the animals are feral. It includes animals like wild pigs, possums, rats/stoats, water fowl etc.
Regulatory requirements	Any legislation, regulation or bylaw that local government may need to react to or have enacted themselves. An example of a mandated requirement from Central Government is something like the *NPS-FM 2014*, while an example of a requirement created by local government itself might be a freedom-camping bylaw.

Variables	Description
Cost of regulation	The direct and indirect cost of regulatory requirements, as realised by local or central government. Direct costs include the financial resources required to implement or respond to a piece of regulation - for example, needing to purchase a piece of equipment. Indirect costs include such things as time, staff time, etc.
Cost of mitigation	The financial and social cost of taking some kind of action that would mitigate faecal contamination of Sawyers Creek. For example, this might be the direct financial cost of a physical structure, or the social and staff cost of undertaking monitoring, compliance or education.
Ability to pay	An individual's, business's or organisation's ability to pay for mitigations.
Clean thinking attitude	This was defined as the attitude that guides people's actions and activities that may lead to or reduce faecal contamination of Sawyers Creek. It could also be defined as being the sense of ownership that people may have over their actions, or broadly the environmental philosophy that guides them (or not).
Awareness and perception of contamination/ risk	This is defined as the level of perception or awareness that people have of actual contamination or the risk of contamination of Sawyers Creek based on their awareness and understanding of the issue. Risk also covers peoples risk of being exposed to actual contamination.

Appendix Table 8. Final list of variables elicited in the Sawyers Creek GMB process.

Final list of Influences and their descriptions included in the CLD for Sawyers Creek.

No.	From variable	To variable	Status	Description
1	**Littering**	**E. coli contamination**	Same (+ve)	The act of intentional or unintentional littering my result in rubbish making its way into or near the creek.
2	**Urban residential/ commercial**	**Urban run-off**	Same (+ve)	The direct relationship between the urban and commercial areas of town, being recognised as the more built up areas of town, and the higher levels of impervious surface that these areas have, resulting in a higher amount of direct run-off of stormwater.
3	**Urban run-off**	**E. coli contamination**	Same (+ve)	Stormwater run-off from predominantly impervious surfaces in urban areas resulting in rubbish and, importantly, animal waste making its way into the creek.
4	**Urban residential/ commercial**	**Combined sewerage**	Same (+ve)	There is an existing relationship between the denser urban areas (residential and commercial) and these properties being connected to an existing combined sewerage system.
5	**Combined Sewerage**	**Sewerage overflows**	Same (+ve)	The higher the amount of combined sewerage the higher the amount of sewerage overflows during rain events.
6	**Sewerage overflows**	**E. coli contamination**	Same (+ve)	The higher the number and volume of sewerage overflows the higher the amount of E. coli contamination in the creek.
7	**Separated sewerage (mitigation)**	**Combined sewerage**	Opposite (-ve)	The more separated sewerage in the wastewater network, the less combined sewerage in the network. As no combined sewerage is being built any more, separated sewerage is either the default in new reticulation or is gradually replacing combined sewerage through an ongoing programme of renewals.

No.	From variable	To variable	Status	Description
8	**Separated sewerage (mitigation)**	**Sewerage overflows**	Opposite (-ve)	The higher the amount separated sewerage the less the number and volume of sewerage overflows during rainfall events.
9	**Rural residential**	**Septic tanks**	Same (+ve)	The more land that is zoned or used as Rural Residential the more septic tanks there will be to cater for the human waste from these dwellings.
10	**Septic tanks**	**Septic tank overflows**	Same (+ve)	The higher the number of septic tanks, the higher the likelihood and eventual number of septic tank overflows.
11	**Septic tank mitigation**	**Septic tank efficacy**	Same (+ve)	The higher the amount of septic tank mitigation that is undertaken, the higher the efficacy of the stock of septic tanks, as a whole.
12	**Septic tank efficacy**	**Septic tank overflows**	Opposite (-ve)	The higher the efficacy of the septic tanks in the catchment, the less septic tank overflows there will be.
13	**Septic tank overflows**	**E. coli contamination**	Same (+ve)	The more septic tank overflows there are the higher the E. coli contamination into the creek.
14	**Farming**	**Farm run-off**	Same (+ve)	The more farming there is, the more farm run-off there will be.
15	**Farming**	**Farm mitigation**	Same (+ve)	The more farming there is, the more farm mitigation will be required.
16	**Farm mitigation**	**Farming**	Opposite (-ve)	The more farm mitigation there is, the less available land there will be for farming. This assumes that farm mitigation will take up at least some pasture land.
17	**Farm mitigation**	**Farm run-off**	Opposite (-ve)	The higher the level of farm mitigation, the less farm run-off there will be.
18	**Farm run-off**	**E. coli contamination**	Same (+ve)	The more farm run-off there is, being defined as farm run-off from livestock farms and therefore likely to include faecal matter, the more E. coli contamination there will be.

No.	From variable	To variable	Status	Description
19	**Tourism**	**Freedom camping**	Same (+ve)	The more tourism there is (in general) the more freedom camping there will be.
20	**Tourism**	**Tourism mitigation**	Same (+ve)	The more tourism there is (and tourists) the more tourism mitigation in the form of public toilets and waste disposal sites will likely be required and therefore built.
21	**Freedom camping**	**Uncontrolled human waste**	Same (+ve)	The more freedom camping there is the more uncontrolled human waste there will be.
22	**Freedom camping**	**Tourism mitigation**	Same (+ve)	The more freedom camping there is, the more tourism mitigation in the form of public toilets and possibly parking/camping facilities will be required and eventually built.
23	**Uncontrolled human waste**	**Tourism mitigation**	Same (+ve)	The more uncontrolled human waste there is, the more tourism mitigation will be required and built.
24	**Tourism mitigation**	**Uncontrolled human waste**	Opposite (-ve)	The more tourism mitigation is built, the less uncontrolled human waste there will be.
25	**Tourism mitigation**	**E. coli contamination**	Opposite (-ve)	The more tourism mitigation that is built (toilets, camp grounds, waste disposal sites etc.) the less E. coli contamination there will be.
26	**Uncontrolled human waste**	**E. coli contamination**	Same (+ve)	The more uncontrolled human waste there is, the more E. coli contamination there will be.
27	**E. coli contamination**	**Tourism**	Opposite (-ve)	The more E. coli contamination there is, over time the less tourism there will be as word of this spreads and NZ's reputation is affected by the contamination. This has been indicated by a delay as this relationship is likely to take time to present.
28	**Tourism**	**Recreational use**	Same (+ve)	The more tourism there is the more recreational use will be made of the stream and the bush in the catchment. This applies to both local use and tourist use.

No.	From variable	To variable	Status	Description
29	**Recreational use**	**Tourism**	Same (+ve)	The more recreational use there is the more the area will also become known as an area to recreate and so it is likely to increase the tourism in the area.
30	**Recreational use**	**Public health**	Same (+ve)	The more the catchment and/or stream is used for recreational purposes the greater the potential impact on public health due to contamination.
31	**Public health**	**Recreational use**	Opposite (-ve)	The greater the perceived or actual risk to public health, the less the areas will be used for recreational use.
32	**Ecological health**	**Animal life**	Same (+ve)	The higher the ecological health of the catchment, the greater the amount of animal life that it will sustain (outside of livestock on farms).
33	**Animal life**	**E. coli contamination**	Same (+ve)	The higher the amount of animal life (non-farm livestock) that is sustained in the catchment, the higher the E. coli contamination levels due to faecal contamination.
34	**Animal life**	**Recreational use**	Same (+ve)	The more animal life there is in the catchment, the more recreational use there will be due to hunting etc.
35	**E. coli contamination**	**Recreational use**	Opposite (-ve)	The higher the E. coli contamination the less recreational use there will be due to the chance of people getting sick.
36	**Cost of mitigation**	**Septic tank mitigation**	Opposite (-ve)	The higher the cost of mitigation, the lower the amount of septic tank mitigation that will occur.
37	**Cost of mitigation**	**Separated sewerage (mitigation)**	Opposite (-ve)	The higher the cost of mitigation, the lower the amount of separated sewerage mitigation that will occur.
38	**Cost of mitigation**	**Farm mitigation**	Opposite (-ve)	The higher the cost of mitigation, the lower the amount of farm mitigation that will occur.

No.	From variable	To variable	Status	Description
39	**Cost of mitigation**	**Tourism mitigation**	Opposite (-ve)	The higher the cost of mitigation, the lower the amount of tourism mitigation that will occur.
40	**Septic tank mitigation**	**Cost of mitigation**	Same (+ve)	The more septic tank mitigation undertaken the higher the costs incurred.
41	**Separated sewerage (mitigation)**	**Cost of mitigation**	Same (+ve)	The more separated sewerage mitigation undertaken the higher the costs incurred.
42	**Farm mitigation**	**Cost of mitigation**	Same (+ve)	The more farm mitigation undertaken the higher the costs incurred.
43	**Tourism mitigation**	**Cost of mitigation**	Same (+ve)	The more tourism mitigation undertaken or built, the higher the costs incurred.
44	**Ability to pay**	**Septic tank mitigation**	Same (+ve)	The greater an individual, businesses or organisation's ability to pay, the more septic tank mitigation that will be carried out.
45	**Ability to pay**	**Separated sewerage (mitigation)**	Same (+ve)	The greater an individual, businesses or organisation's ability to pay, the more separated sewerage mitigation that will be carried out.
46	**Ability to pay**	**Farm mitigation**	Same (+ve)	The greater an individual, businesses or organisation's ability to pay, the more farm mitigation that will be carried out.
47	**Ability to pay**	**Tourism mitigation**	Same (+ve)	The greater an individual, businesses or organisations ability to pay, the more tourism mitigation that will be carried out.
48	**Natural characteristics**	**Septic tank overflows**	Same (+ve)	In this relationship, the predominant natural characteristic considered is rainfall. The more rainfall the more septic tank overflows.
49	**Natural characteristics**	**Sewerage overflows**	Same (+ve)	In this relationship, the predominant natural characteristic considered is rainfall. The more rainfall the more sewerage overflows.

No.	From variable	To variable	Status	Description
50	**Natural characteristics**	**Farm mitigation**	Undefined (?)	This relationship is the only undefined relationship in the entire CLD. The more or less favourable the natural characteristics, then the more or less farm mitigation that will occur. For example, the steeper the ground, the less likely that planting or settling ponds can be implemented. As so much is involved in the factor of natural characteristics, this can affect farm mitigations in several ways in both same and opposite ways.
51	**Natural characteristics**	**Farm run-off**	Same (+ve)	In this relationship, the predominant natural characteristic considered is rainfall. The more rainfall the more farm run-off.
52	**E. coli contamination**	**Awareness and perception of contamination/ risk**	Same (+ve)	The higher the E. coli contamination, the higher the awareness or perception of actual contamination or the risk of contamination.
53	**Awareness and perception of contamination/ risk**	**Regulatory requirements**	Same (+ve)	The higher the actual or perceived contamination or risk of contamination, the higher the changes or reaction of regulatory requirements.
54	**Public health**	**Regulatory requirements**	Same (+ve)	The higher the risk to public health, the higher the level (or chances) of regulatory requirements.
55	**Regulatory requirements**	**Cost of regulation**	Same (+ve)	The higher the regulatory requirements, the higher the costs of those regulatory requirements.
56	**Cost of regulation**	**Regulatory requirements**	Opposite (-ve)	The higher the cost of regulatory requirements, the lower the changes of further regulatory requirements being implemented.

No.	From variable	To variable	Status	Description
57	**Regulatory requirements**	**Septic tank mitigation**	Same (+ve)	The higher the regulatory requirements, the more septic tank mitigation will be required.
58	**Regulatory requirements**	**Separated sewerage (mitigation)**	Same (+ve)	The higher the regulatory requirements, the more separated sewerage mitigation will be required.
59	**Regulatory requirements**	**Farm mitigation**	Same (+ve)	The higher the regulatory requirements, the more farm mitigation will be required.
60	**Regulatory requirements**	**Tourism mitigation**	Same (+ve)	The higher the regulatory requirements, the more tourism mitigation will be required.
61	**Ecological health**	**Clean thinking attitude**	Same (+ve)	The higher the ecological health of the catchment, the more this will reinforce a clean thinking attitude and value of the healthy environment amongst residents.
62	**Awareness and perception of contamination/ risk**	**Clean thinking attitude**	Same (+ve)	The higher the awareness/perception of a risk of or actual contamination, the more this will reinforce a clean attitude and valuing of a clean environment by residents.
63	**Clean thinking attitude**	**Septic tank mitigation**	Same (+ve)	The greater the clean thinking value and attitude of residents, the more septic tank mitigation will occur.
64	**Clean thinking attitude**	**Separated sewerage (mitigation)**	Same (+ve)	The greater the clean thinking value and attitude of residents, the more separated sewerage mitigation will occur.
65	**Clean thinking attitude**	**Farm mitigation**	Same (+ve)	The greater the clean thinking value and attitude of residents, the more farm mitigation will occur.

No.	From variable	To variable	Status	Description
66	**Clean thinking attitude**	**Tourism mitigation**	Same (+ve)	The greater the clean thinking value and attitude of residents, the more tourism mitigation will occur.
67	**Clean thinking attitude**	**Freedom camping**	Same (+ve)	The greater the clean thinking value and attitude of residents, the more freedom camping will occur.
68	**Clean thinking attitude**	**Recreational use**	Same (+ve)	The greater the clean thinking value and attitude of residents, the more recreational use will occur.
69	**Septic tank mitigation**	**Clean thinking attitude**	Same (+ve)	The higher the level of septic tank mitigation the greater impact this will have on the valuing and attitude of having a clean catchment this will have on residents.
70	**Separated sewerage (mitigation)**	**Clean thinking attitude**	Same (+ve)	The higher the level of separated sewerage mitigation the greater impact this will have on the valuing and attitude of having a clean catchment this will have on residents.
71	**Farm mitigation**	**Clean thinking attitude**	Same (+ve)	The higher the level of farm mitigation the greater impact this will have on the valuing and attitude of having a clean catchment this will have on residents.

Appendix 20 Detailed description, analysis and discussion of the CLDs and archetypes found

This appendix provides a more detailed analysis of the CLDs for each project. It is divided into the following sections: The process outlining how the CLDs were analysed is provided; then an overview of the final CLDs; a detailed description and analysis of the CLDs; a description and analysis of the system archetypes found; and a discussion of the CLDs and archetypes found within them.

How the CLDs were analysed

The CLDs were analysed in the following way:

1. **Number of variables and influences:** A quantitative analysis of the total number of variables and influences, noting whether the polarity of influences could be clearly labelled or not.
2. **Most influencing and most influenced variables:** A quantitative analysis of the number of times that variables *influenced* or were *influenced* by other variables.
3. **Partial CLD analysis:** Qualitative analysis of the CLDs that built up the CLDs in stages for ease of understanding and analysis.
4. **Analysis for system archetypes:** The CLDs were analysed for system archetypes (or 'common patterns') according to those described by Peter Senge (1990).

An overview of the final CLDs

This section provides an overview of the CLDs for both groups.

An overview of the final CLD: Rangitāiki River

A **total of 15 variables** were identified by the Rangitāiki group. Two of these were 'overarching' or guiding concepts (mauri and sustainable development) and thus were not included in the CLD directly. The other 13, including the two primary variables from the focus question (water quality and water quantity), were incorporated into the CLD (Appendix Table 9).

Appendix Table 9. Summary of variables in Rangitāiki River CLD.

Summary of variables in CLD: Rangitāiki River	
• **Water quality** • **Water quantity** • **Community vibrancy** • **Business adaptability** • **Financial viability** • **Population** • **Technology**	• **Water allocation** • **Structures** • **Irrigation** • **Land characteristics** • **Rainfall** • **Temperature**

The above list does not include the 'overarching' variables of mauri and sustainable development. A detailed description of variables can be found in 0.

A **total of 54 influences** were identified, nearly half of which (24 or 45%) were **undefined** and not able to be clearly labelled as **same** or **opposite** influences. Of those that were clearly labelled, the majority were **same** influences (19 or 35% same influences versus 11 or 20% opposite influences) (Appendix Table 10).

Appendix Table 10. Summary of influences in CLD: Rangitāiki River

Direction of influence	Number	Percentage
Same (positive)	19	35%
Opposite (negative)	11	20%
Undefined or both (?)	24	45%
Total	**54**	**100%**

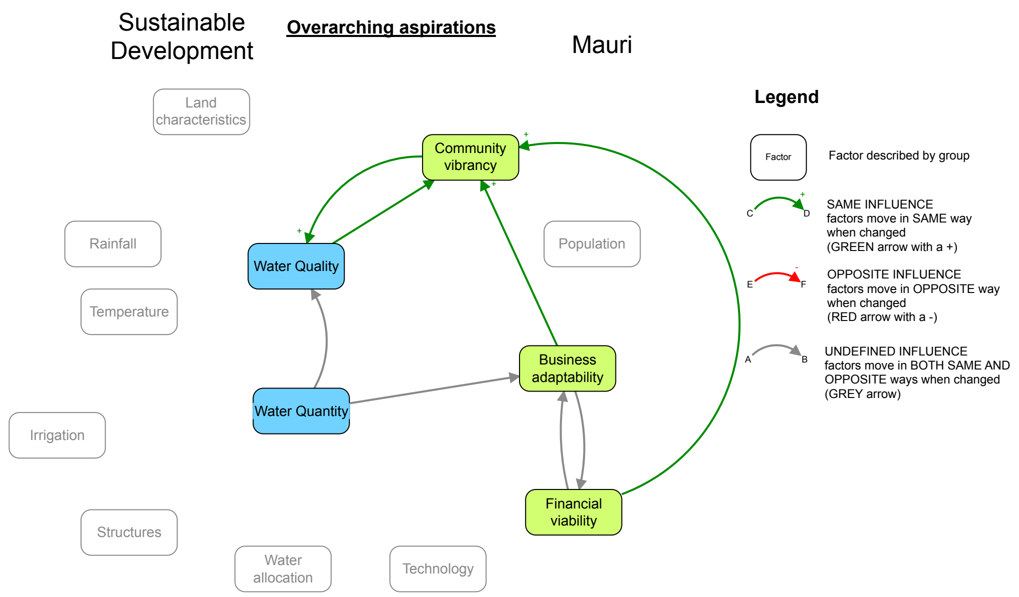
A comparison of the **most influencing and influenced variables** is shown below in Appendix Table 11. Note that some variables appear near the top of both lists (such as business adaptability and water quantity) while others are more influenced by others and/or are very limited in the number that they influence (such as water quality and community vibrancy).

Appendix Table 11. Ranking of influencing and influenced variables: Rangitāiki River CLD

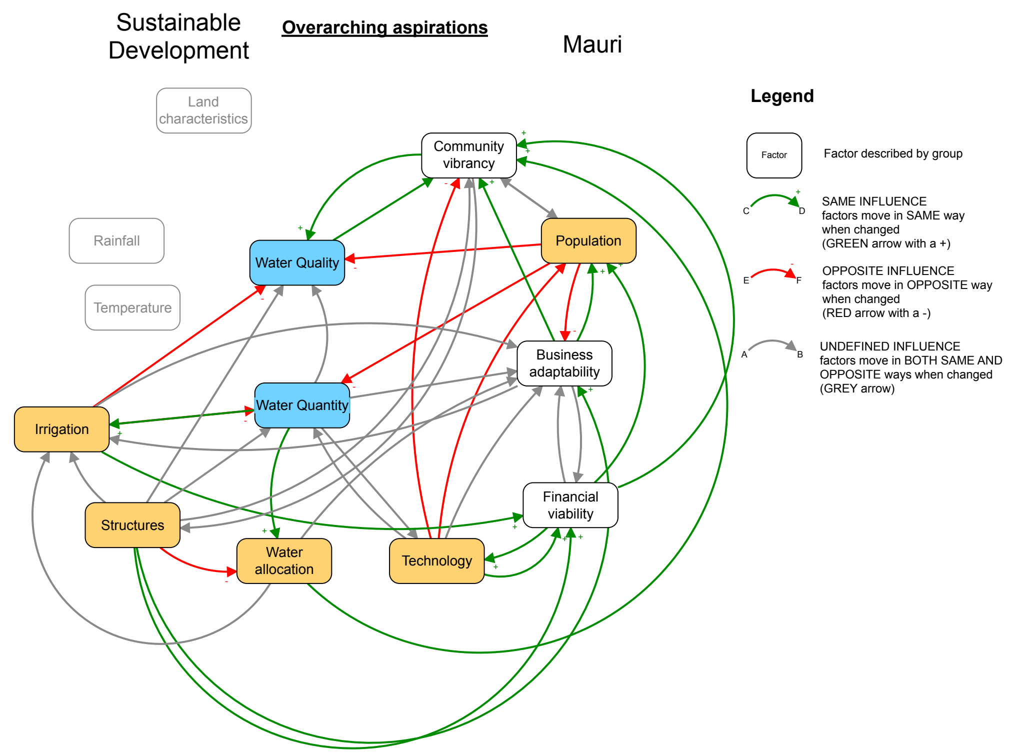
VARIABLES THAT INFLUENCE		VARIABLES THAT ARE INFLUENCED	
Variable	**Number**	**Variable**	**Number**
Land Characteristics	**7**	**Business Adaptability**	**8**
Structures	**7**	**Community Vibrancy**	**7**
Water Quantity	**7**	**Water Quantity**	**7**
Business Adaptability	**5**	**Water Quality**	**6**
Technology	**5**	**Financial Viability**	**5**
Financial Viability	**4**	**Land Characteristics**	**5**
Irrigation	**4**	**Population**	**5**
Population	**4**	**Irrigation**	**4**
Community Vibrancy	**3**	**Water Allocation**	**3**
Rainfall	**3**	**Structures**	**2**
Temperature	**2**	**Technology**	**2**
Water Allocation	**2**	**Rainfall**	**0**
Water Quality	**1**	**Temperature**	**0**

The CLD is built up in three stages, to make its description more accessible. The first stage begins with water quality and water quantity and includes the three variables that the group spent the most time discussing – **community vibrancy**, **business adaptability** and **financial viability** (Appendix Figure 31). The second adds five factors that are more clearly defined – **population**, **technology**, **water allocation**, **structures** and **irrigation** (Appendix Figure 32). The final stage adds the remaining three factors that human action would have the least immediate ability to change – **land characteristics**, **rainfall** and **temperature** (Appendix Figure 33).

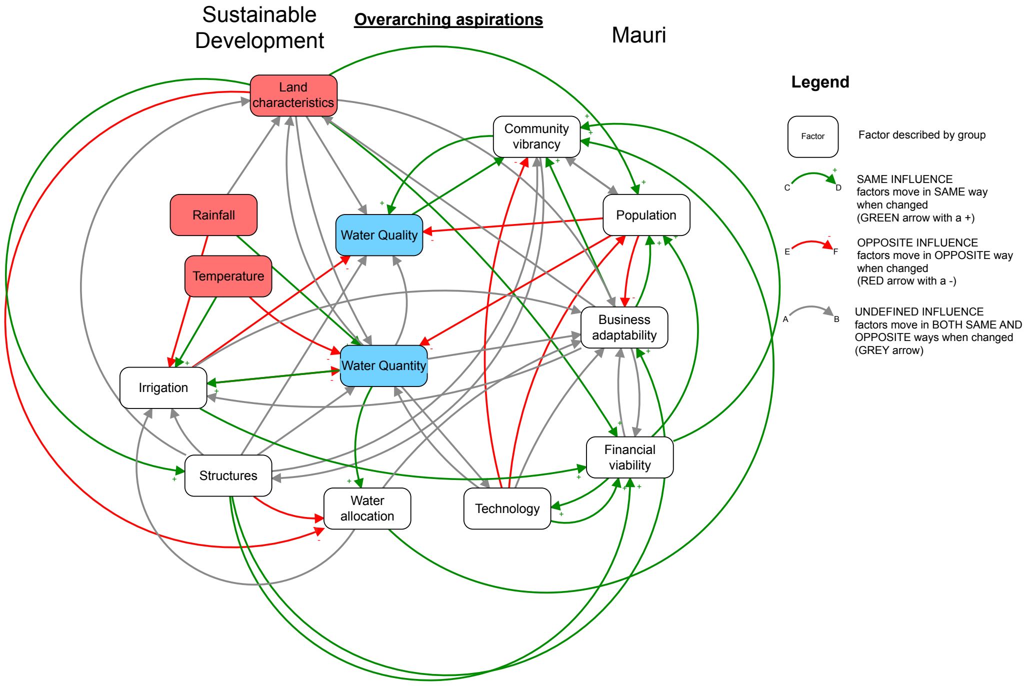
Appendix Figure 31. Partial CLD system archetype analysis – Stage I



Appendix Figure 32. Partial CLD system archetype analysis – Stage II



Appendix Figure 33. Partial CLD system archetype analysis – Stage III



A more detailed description of these can be found in Section 0.

An overview of the final CLD: Sawyers Creek

A **total of 30 variables** were identified by the Sawyers Creek group. All 30, including the primary variable from the focus question (*E. coli* contamination), were incorporated into the CLD (Appendix Table 12).

Appendix Table 12. Summary of variables in Sawyers Creek CLD

Summary of variables in CLD: Sawyers Creek	
• *E. coli* contamination • Septic tank overflows • Sewerage overflows • Farm run-off • Uncontrolled human waste • Urban run-off • Littering • Animal life • Rural residential • Septic tanks • Septic tank efficacy • Septic tank mitigation • Urban residential • Combined sewerage • Separated sewerage (mitigation)	• Sewerage efficacy • Ecological health • Tourism • Freedom camping • Tourist mitigation • Farming • Farm mitigation • Natural characteristics • Cost of mitigation • Regulatory requirements • Cost of regulation • Public health • Awareness and perception of risk • Ability to pay • Clean thinking attitude

A detailed description of variables can be found in 0.

A **total of 71 influences** were identified, nearly all (55 or 78%) were labelled as **same** influences, while all the rest (bar one, or 1%) were labelled as **opposite** (15 or 21%) (Appendix Table 13).

Appendix Table 13. Summary of influences in CLD: Sawyers Creek

Direction of influence	Number	Percentage
Same (positive)	55	78%
Opposite (negative)	15	21%
Undefined or both (?)	1	1%
Total	**71**	**100%**

A comparison of the **most influencing and influenced variables** is shown below in Appendix Table 14. Note that some variables appear near the top of both lists (such as the various mitigations), while the most influential are social factors (such as attitudes and regulatory responses).

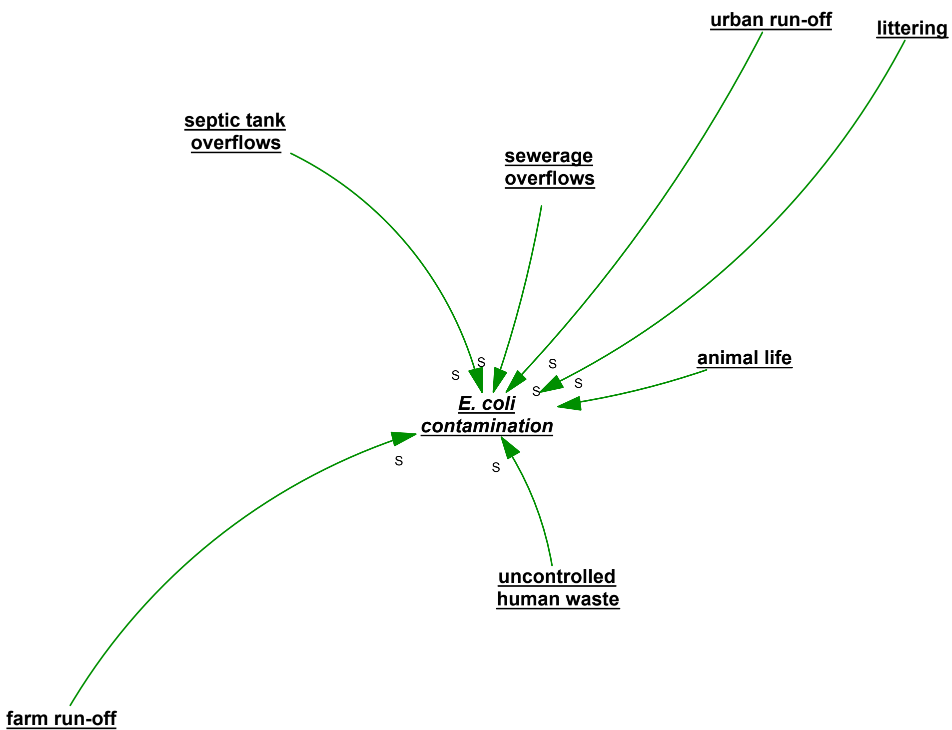
Appendix Table 14. Ranking of influencing and influenced variables: Sawyers Creek CLD.

VARIABLES THAT INFLUENCE		VARIABLES THAT ARE INFLUENCED	
Factor	**Number**	**Factor**	**Number**
Clean thinking attitude	6	E. coli contamination	8
Regulatory requirements	5	Tourism mitigation	7
Farm mitigation	4	Farm mitigation	6
Separated sewerage (mitigation)	4	Recreational use	5
Natural characteristics	4	Clean thinking attitude	5
Cost of mitigation	4	Separated sewerage (mitigation)	4
Ability to pay	4	Septic tank mitigation	4
E. coli contamination	3	Cost of mitigation	4
Septic tank mitigation	3	Sewerage overflows	3
Tourism mitigation	3	Septic tank overflows	3
Tourism	3	Farm run-off	3
Animal life	2	Regulatory requirements	3
Ecological health	2	Combined sewerage	2
Freedom camping	2	Tourism	2
Uncontrolled human waste	2	Freedom camping	2
Farming	2	Uncontrolled human waste	2
Awareness and perception of contamination/ risk	2	Urban run-off	1
Public health	2	septic tanks	1
Urban residential/ commercial	2	Septic tank efficacy	1
Recreational use	2	Farming	1
Farm run-off	1	Public health	1
Cost of regulation	1	Animal life	1
Combined sewerage	1	Cost of regulation	1
Sewerage overflows	1	Awareness and perception of contamination/ risk	1
Rural residential	1	Urban residential/ commercial	0
Urban run-off	1	Sewerage efficacy	0

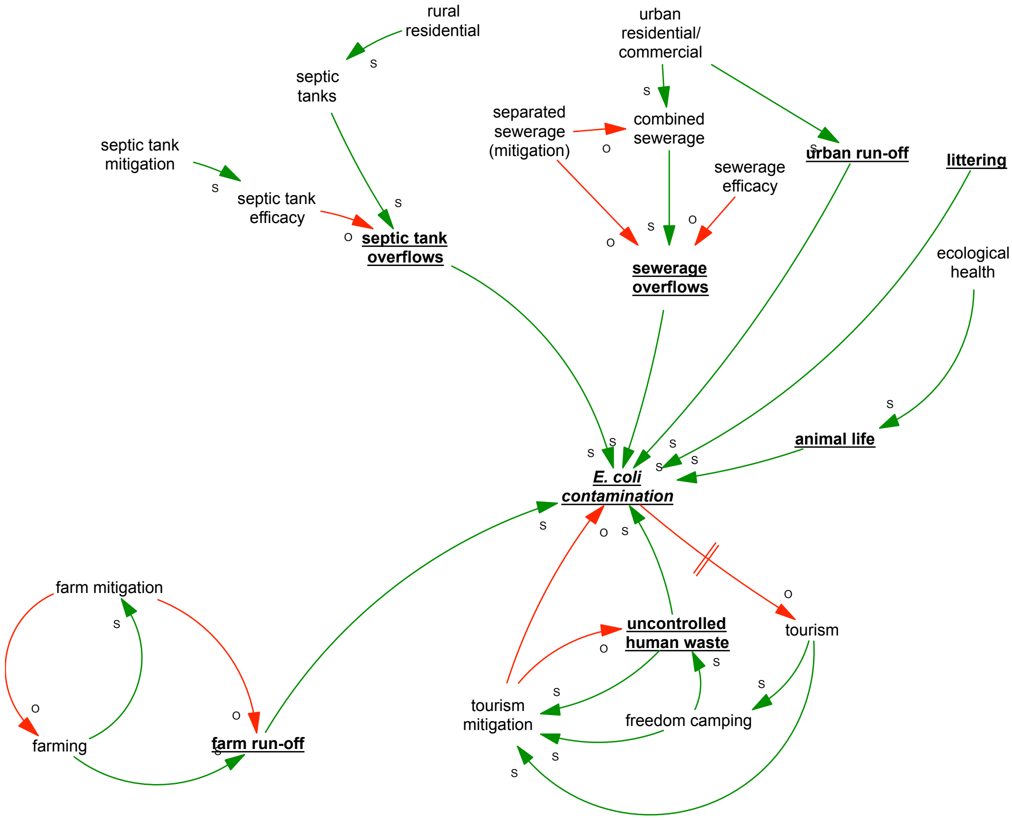
VARIABLES THAT INFLUENCE		VARIABLES THAT ARE INFLUENCED	
Factor	Number	Factor	Number
Littering	1	Rural residential	0
Septic tank overflows	1	Littering	0
septic tanks	1	Natural characteristics	0
Septic tank efficacy	1	Ecological health	0
Sewerage efficacy	0	Ability to pay	0

The CLD is built up in four stages to make it more accessible. The first stage begins with the main variables that are the **sources of contamination** (Appendix Figure 34). The second adds variables that were identified as the **main reasons** leading to these sources of contamination (Appendix Figure 35), while the third stage adds variables that are the **physical influences**, the **societal responses** and the **impacts** of contamination (Appendix Figure 36). The final stage adds the **psychological** variables that influence contamination (Appendix Figure 37).

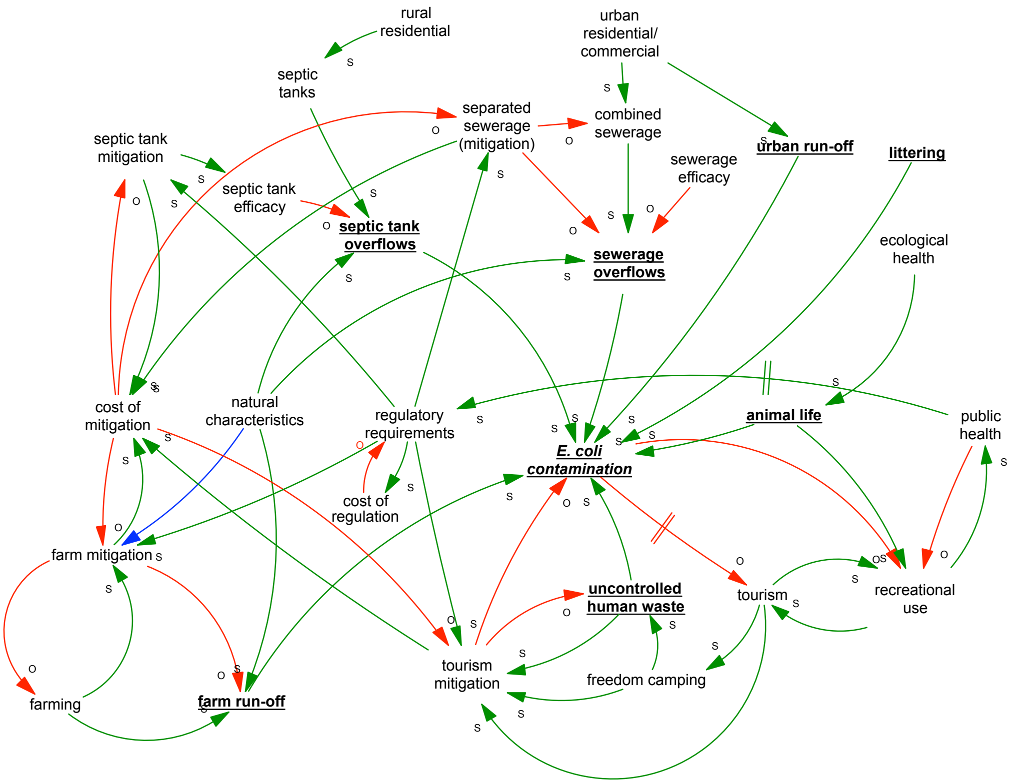
Appendix Figure 34. Partial CLD system archetype analysis – Stage I



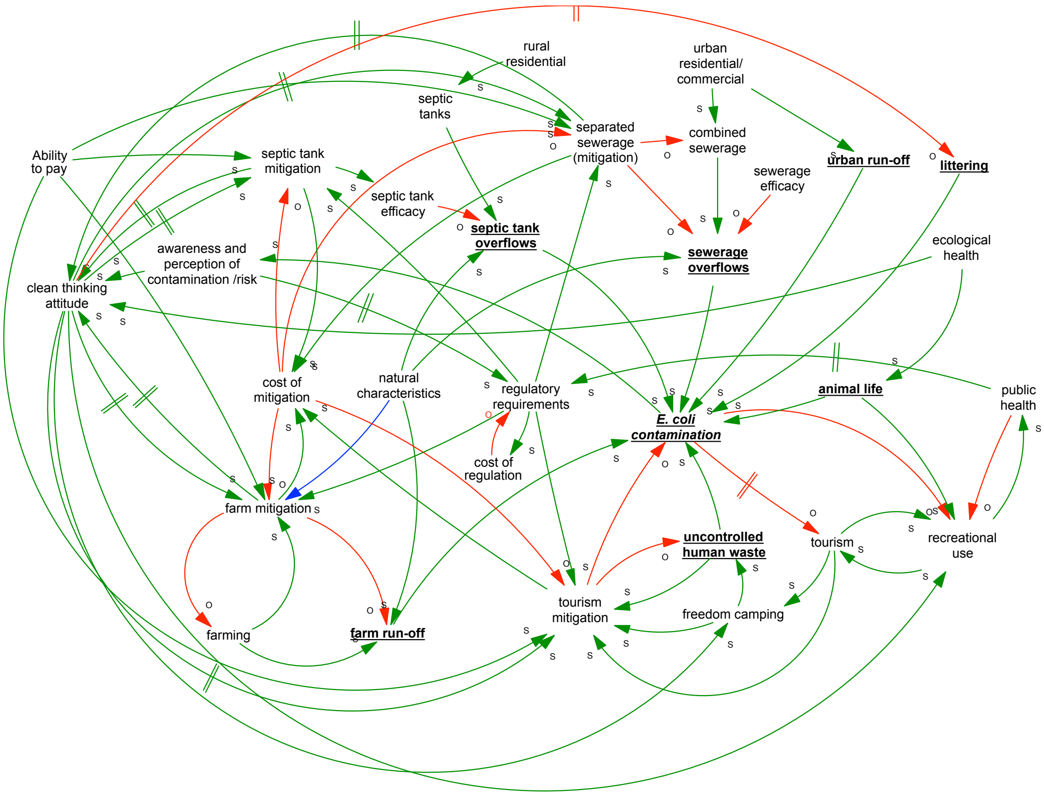
Appendix Figure 35. Partial CLD system archetype analysis – Stage II



Appendix Figure 36. Partial CLD system archetype analysis – Stage III



Appendix Figure 37. Partial CLD system archetype analysis – Stage IV (complete)



A more detailed description of these can be found below.

Detailed description and analysis of the CLDs

Detailed description and analysis of the CLD: Rangitāiki River

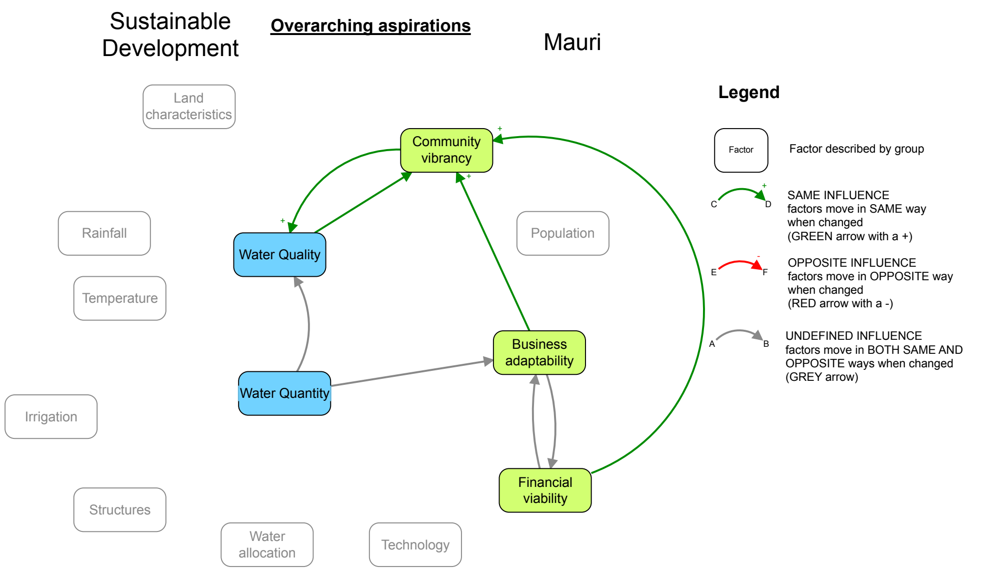
The partial build-up of the causal-loop diagram

The CLD was analysed and presented back to the group in the following structured manner. Starting with the two factors of water quality and quantity that were core parts of the focus question, the other factors were then added in three stages based on their perceived importance to the group. The first set of factors were: mauri, community vibrancy, sustainable development and economics. The second set of factors were: population, technology, water allocation, structures and irrigation. The final set of factors were: land characteristics, rainfall and temperature. The justification for these groupings are provided in Appendix Table 15. Images of the partial CLDS are provided in Appendix Figure 38, Appendix Figure 39 and Appendix Figure 40.

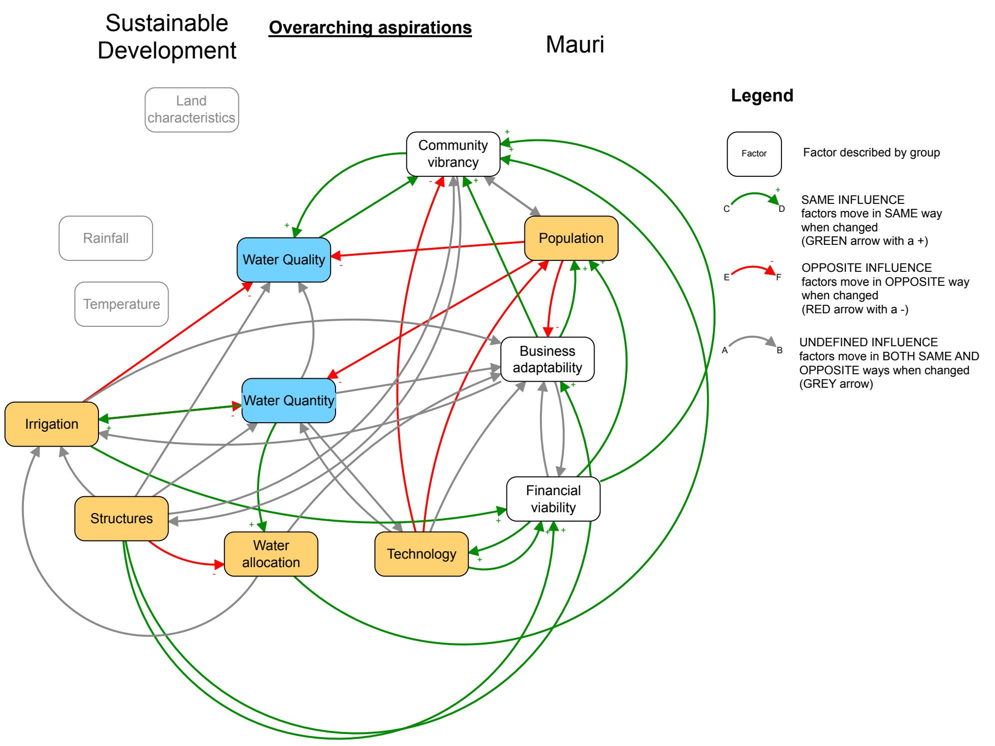
Appendix Table 15. Groupings of factors for system archetype analysis.

Stage	Factors	Reason
I	• **Community vibrancy** • **Business adaptability** • **Financial viability**	These were analysed first as these were considered the factors that the group spent a large amount of time discussing. They also can loosely be characterised as things that the group are trying to *achieve*. It is noted that two of the factors can be considered as high-level and may need further discussion as a group to break down further are included in this grouping – *Community vibrancy* and *Business adaptability*.
II	• **Population** • **Technology** • **Water allocation** • **Structures** • **Irrigation**	The second grouping is made up of factors that are more clearly defined. Four of the five factors may also be viewed as 'levers' through which some of the other higher-level outcomes may be achieved – *Technology*, *Water allocation*, *Structures* and *Irrigation.*
III	• **Land characteristics** • **Rainfall** • **Temperature**	The final grouping of factors has a huge ability to influence water quality and quantity in the catchment. However, they are largely factors that remain out of human control, with some exception in the case of *Land characteristics*. The factors identified earlier best characterise the human responses to these influences.

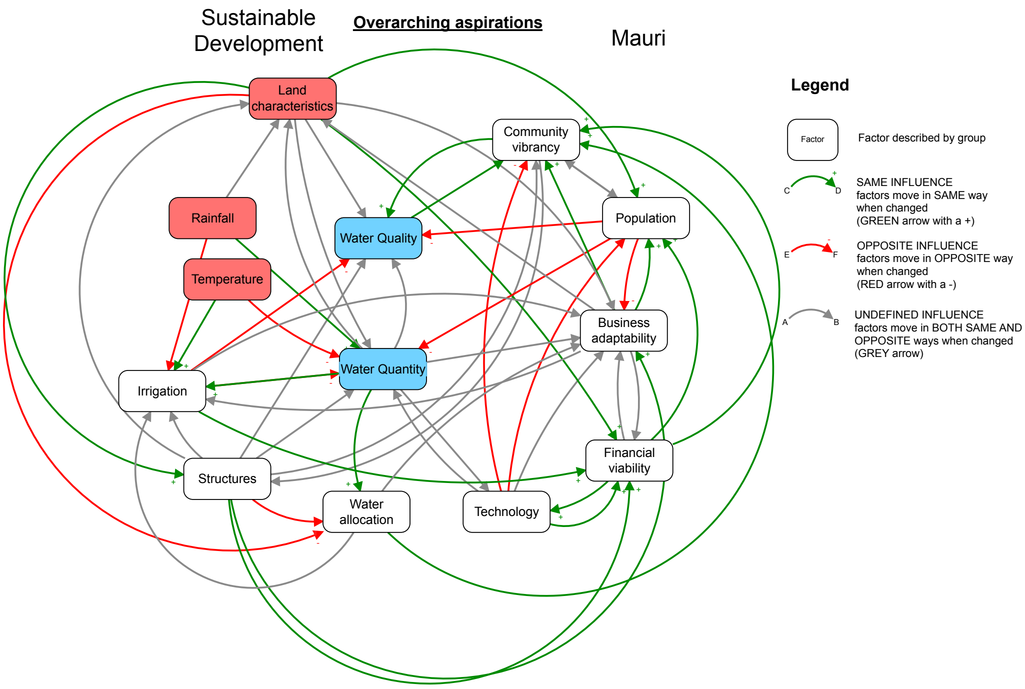
Appendix Figure 38. Partial CLD system archetype analysis – Stage I



Appendix Figure 39. Partial CLD system archetype analysis – Stage II



Appendix Figure 40. Partial CLD system archetype analysis – Stage III



The causal-loop diagram – quantitative analysis

A total of 54 influences were identified and described. 19 of these were 'same' (positive), 11 were 'opposite' (negative) and 24 where undefined – being a combination of same and opposite (positive and negative). The same and opposite influences totalled 30, meaning the polarity of the majority (55%) was determined (see Appendix Table 16). A detailed list of the influences and their descriptions is provided in 0.

Appendix Table 16. Summary of influences in CLD: Rangitāiki River

Direction of influence	Number	Percentage
Same (positive)	19	35%
Opposite (negative)	11	20%
Undefined or both (?)	24	45%
Total	**54**	**100%**

A closer look at these influences indicates that some are much more likely to *be an influence* (Appendix Table 17), while others are much more likely to *be influenced* (Appendix Table 18).

Appendix Table 17. Factors that influence

FACTORS THAT INFLUENCE			
Factor	Number	Factor	Number
Land Characteristics	7	Population	4
Structures	7	Community Vibrancy	3
Water Quantity	7	Rainfall	3
Business Adaptability	5	Temperature	2
Technology	5	Water Allocation	2
Financial Viability	4	Water Quality	1
Irrigation	4		

The factors that were most likely to be an influence were ***land characteristics***, ***structures*** and ***water quantity***, followed closely by ***business adaptability*** and ***technology***.

Land characteristics was the first factor discussed. The group identified many influences relating to this factor. This is likely because it was the first factor, it was discussed before the discussion got much more complex and involved and perhaps it was easier to identify influences for this factor in the absence of others.

That aside, two other factors with many links were not original variables but were added during conversation in the first workshop. ***Technology*** was added during conversation while ***structures*** was identified in the second sort of factors described earlier (see Section 5.2.5). This would indicate that they are important factors of influence.

Water quantity was the third of the three highest-equal influencing factors. This is interesting as it was a default factor due to it being a subject of the focus question, as well as being one that the group identified as influencing many other things in the catchment.

Appendix Table 18. Factors that are influenced

FACTORS THAT ARE INFLUENCED			
Factor	Number	Factor	Number
Business Adaptability	8	Irrigation	4
Community Vibrancy	7	Water Allocation	3
Water Quantity	7	Structures	2
Water Quality	6	Technology	2
Financial Viability	5	Rainfall	0
Land Characteristics	5	Temperature	0
Population	5		

The factor most likely to be influenced was ***business adaptability***, followed jointly by ***community vibrancy*** and ***water quantity***. This was followed closely by ***water quality***.

Only ***business adaptability*** and ***water quantity*** appear at the top of both tables, indicating they are both *strong influences* and *strongly influenced* by other factors. Many of the things that a community is likely to want to achieve as an outcome, or might be viewed as a sign of a prosperous community, also appeared highly on the *influenced* list. Examples of these include ***business adaptability***, ***community vibrancy*** and ***water quality***. Of the top factors of each table there was a notable deficit between how much ***water quality*** was *influenced* compared to being an *influence*.

Two factors are not influenced by any others – rainfall and temperature. The session did not continue long enough for all factors identified to be included in the CLD; if it did, it is likely that ***climate change*** would have been the factor that directly influenced these factors.

Two of the factors influenced the most (***business adaptability*** and ***community vibrancy***) are factors that the group viewed as highly aggregated and many different elements were considered within these factors. Some feedback on the day indicated that several people had reservations about the high-level nature of these important factors. The conversations around the influences had been very good and helped the participants learn a lot from each other, but remained difficult to quantify. This reinforces the results of the pilot sessions, where it was identified that simulation modelling would have been difficult to apply within the constraints faced within each GMB process.

Identifying feedback loops

This section summarises the feedback loops found in each case study.

Reinforcing or balancing feedback loops

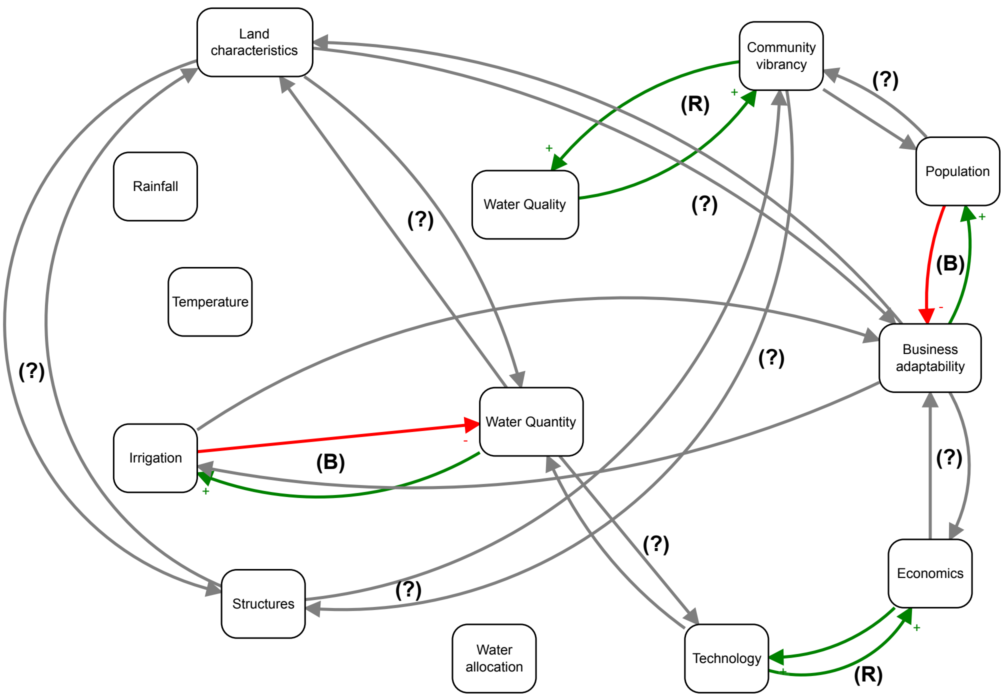
Reinforcing and balancing loops are the basic building blocks for understanding the inter-relationships within systems. As described by Senge (1990), a reinforcing loop is where factors influence each other in a continuous loop that gradually encourages more and more of the same effect, either in an increasing or decreasing direction. In contrast, a balancing loop is defined by influences that tend to cancel each other out, thus effectively negating any reinforcing effect.

Looking for simple feedback loops first, several two-factor loops were identified. These are tabulated in Appendix Table 19 and shown in Appendix Figure 41. A total of 12 loops were identified, only four of which could be clearly labelled as either reinforcing (two) or balancing (two), given that most influences described by the group contained both ***same*** and ***opposite*** influences.

Appendix Table 19. Feedback loops between two factors (table)

Type of feedback loop	Number
Reinforcing (same & same)	2
balancing (same & opposite)	2
Undefined (?)	8
Total	**12**

Appendix Figure 41. Feedback loops between two factors (diagram)



The two reinforcing loops were ***water quality – community vibrancy*** and ***technology – economics***. This indicates that improved water quality and community vibrancy would reinforce each other, while improvements in technology would improve the profitability and financial success of business efforts.

The two balancing loops were ***water quantity – irrigation*** and ***population – sustainable development***. This indicates that increases in one of the factors in each of these loops would eventually balance out potential increases in the other. For example, if there is more water available (***water quantity***) then there would be more irrigation, which would likely lead to more water use and therefore *less* water being available. Similarly, an increase in ***sustainable development*** may lead to an increase in the ***population*** due to the availability of fulfilling and financially rewarding work. However, this increase would itself put pressure on the very ***sustainable development*** that would drive a ***population*** increase.

System archetypes: Rangitāiki River

The system archetypes identified are outlined in the section *Systems archetypes found*.

Detailed description and analysis of the CLD: Sawyers Creek

The previous section analysed the CLD for the Rangitāiki catchment. This section will do the same for the Sawyers Creek catchment, first building up the CLD in stages, then doing quantitative analysis of the CLD, and then analysing feedback loops and archetypes.

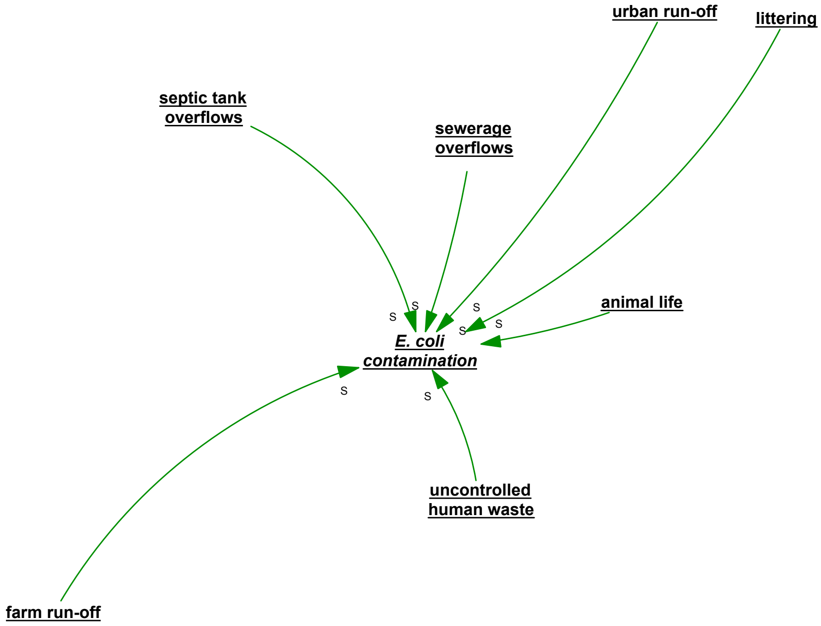
The partial build-up of the causal-loop diagram

The CLD was analysed and presented back to the group in the following structured manner. The factor of *E. coli* contamination was placed in the middle and then the other factors were then added in stages. First, the **main sources** of contamination, then the **main reasons**. This was followed by a range of **physical** influences, **societal responses** and **impacts**. Finally, **psychological** factors influencing contamination were placed on the diagram. These groupings are provided in Appendix Table 20. Images of the partial CLDS are provided in Appendix Figure 42, Appendix Figure 43, Appendix Figure 44 and Appendix Figure 45.

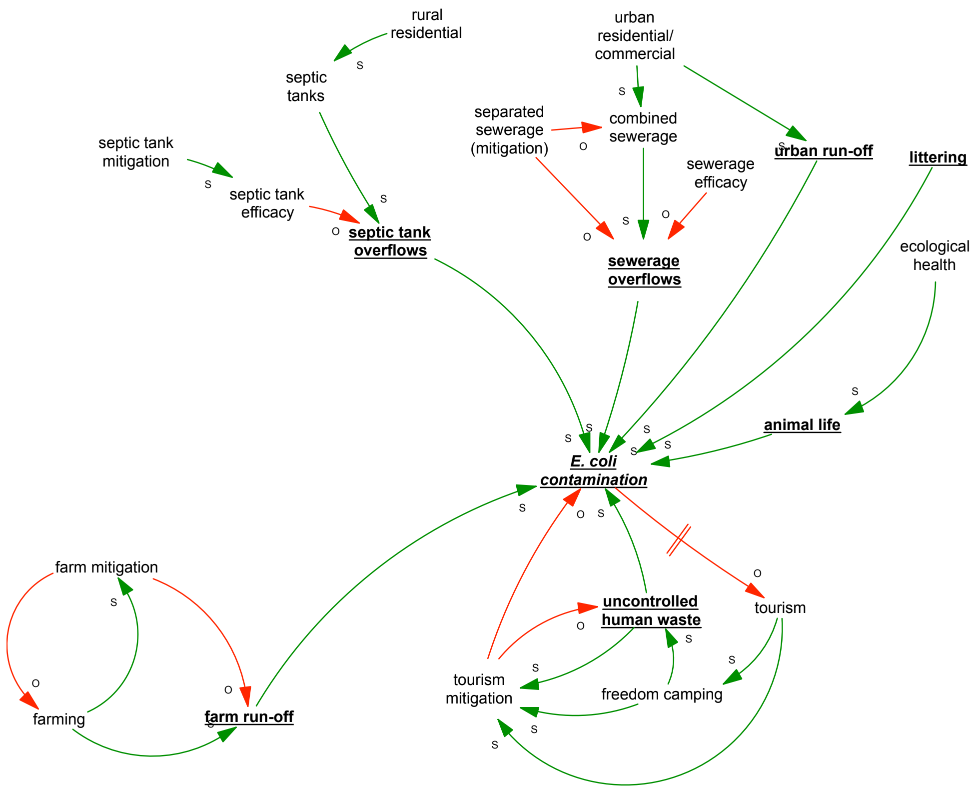
Appendix Table 20. Groupings of factors for system archetype analysis

Stage	Factors	Reason
I	• **Septic tank overflows** • **Sewerage overflows** • **Farm run-off** • **Uncontrolled human waste** • **Urban run-off** • **Littering** • **Animal life**	These were the ***main sources*** of *E. coli* contamination identified in Sawyers Creek.
II	• **Rural residential** • **Septic tanks** • **Septic tank efficacy** • **Septic tank mitigation** • **Urban residential** • **Combined sewerage** • **Separated sewerage (mitigation)** • **Sewerage efficacy** • **Ecological health** • **Tourism** • **Freedom camping** • **Tourist mitigation** • **Farming** • **Farm mitigation**	These were the ***main reasons*** leading to the identified sources contaminating.
III	• **Natural characteristics** • **Cost of mitigation** • **Regulatory requirements** • **Cost of regulation** • **Public health**	These were a mix of things including the ***physical influences*** of contamination (natural characteristics), the ***societal responses*** to contamination (regulation and the cost of mitigation), and the ***impacts*** of contamination (public health).
IV	• **Awareness and perception of risk** • **Ability to pay** • **Clean thinking attitude**	These are identified as being ***psychological*** factors that influenced contamination.

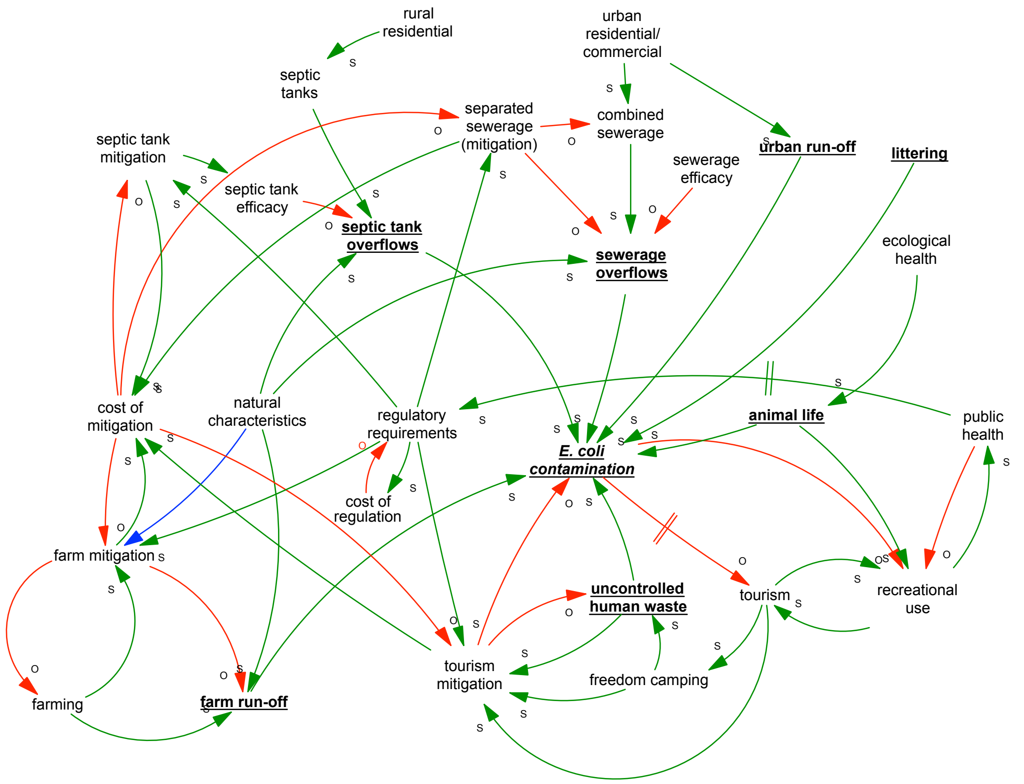
Appendix Figure 42. Partial CLD system archetype analysis – Stage I



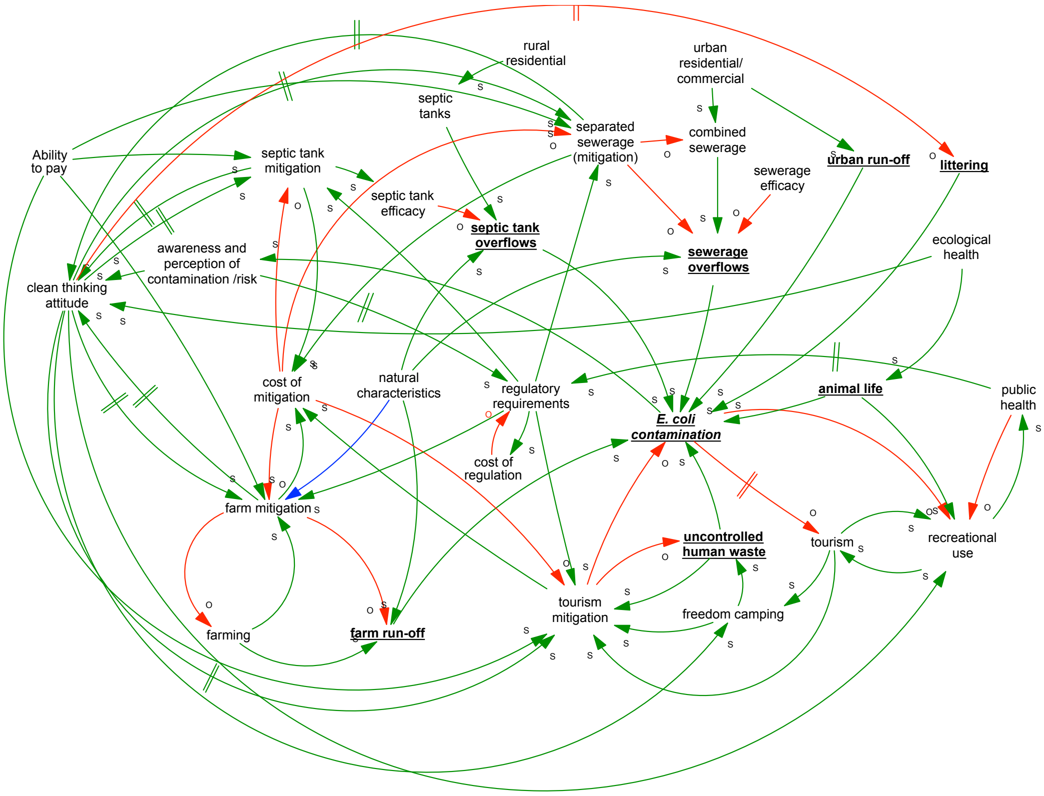
Appendix Figure 43. Partial CLD system archetype analysis – Stage II



Appendix Figure 44. Partial CLD system archetype analysis – Stage III



Appendix Figure 45. Partial CLD system archetype analysis – Stage IV (complete)



The CLD – quantitative analysis

A total of 71 influences were identified and described. Of these, by far the majority (55) were 'same' (positive). Only 15 were 'opposite' (negative) while only 1 was undefined, meaning clearly labelled influences totalled 70 of the 71 or 98% (see Appendix Table 21). This made identifying feedback loops and archetypes much easier than in the first case study. A detailed list of the influences and their descriptions is provided in 0.

Appendix Table 21. Quantitative summary of influences in CLD

Direction of influence	Number	Percentage
Same (positive)	55	78%
Opposite (negative)	15	21%
Undefined or both (?)	1	1%
Total	**71**	**100%**

A closer look at these influences indicate that some are much more likely to *be an influence* (Appendix Table 22), while others are much more likely to *be influenced* (Appendix Table 23).

Appendix Table 22. Factors that influence

FACTORS THAT INFLUENCE			
Factor	Number	Factor	Number
Clean thinking attitude	6	Awareness and perception of contamination/ risk	2
Regulatory requirements	5	Public health	2
Farm mitigation	4	Urban residential/ commercial	2
Separated sewerage (mitigation)	4	Recreational use	2
Natural characteristics	4	Farm run-off	1
Cost of mitigation	4	Cost of regulation	1
Ability to pay	4	Combined sewerage	1
E. coli contamination	3	Sewerage overflows	1
Septic tank mitigation	3	Rural residential	1
Tourism mitigation	3	Urban run-off	1
Tourism	3	Littering	1
Animal life	2	Septic tank overflows	1
Ecological health	2	septic tanks	1
Freedom camping	2	Septic tank efficacy	1
Uncontrolled human waste	2	Sewerage efficacy	0
Farming	2		

The factor that influences the most other factors is ***clean thinking attitude*** followed by ***regulatory requirements.*** These are then followed by five factors that are equal in the number of factors they influence, these are: ***ability to pay***, ***cost of mitigation***, ***farm mitigation***, ***natural characteristics*** and ***separated sewerage (mitigation)***.

It is interesting that the two most influential characteristics (by number) are both social rather than physical, as is one of the third most influential (***ability to pay***). This is likely to be a realistic reflection of how social attitudes and norms are an element of all physical actions, regardless of what they are, and reinforces the normative nature of decision-making. It also highlights the primacy of human needs viewed by many stakeholders within integrated social-biophysical systems.

Factors such as ***costs of mitigation*** and ***natural characteristics*** also have an equal impact on a range of actions, regardless of their technical nature. This accounts for them being near the top of the list.

While ***farm mitigation*** and ***separated sewerage (mitigation)*** rank higher than the other major mitigations identified (***septic tank mitigation*** and ***tourism mitigation***), this is only by a single factor. This single factor is unlikely to indicate any significant dominance of these as influencing factors based on numerical influence analysis alone and not accounting for any weighting of such activities.

Appendix Table 23. Factors that are influenced

FACTORS THAT INFLUENCE			
Factor	Number	Factor	Number
Clean thinking attitude	6	Awareness and perception of contamination/ risk	2
Regulatory requirements	5	Public health	2
Farm mitigation	4	Urban residential/ commercial	2
Separated sewerage (mitigation)	4	Recreational use	2
Natural characteristics	4	Farm run-off	1
Cost of mitigation	4	Cost of regulation	1
Ability to pay	4	Combined sewerage	1
E. coli contamination	3	Sewerage overflows	1
Septic tank mitigation	3	Rural residential	1
Tourism mitigation	3	Urban run-off	1
Tourism	3	Littering	1
Animal life	2	Septic tank overflows	1
Ecological health	2	septic tanks	1
Freedom camping	2	Septic tank efficacy	1
Uncontrolled human waste	2	Sewerage efficacy	0
Farming	2		

For obvious reasons, ***E. coli contamination*** ranks as the highest factor that will be influenced. Following this as the second highest influenced factor is ***tourism mitigation*** followed by ***farm mitigation***. ***Recreational use*** and ***clean thinking attitude*** rank equally as the fourth most influenced factors.

The higher ranking of ***tourism mitigation*** and ***farm mitigation*** is due to these having been linked by the group to the dynamic factors of their associated activities, ***tourism*** and ***farming*** respectively. This not only increases the number of influences to these factors but also highlights their association with activities that have a more commercial nature, rather than activities that would simply respond to the population level (as the remaining factors arguably do).

The high ranking of ***clean thinking*** again indicates the significance of social factors in this system to the group. The equally high-ranking factor of ***recreational use*** is also arguably a factor heavily dependent on social perceptions and decision-making.

Identifying feedback loops

Having outlined how the CLD was analysed and presented to the group and the quantity of influences found, this section summarises the feedback loops and archetypes found.

Reinforcing or balancing feedback loops

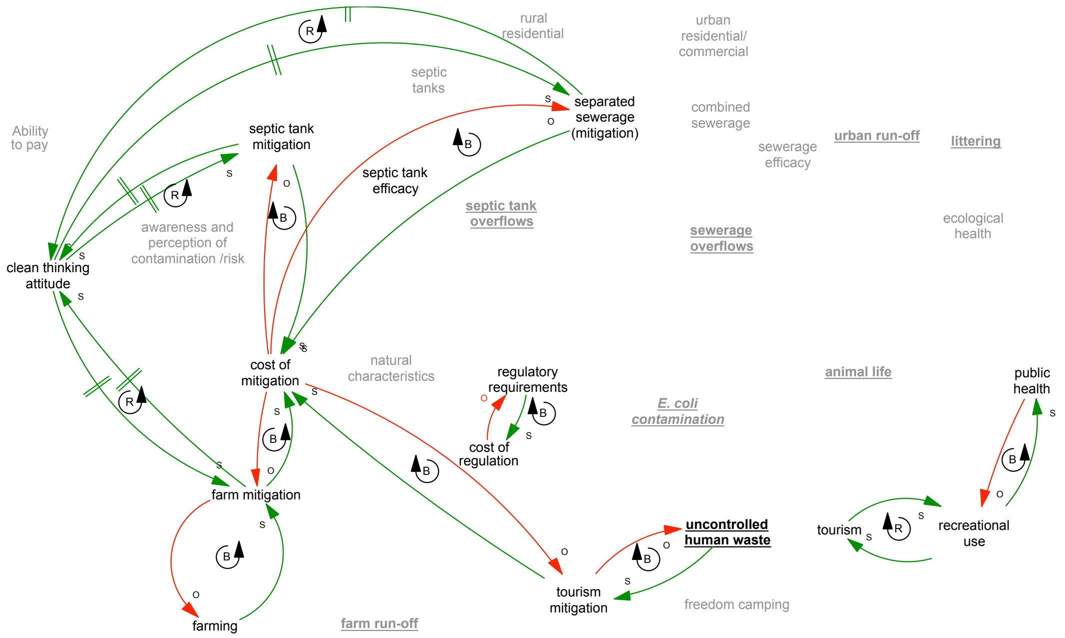
Having looked quantitatively at the factors and influences in the CLD, it is now important to analyse it further to see if it contains any balancing or reinforcing feedback loops. A range of literature outlines the basic building blocks of CLDs, reinforcing and balancing loops (Richardson & Pugh, 1989; Senge, 1990; Sterman, 2000).

Feedback loops identified between two factors are shown in Appendix Figure 46 and totalled in Appendix Table 24. A total of 12 loops were identified, all of which could be clearly labelled as either reinforcing (four) or balancing (eight).

Appendix Table 24. Feedback loops between two factors (table)

Type of feedback loop	Number
Reinforcing (same & same)	4
balancing (same & opposite)	8
Total	**12**

Appendix Figure 46. Feedback loops between two factors (diagram)



Three of the reinforcing loops had ***clean thinking*** as a factor, indicating the importance of this factor in reinforcing feedback.

Only one of these 2-factor loops included one of the main contamination factors. This was ***uncontrolled human waste*** and ***tourism mitigation***.

Costs of mitigation formed *balancing loops* with all four of the main mitigations (***septic tank mitigation***, ***separated sewerage (mitigation)***, ***farm mitigation*** and ***tourism mitigation***). It is also noted that three of the main mitigations (***septic tank mitigation***, ***separated sewerage (mitigation)*** and ***farm mitigation***) formed both a *balancing loop* with ***costs of mitigation*** *and a reinforcing loop* with ***clean thinking attitude***. This would appear to indicate that costs are an influential feature and this is explored further in the system archetypes identified in the next section.

System archetypes: Sawyers Creek

The system archetypes identified are outlines in the next section.

System archetypes found

Feedback loops and archetypes are ‘generic structures’ found in CLDs. “System archetypes” (Senge, 1990) are combinations of reinforcing and/or balancing feedback loops that produce common behaviours seen in systems. In addition to simple feedback and balancing loops, a range of common system archetypes have been described by Senge (1990) and these are provided in detail in Appendix 21. A summary of them is provided in Appendix Table 25.

Appendix Table 25. System archetypes as described by Senge (1990)

System archetype	Common symptom or early way of identifying
Balancing process with delay	*“We thought we were in balance, but then we overshot the mark.” (Later, you might overshoot in the other direction again.)*
Limits to growth	*“Why should we worry about problems we don’t have? We’re growing tremendously.” (A little later, “Sure there are some problems, but all we have to do is go back to what was working before.” Still later, “The harder we run, the more we seem to stay in the same place.”)*
Shifting the burden	*“Look here, this solution has worked so far! What do you mean, there’s trouble down the road?”*
Eroding goals	*“It’s okay if our performance standards slide a little, just until the crisis is over.”*
Escalation	*“If our opponent would only slow down, then we could stop fighting this battle and get some things done.”*
Success to the successful	*One of the two interrelated activities, groups, or individuals is beginning to do very well and the other is struggling.*
Tragedy of the commons	*“There used to be plenty for everyone. Now things are getting tough. If I’m going to get any profit out of it this year, I’ll have to work harder.”*
Fixes that fail	*“It always seemed to work before; why isn’t it working now?”*
Growth and underinvestment	*“Well, we used to be the best, and we’ll be the best again, but right now we have to conserve our resources and not over-invest.”*

Adapted from Senge (1990)

Peter Senge (1990) is not the only person to catalogue archetypes. Several complex archetypes have been added to this core stock (Braun, 2002) while other authors have even proposed the core archetypes be simplified and reduced in number (Wolstenholme, 2003). The archetypes catalogued in *The fifth discipline* (Senge, 1990) are used in part because they are well established and in part because some participants may have already encountered this highly influential book.

The archetypes found in the CLDs was the subject of much of the presentation in the second workshop. This section provides an overview of the archetypes found. A more detailed analysis of the archetypes follows.

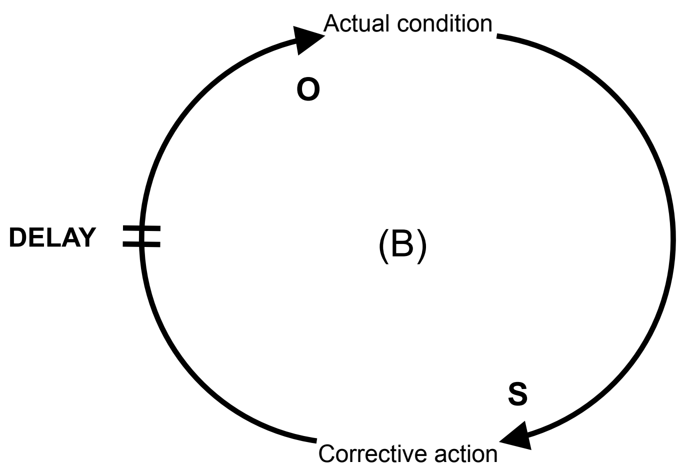
Main system archetypes found: Rangitāiki River

Two types of archetype were identified in the Rangitāiki River CLD – *balancing process with delay* and *limits to growth*.

Balancing process with delay

The archetype template is described below

Appendix Figure 47. Balancing process with delay - archetype



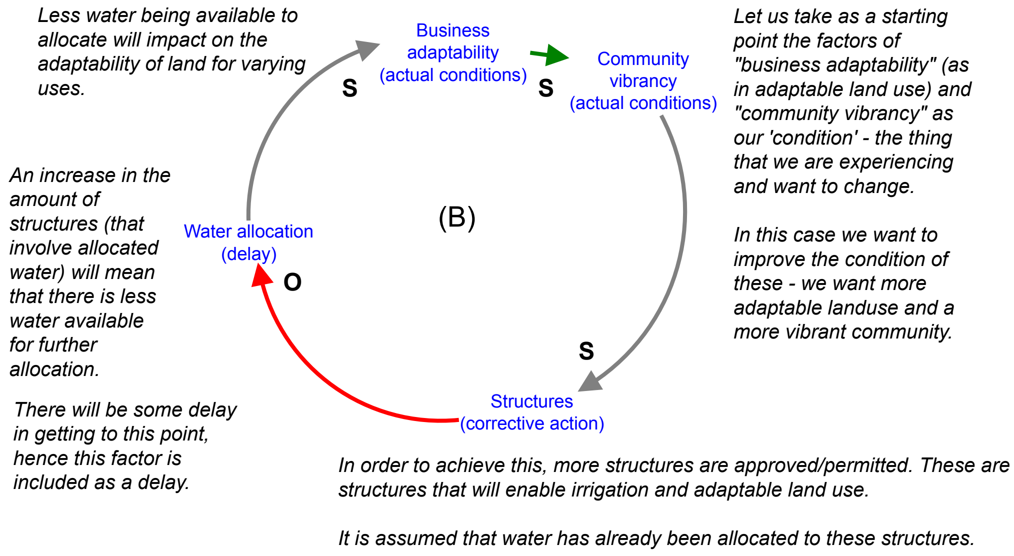
Description: In the pursuit of a goal some action is taken. If you are not conscious of the delay then more corrective action might be taken than is necessary.

Symptom: "We thought we were in balance, but then we overshot the mark" (later you might overshoot in the other direction again).

To manage: In a slow system, agressiveness produces instability. Be patient or make the system more responsive.

Two examples of this were found. One related to **structures** and **water allocation**, the other to **water allocation** and **irrigation**. The **structures and water allocation** example of this is shown in Appendix Figure 48.

Appendix Figure 48. Balancing process with delay – structures and water allocation

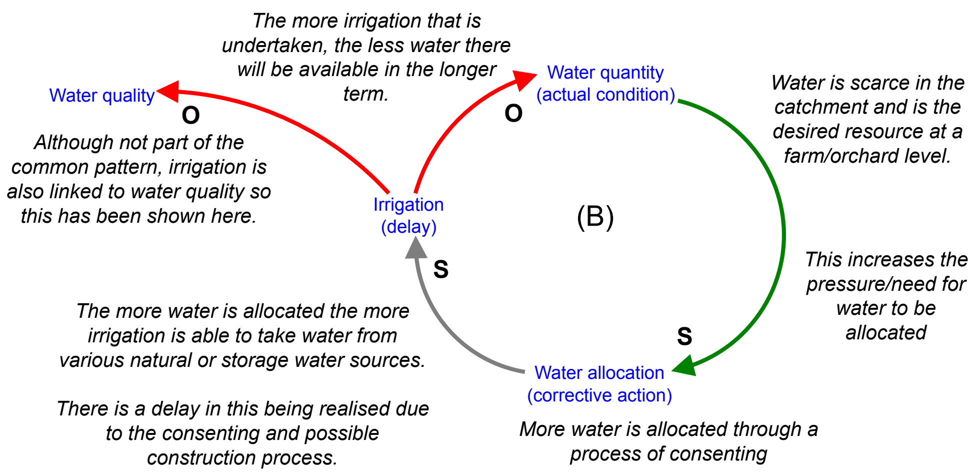


Business adaptability and community vibrancy are the 'actual conditions' within the Rangitāiki catchment, and healthy states of these factors are considered (at least some of) what is desired by the wider community. To achieve these, there is a continued investment in various forms of infrastructure – flood protection assets to ensure community protection, water storage, distribution and irrigation assets to support various forms of land use and business adaptability.

A continued investment in structures and infrastructure has been identified as having an opposite effect on water allocation and, as there would be a delay in this process occurring, this factor has been taken to be the delay in the archetype. Over time this delay will result in a balancing impact on the desired conditions of business adaptability and community vibrancy.

The second balancing feedback loop with a delay related to **water allocation and irrigation** is shown in Appendix Figure 49.

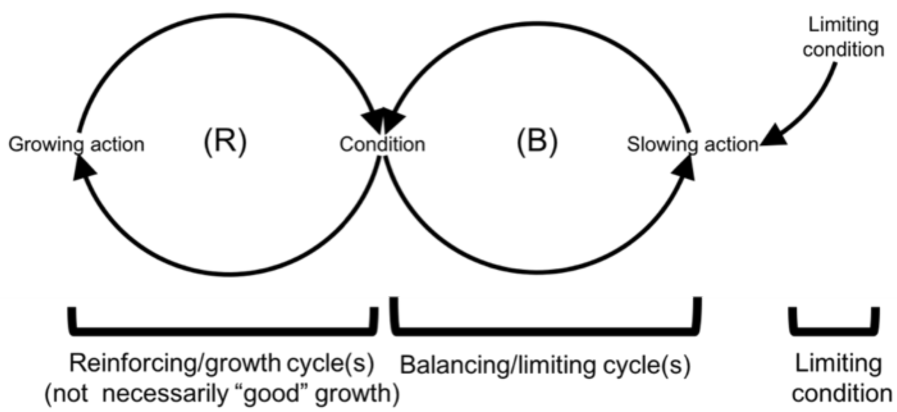
Appendix Figure 49. Balancing process with delay – water allocation and irrigation



Limits to growth

The archetypes template is described in Appendix Figure 50 below.

Appendix Figure 50. Limits to growth – archetype



Description: A process feeds on itself to produce a period of accelerated growth or expansion. Then the growth begins to slow (often inexplicably) and eventually comes to a halt, and may even reverse or enter accelerated collapse.

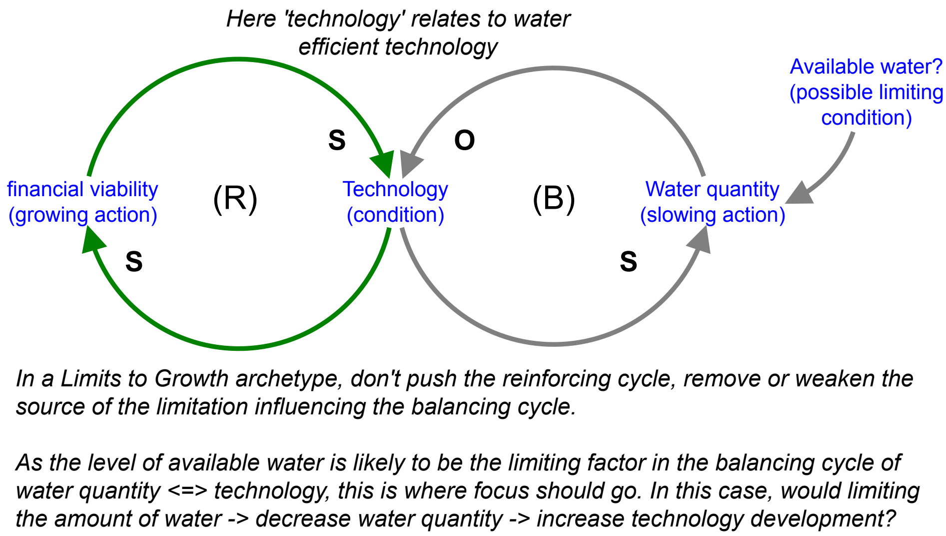
Symptom: "Why should we worry about problems we don't have? We're growing tremendously." (A little later, "sure there are som eproblems, but all we have to do is go back to what was working before." Still later "The harder we run the more we seem to stay in the same place.")

To manage: In a Limits to Growth archetype, don't push the reinforcing cycle, remove or weaken the source of the limitation influencing the balancing cycle.

Two potential limits to growth archetypes were found, where the growing actions in each were **financial viability** and **business adaptability**.

The financial viability example is shown in Appendix Figure 51.

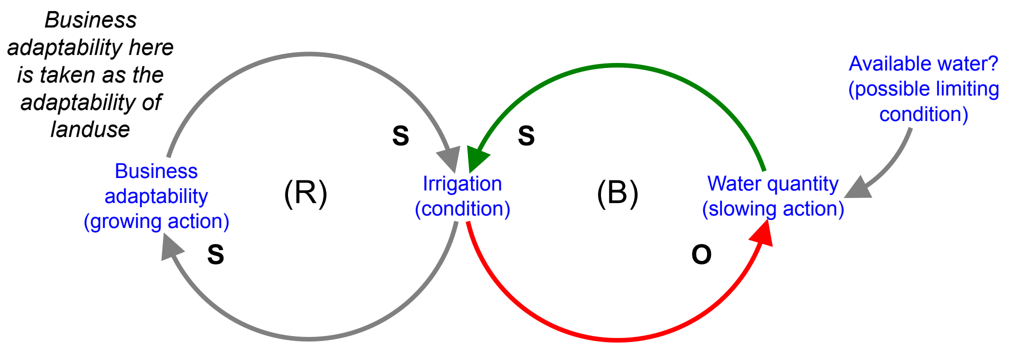
Appendix Figure 51. Limits to growth – financial viability



Improved financial viability is pursued by improving technology, which in turn again further improves financial viability. However, as available water is likely to be the limiting factor in the balancing feedback loop between water quantity and technology, this is where focus should go. In this case, would restricting the amount of water available effectively decrease the amount of water available for allocation (water quantity) and thus incentivise an increase in technology development? This is turn would then feed into the reinforcing cycle on the left and improve financial viability.

The second limits to growth archetype identified, relating to business adaptability, is shown in Appendix Figure 52.

Appendix Figure 52. Limits to growth – business adaptability



In a Limits to Growth archetype, don't push the reinforcing cycle, remove or weaken the source of the limitation influencing the balancing cycle.

As the level of available water is likely to be the limiting factor in the balancing cycle of water quantity <=> irrigation, this is where focus should go. In this case, would increasing the amount of available water -> increase water quantity -> increasing the level of irrigation?

Business adaptability (focusing here on the adaptability of land use) is pursued through irrigation, which in turn further drives the adaptation of land use. Yet the water quantity, or water available for allocation, is likely to be the limiting factor in the balancing cycle on the right, reducing the amount of irrigation that can occur. In this case, would increasing the amount of available water for allocation in turn increase the amount of water available for increasing irrigation? Moreover, would this contribute to the reinforcing cycle of adaptability of land use in the left-hand feedback loop?

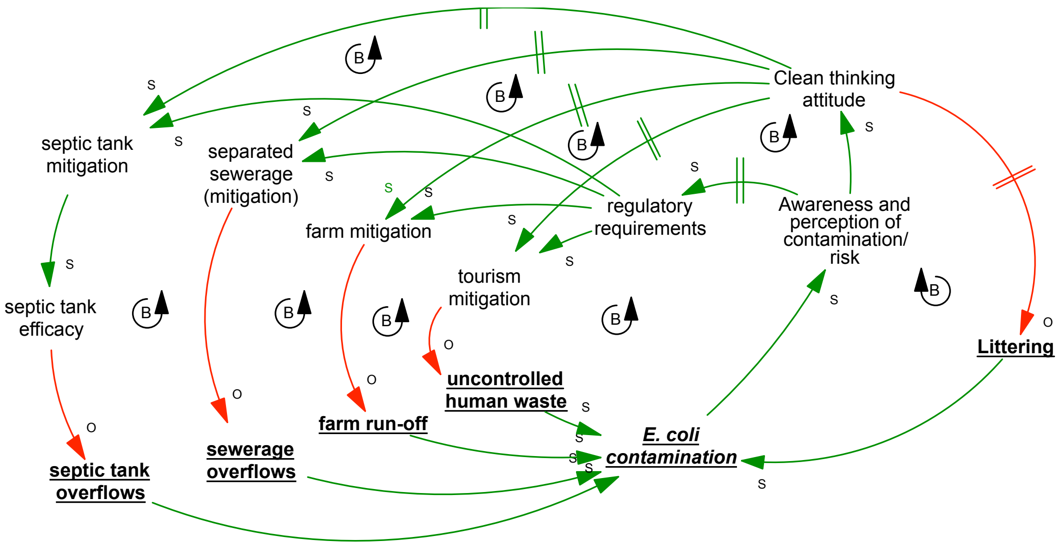
Main system archetypes found: Sawyers Creek

Two types of archetype were identified in the Sawyers Creek CLD – *balancing process with delay* and *limits to growth*.

Balancing process with delay

The archetype template for *balancing process with delay* is provided earlier in Appendix Figure 47. Nine major balancing processes with delays were found in the CLD, these are shown in Appendix Figure 53 and link through *E. coli*, then *awareness and perception of contamination/risk* before linking via either *regulatory requirements* or *clean thinking attitude*.

Appendix Figure 53. Balancing processes with delay



Four main mitigations were identified by the group and eight of these balancing loops link via these mitigations, two for each mitigation – one each via regulatory requirements and clean thinking attitude. The ninth balancing loop links via *clean thinking attitude* and *littering*.

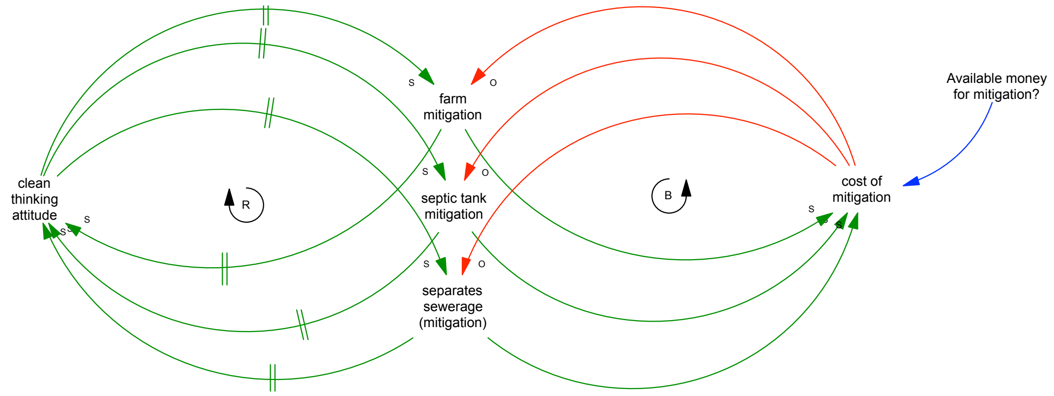
This demonstrates how it is the same societal structures and psychological influences that are the main driving force behind the mitigations, indicating these influencing factors are likely to be where leverage is gained for the benefit of all mitigations and therefore the system.

The CLD indicated that if *E. coli* contamination increased, this would eventually create pressure on regulators to introduce more stringent regulation or legislation. Once new regulation was in place, then further mitigations would be implemented, eventually leading to a reduction in *E. coli* contamination levels. It was identified by the group that it was this process that had played out in the introduction of the *NPS-FM 2014*.

Limits to growth & Limits to decline

The archetype template for *Limits to Growth* is provided earlier in Appendix Figure 50. As above, this archetype was mirrored through three of the mitigations; *farm mitigation*, *septic tank mitigation* and *separated sewerage (mitigation),* as shown in Appendix Figure 54.

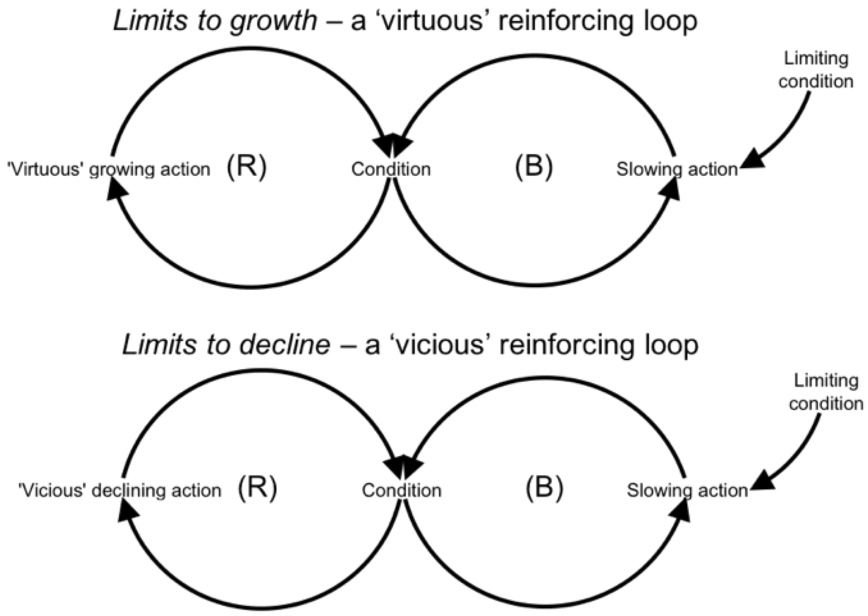
Appendix Figure 54. **Limits to growth – Clean thinking impact on mitigations (combined)**



This shows that while increases in clean thinking will form a reinforcing loop with the three mitigations, the extent to which this loop can operate will be limited by the money available for mitigations, as the cost of mitigations will have a balancing impact on how much mitigation will be implemented. This has implications for the development of policy because while increasing clean thinking attitudes was identified in the previous section as one area of intervention, this archetype indicates that the extent that this can be achieved will be limited by amounts of available money. So, this effectively suggests that a joint policy approach of increasing awareness and influencing attitudes, as well as finding additional sources of funding, could be suitable.

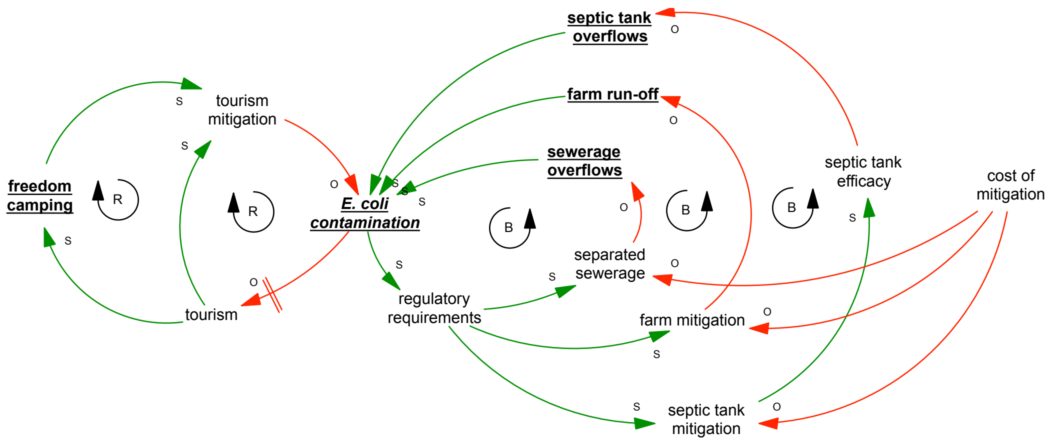
While the archetype is called *Limits to growth*, this research suggests that it can also work in the opposite direction, instead acting as *Limits to Decline*. A reinforcing loop can be either *virtuous* or *vicious* (Senge, 1990). If that present in a *Limits to growth* archetype is a *virtuous* reinforcing loop, then when it works in the opposite direction and become a vicious loop, the archetype describes *Limits to decline* behaviour. When coupled with a balancing loop and a limiting factor, the same dynamics would be present than with *Limits to growth*, but simply in reverse. This is demonstrated conceptually in Appendix Figure 55.

Appendix Figure 55. **Demonstration of the 'Limits to decline' application of the 'Limits to growth' archetype. Note the opposite 'vicious' reinforcing loop and the identification of an 'enabling' factor rather than a 'limiting' factor.**



The impacts of *E. coli* contamination on tourism were identified as a series of vicious reinforcing loops (via *E. coli contamination*), while the balancing loops were those through the three main mitigations already discussed and the limiting condition is the *cost of mitigation*. This is shown in Appendix Figure 56.

Appendix Figure 56. **Limits to decline – *E. coli* contamination impact on tourism**



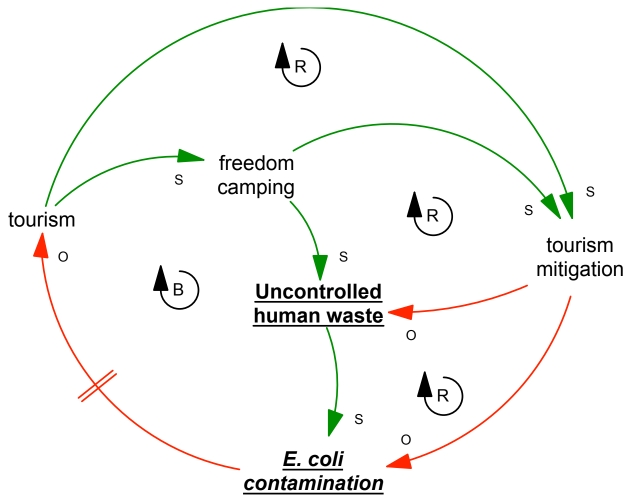
As *E. coli contamination* increases, this will have an opposite impact on tourism and its contribution to contamination. However, it will in turn decrease the amount of *tourism mitigation* (general waste and toilet infrastructure tourists and freedom campers) put in place, resulting in the reinforcing impact of further *E. coli contamination* occurring. To reverse this, *E. coli* contamination must be reduced by the mitigations already discussed earlier, which in turn are limited by the *cost of mitigation*. This archetype could operate via any combination of the balancing and reinforcing loops identified, so all are shown together, rather than all combinations individually. It is also noted that while the *cost of mitigation* is the limiting factor of the balancing loops, it was also identified as an opposite influence on tourism mitigation. While this is not strictly a part of the *Limits to Growth* archetype, it has been included in the diagram to demonstrate the common influence that this factor has on all mitigations identified.

This archetype is important to note for any possible policy development because it would suggest that the *cost of mitigation* is a primary target for long-term policy leverage in the system. However, intervention in this area would also impact on the reinforcing side of the archetype, thus influencing the desired outcome from several areas of intervention.

The tourism sub-system

While the sub-system of tourism is not itself an archetype, it is worth noting as it is a major industry of the West Coast and one where continued growth is both desired and probable based on current trends in tourism. Because of this, some patterns within the tourism sub-system are worth noting. A summary of the tourism sub-system is shown in Appendix Figure 57.

Appendix Figure 57. The tourism sub-system



As shown in the figure, the tourism sub-system is made up of three reinforcing loops and one balancing loop.

The single balancing loop indicates that any increase in tourism means a corresponding increase in freedom camping, resulting in an increase in ***uncontrolled human waste***. This increases *E. coli* contamination which in turn has an ***opposite*** effect on tourism, resulting in a *balancing* feedback loop. This means that any benefits gained in tourism numbers have the potential to be negated through an increase in freedom camping and *E. coli* contamination. This sub-system has major potential implications for tourism-related policy and is acknowledged as an important insight, even though no potential policy levers were identified by the group.

The *reinforcing* loops indicate that the less *E. coli* contamination there is, the better the tourist experience and therefore the more tourists would visit New Zealand in the longer term. This is due to the delayed effect of word of mouth amongst travellers and/or return visits by tourists. Over time, this would increase the amount of tourist facilities that are built (tourism mitigation), which in turn will continue to decrease the potential for *E. coli* contamination. This insight shows that tourism policy should ensure tourism mitigation is put in place as much as a *driver* of tourism, as a *response* to it. Given the delays in word of mouth or potential return travellers, this factor has been identified as having an influence on the number of future tourists as much as the experience of existing ones.

Discussion of CLDs and system archetypes

This section focuses on the comparing and contrasting the feedback loops and archetypes across both case studies. In addition to the simple feedback loops identified, the only archetypes (as described by Senge, 1990) found in the CLDs were *Balancing process with delay* and *Limits to growth (Senge, 1990)*. A 'vicious' example Limits to growth is proposed and called *Limits to decline*.

Individual CLDs naturally reflect the individual circumstances of the system it represents from the perspective of those that built it. It is noted that the Sawyers Creek project generated a much higher number of variables and that all the influences (bar one) were clearly labelled as either **same** or **opposite**. The reasons for this have already been discussed in section 0 and these are acknowledged here.

As discussed, after the first workshop, both CLDs were analysed to identify simple two-variable feedback loops. Interestingly, *both* projects had the same number (12) but only four of these were clearly labelled as either reinforcing or balancing in the Rangitāiki CLD as most of the influences were 'undefined'. All of them were labelled in the Sawyers Creek CLD. Of these relationships in the Sawyers Creek CLD, two thirds were balancing, indicating a large amount of natural balancing in the system at a fundamental level of interaction (two-variable interaction). As these loops are the fundamental building blocks for understanding the system (Senge, 1990), it is likely that much of the activity in the Sawyers Creek system is likely to balance itself out, possibly demonstrated as the oscillation of different variables around certain levels (Sterman, 2000). This reinforces the benefit of having a clear problem focus to the modelling effort (Sterman, 2000; van den Belt, 2004; Vennix, 1996).

Single feedback loops are most useful for highlighting the time delay component of a system (Senge, 1990) and tend to be single problem focused (Braun, 2002). It is their interaction with other feedback loops in other archetype structures that is more likely to highlight areas of intervention in at a system level. The first of the two main archetypes identified was the balancing process with delay (Senge, 1990), which is a logical extension of simply identifying two-variable feedback loops. While these were straight forward in the Rangitāiki CLD (see Appendix Figure 48 and Appendix Figure 49), they were much more numerous in Sawyers Creek (see Appendix Figure 53), where a large number of them were linked through the problem variables of *E. coli* contamination and either *regulatory requirements* or *clean-thinking attitude*. This is considered a direct result of the clearer problem focus advocated for SD modelling (Sterman, 2000; Vennix, 1996). For the Sawyers Creek CLD as well, this also highlighted the way that most sources of contamination were also influenced by similar variables – attitudes and regulation.

Limits to growth was the other archetype identified in the CLDs. Of the archetypes described by Senge (1990), it is one of the more accessible, utilising only two interconnected feedback loops. While it is not the only archetype utilising two interconnected feedback loops (Senge, 1990), it is an archetype that applies when actors are concerned with trying to sustain growth in a context in which constraints to this expansion exist, which aligns with the context of the two case studies (Braun, 2002).

As discussed previously (section 0), the undefined nature of many of the influences in the Rangitāiki CLD resulted in the researcher having to make some assumptions to hypothesise the existence of various archetypes – especially *Limits to growth* examples. This provided finer insight in an environment where the CLD had become quite coarse because of poor clarity inherent within the focus question. However, it led to potential distrust of the archetype amongst group participants, given their reluctance to accept without analysis the conclusions that others, rather than themselves, had reached (Schein, 1988).

It is also noted that given the highly-aggregated scale of some of the variables defined by the Rangitāiki group, some were likely to include elements that were *exogenous* to the catchment – but not the problem. While trying to incorporate the system boundary within an archetype is something that is advocated by Wolstenholme (2003), it has not been attempted here. This is partly because that would have required an investment of time that was not available to educate participants on this aspect of archetype definition. Instead, the approach was taken that the archetypes were a key communication device that enabled key dynamic insights (Wolstenholme, 2003), but did not include discussions around what constitutes an appropriate model boundary, in line with general theory (Senge, 1990).

For the Sawyers Creek CLD this was not an issue, and the clarity provided by the research question allowed clear archetypes to be defined. The smaller geographic scale of the problem also seemed to avoid issues of variables being *exogenous* to a geographic system, although they were often exogenous to an *organisational* one (e.g. responsibilities for variables identified lay with different councils). Given the inter-related nature of many of the variables and their linkage through a clearly defined problem variable (*E. coli contamination*), the range of *Limits to growth* archetypes developed were quite comprehensive and exhibited a strong sense of similarity too.

While it has been acknowledged that the *Limits to growth* archetype can be applied with either a *virtuous* or *vicious* reinforcing loop, this research takes the step of labelling the *vicious* version ‘Limits to decline’, as described in the earlier section called *Main system archetypes found: Sawyers Creek* and shown in Appendix Figure 55. While *Limits to growth* certainly originated from the application of SD modelling to environmental problems (Braun, 2002; Meadows et al., 1974), this was usually observed in relation to the *growth* of a stock against some environmental limit. The application of the *vicious* cycle version here is an attempt to recognise the salience of a *decline* in the quantity or quality of environmental stocks, such as water quality or quantity, with economic activity.

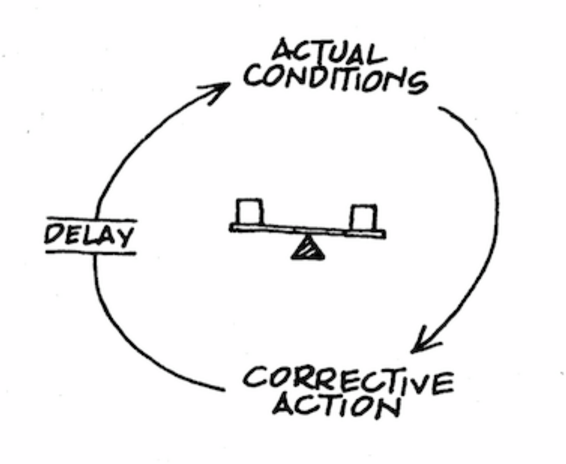
Appendix 21 System archetypes

This section provides a summary of the system archetypes as described by Peter Senge (1990). The images and accompanying text have been taken directly from:

Senge, P. (1990). *The fifth discipline - The art and practice of the learning organization*. London, United Kingdom: Random House.

Balancing process with delay

Structure:



Description:

A person, a group, or an organization, acting toward a goal, adjusts their behaviour in response to a delayed feedback. If they are not conscious of the delay, they end up taking more corrective action that needed, or (sometimes) just giving up because they cannot see that any progress is being made.

Early Warning Symptom:

“We thought we were in balance, but then we overshot the mark.” (Later, you might overshoot in the other direction again.)

Management Principle:

In a sluggish system, aggressiveness produces instability. Either be patient or make the system more responsive.

Business Story:

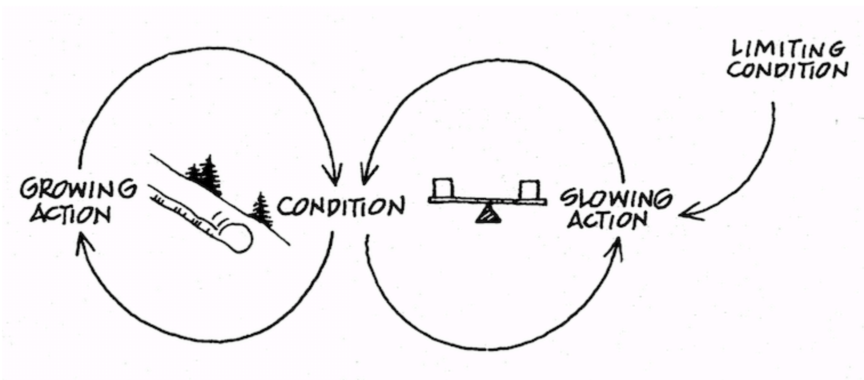
Real estate developers keep building new properties until the market has gone soft – but, by then, there are already enough additional properties still under construction to guarantee a glut.

Other Examples:

A shower where the hot water responds sluggishly to changes in the faucet positions; production/distribution glut and shortage cycles (such as that of the beer game); cycles in production rates and in-process inventory due to long manufacturing cycle times; the Tiananmen Square massacre. In which the government its action to protest, and then cracked down unexpectedly hard; sudden excessive stock market soars and crashes.

Limits to growth

Structure:



Description:

A process feeds on itself to produce a period of accelerating growth or expansion. Then the growth begins to slow (often inexplicably to the participants in the system) and eventually comes to a halt, and may even reverse itself and begin an accelerating collapse.

The growth phase is caused by a reinforcing feedback process (or by several reinforcing feedback processes). The slowing arises due to a balancing process brought into play as a "limit" is approached. The limit can be a resource constraint, or an external or internal response to growth. The accelerating collapse (when it occurs) arises from the reinforcing process operating in reverse, to generate more and more contraction.

Early Warning Symptom:

“Why should we worry about problems we don’t have? We’re growing tremendously.” (A little later, “Sure there are some problems, but all we have to do is go back to what was working before.” Still later, “The harder we run, the more we seem to stay in the same place.”)

Management Principle:

Don’t push on the reinforcing (growth) process, remove (or weaken) the source of the limitation (barrier to growth).

Business Story:

A company instituted an affirmative action program, which grew in support and activity as well-qualified minority employees were successfully introduced into work teams throughout the company. But eventually resistance emerged; the new staffers were perceived as not having “earned” their positions over other qualified aspirants. The harder individual teams were pressured to accept the new members the more they resisted.

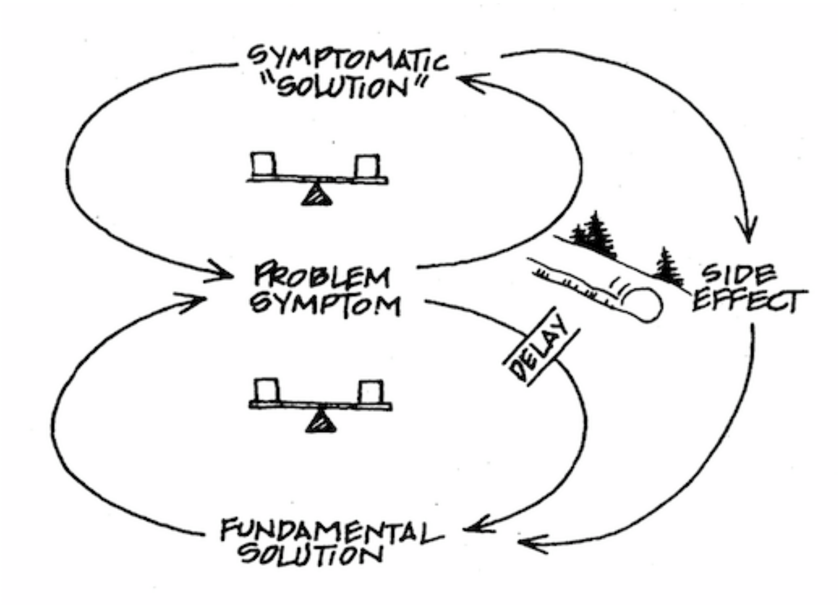
Other Examples:

Learning a new skill, such as tennis, you make a rapid progress early on as your competence and confidence builds, but then you begin to encounter limits to your natural abilities that can be overcome only by learning new techniques that may come “less naturally” at first.

A new start-up that grows rapidly until it reaches a size that requires more professional management skills and formal organization; a new product team that works beautifully until its success causes it to bring in too many new members who neither share the work styles nor values of the founding members; a city that grows steadily until available land is filled, leading to rising house prices; a social movement that grows until it encounters increasing resistance from “nonconverts”; an animal population that grows rapidly when its natural predators are removed, only to overgraze its range and decline due to starvation.

Shifting the burden

Structure:



Description:

A short-term “solution” is used to correct a problem, with seemingly positive immediate results. As this correction is used more and more, more fundamental long-term corrective measures are used less and less. Over time, the capabilities for the fundamental solution may atrophy or become disabled, leading to even greater reliance on the symptomatic solution.

Early Warning Symptom:

“Look here, this solution has worked so far! What do you mean, there’s trouble down the road?”

Management Principle:

Focus on the fundamental solution. If symptomatic solution is imperative (because of delays in fundamental solution), use it to gain time while working on the fundamental solution.

Business Story:

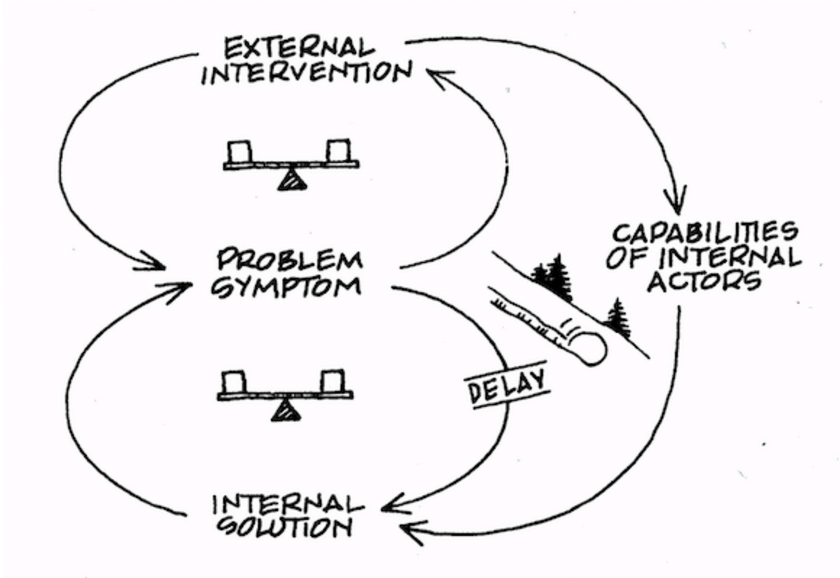
A dramatic new circuit board technology can be used to develop unique functionality and cost savings in a great many new product applications, but it can also be substituted for existing boards in current products. Salespeople can try to sell to “speciality customers” who appreciate the special properties of the technology and will eventually design new products which exploit it fully (the “fundamental solution”) or sell to “commodity customers” who do not care about its special properties and will simply substitute it for other boards (the “symptomatic solution”). Given management pressures to meet quarterly sales targets, salespeople sell to whoever is ready to buy, which usually will be commodity customers since there are more of them and delays in the selling cycle are shorter. Over time, the dramatic new technology fails to develop a loyal customer base and becomes subject to the price and margin pressures that characterise commodity products.

Other Examples:

Selling more to existing customers rather than broadening the customer base; paying bills by borrowing, instead of going through the discipline of budgeting; using alcohol, drugs, or even something as benign as exercise to relieve work stress and thereby not facing the need to control the workload itself; and any addiction, anywhere, to anything.

Special case: shifting the burden to the intervenor

Structure:



One area where shifting the burden structures are so common and so pernicious that it warrants special notice is when outside "intervenors" try to help solve problems. The intervention attempts to ameliorate obvious problem symptoms, and does so successfully that the people within the system never learn to deal with the problem themselves.

Management Principle:

"Teach people to fish, rather than giving them fish." Focus on enhancing the capabilities of the "host system" to solve its own problems. If outside help is needed, "helpers" should be strictly limited to a one-time intervention (and everyone knows this in advance) or be able to help people develop their own skills, resources, and infrastructure to be more capable in the future.

Business Story:

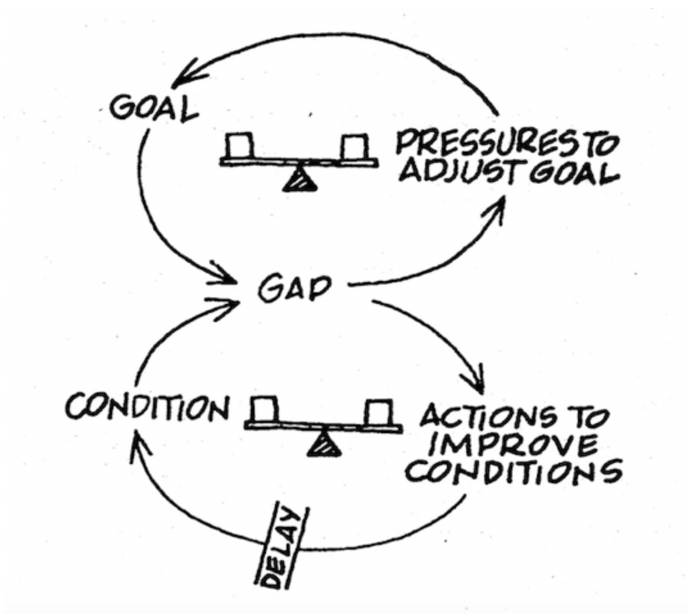
An innovative insurance company was committed to the concept of independent local offices that would call on headquarters staff only for occasional help. Initially the concept worked well, until the industry went through a crisis. Facing sudden severe losses, the local offices called in the more experienced central management for help in rewriting new structure – a process which took months. Meanwhile, the local managers focused their attention on managing the crisis. The crisis was resolved, but the next time rate structures were called into questions, the local offices had lost some of their confidence. They called in the central managers as "insurance." After several years of this behaviour, the local offices found themselves without underwriters who could manage rate structure changes independently.

Other Examples:

Dependence on outside contractors instead of training your own people. Numerous forms of government aid that attempt to solve pressing problems only to foster dependency and need for increasing aid: welfare systems that foster single-family households; housing and job training programs that attract the needy to cities with the best programs; food aid to developing countries which lowers deaths and increases population growth; social security systems that reduce personal savings and encourage the breakup of the extended family.

Eroding goals

Structure:



Description:

A shifting the burden type structure in which the short-term solution involves letting a long-term, fundamental goal decline.

Early Warning Symptom:

"It's okay if our performance standards slide a little, just until the crisis is over."

Management Principle:

Hold the vision.

Business Story:

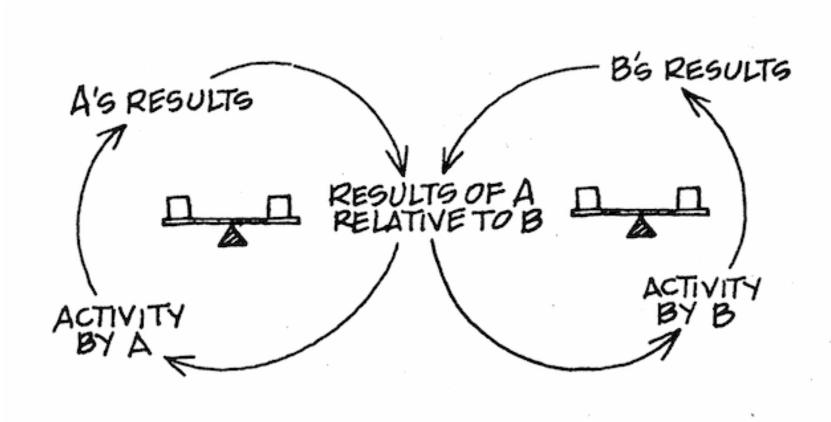
A high-tech manufacturer finds itself losing market share, despite a terrific product and ongoing improvements. But the firm, oriented towards its design "geniuses", had never gotten production scheduling under control. An outside investigator discovered that customers were increasingly dissatisfied with late schedules, and were turning to competitors instead. The company stood on its record: "We've maintained a consistent 90 percent success in meeting the delivery time quoted to the customer." I therefore looked elsewhere for the problem. However, every time the company began to slip its schedules, it responded by making the quoted delivery time a little longer. Thus, the quoted delivery time to customers was getting lengthier, and lengthier, and lengthier…

Other Examples:

Successful people who lower their own expectations for themselves and gradually become less successful. Firms that tacitly lower their quality standards by cutting budgets rather than investing in developing new higher quality (and perhaps lower cost) ways of doing things, all the while proclaiming their continued commitment to quality. Lowered government targets for "full employment" or balancing the federal deficit. Sliding targets for controlling dangerous pollutants or protecting endangered species.

Escalation

Structure:



Description:

Two people or organisations each see welfare as depending on a relative advantage over the other. Whatever one side gets ahead the other is more threatened, leading it to act more aggressively to re-establish its advantage, which threatens the first, increasing its aggressiveness, and so on. Often each side sees its own aggressive behaviour as a defensive response to the other's aggression; but each side acting "in defence" results in a build-up that goes far beyond either side's desires.

Early Warning Symptom:

"If our opponent would only slow down, then we could stop fighting this battle and get some things done."

Management Principle:

Look for a way for both sides to "win", or to achieve their objectives. In many instances, one side can unilaterally reverse the vicious spiral by taking overtly aggressive "peaceful" actions that cause the other to feel less threatened.

Business Story:

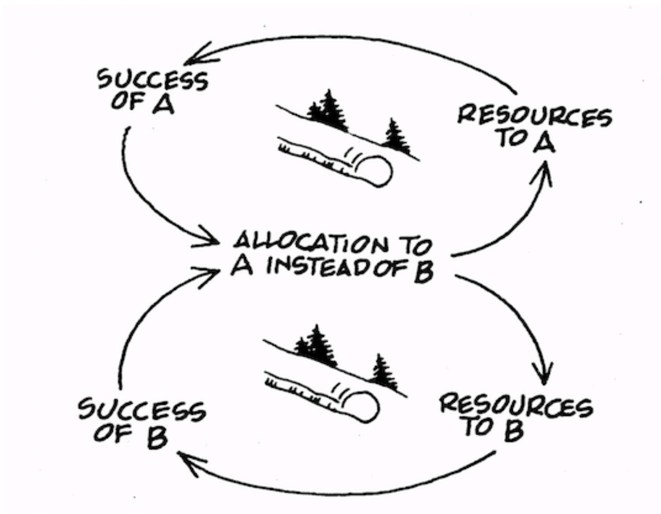
A company developed an ingenious design for a stroller, which carried three toddlers at once, yet was light and convenient for travel. It was an immediate hit with families with several young children. Almost simultaneously, a competitor emerged with a similar product. After several years, jealous of the other company's share of the market, the first company lowered its price by 20 percent. The second company felt a decline in sales, and lowered its price too. Then the first company, still committed to boosting share, lowered its prices still further. The second company reluctantly did the same, even though its profits were beginning to suffer. Several years later, both companies were barely breaking even, and survival of the triple carriage was in doubt.

Other Examples:

Advertising wars. Increasing reliance on lawyers to settle disputes. Gang warfare. The breakup of a marriage. Inflating budget estimates: as some groups inflate their estimates, others find themselves doing likewise in order to get "their piece of the pie." Which leads to everyone inflating his estimates still further. Battle for the "ear" of the president of a company. And, of course, the arms race and the war on terror.

Success to the successful

Structure:



Description:

Two activities compete for limited support and resources. The more successful one becomes, the more support it gains, thereby starving the other.

Early Warning Symptom:

One of the two interrelated activities, groups, or individuals is beginning to do very well and the other is struggling.

Management Principle:

Look for the overarching goal for balanced achievement of both choices. In some cases, break or weaken the coupling between the two, so that they do not compete for the same limited resource (this is desirable in cases where the coupling is inadvertent and creates an unhealthy competition for resources)

Business Story:

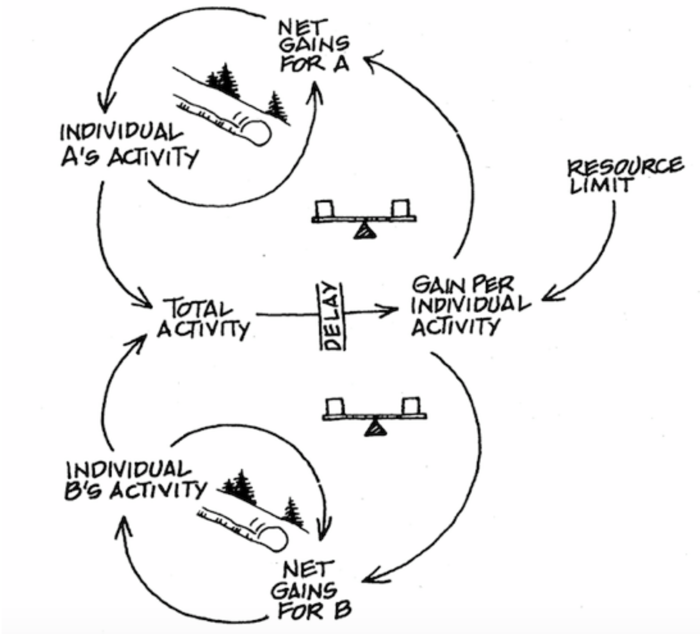
A manager has two protégés, and wishes to bring both along equally in the firm. However, one of the two ends up getting preferential treatment because the other is out sick for a week. When the second protégé returns to work, the manager feels guilty, and avoids the person, thereby giving still more opportunity to the first protégé. The first protégé, feeling the approval, flourishes, and therefore gets more opportunity. The second protégé, feeling insecure, does less effective work and receives even fewer opportunities, although the two people had equal ability in the beginning. Eventually, the second protégé leaves the firm.

Other Examples:

Balancing home and work life, in which a worker gets caught working overtime so much that relationships at home deteriorate and it gets more and more “painful” to go home, which, of course, makes the worker even more likely to neglect home life in the future. Two products compete for limited financial and managerial resources with a firm; one is an immediate hit in the marketplace and receives more investment, which depletes resources available to the other, setting in motion a reinforcing spiral fuelling growth of the first and starving the second. A shy student gets off to a poor start in school (perhaps because of emotional problems or an undetected learning disability), becomes labelled a “slow learner”, and gets less and less encouragement and attention that his or her more outgoing peers.

Tragedy of the commons

Structure:



Description:

Individuals use a commonly available but limited resource solely on the basis of individual need. At first they are rewarded for using it; eventually they get diminishing returns, which causes them to intensify their efforts. Eventually, the resource is either significantly depleted, eroded, or entirely used up.

Early Warning Symptom:

“There used to be plenty for everyone. Now things are getting tough. If I’m going to get any profit out of it this year, I’ll have to work harder.”

Management Principle:

Manage the “commons” either through educating everyone and creating forms of self-regulation and peer pressure, or through an official regulating mechanism, ideally designed by participants.

Business Story:

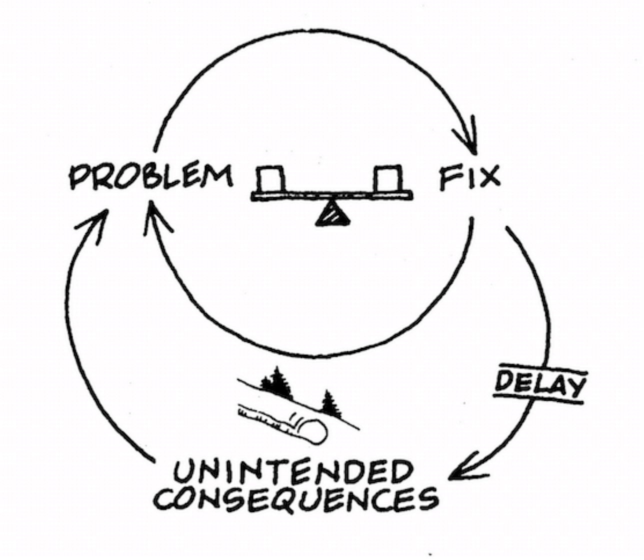
Several divisions of a company agreed to share a retail salesforce. Each district manager was initially concerned that the shared salesforce wouldn't give enough attention to his or her particular business, and that volume would decline. One particularly aggressive manager advised all his account managers to set higher sales targets than were truly needed, so that the salesforce would at least give them the minimum support they needed. The other divisions saw this divisions pushing for extra work, and decided to employ the same strategy. The new salesforce's managers wanted to accommodate all of their "clients," so they continued to accept the higher requests from the divisions. This created a tremendous overburden of work, lowered performance, and increased turnover. Pretty soon, joining the retail salesforce was only slightly more popular than joining the French Foreign Legion, and each division had to go back to maintaining its own salesforce.

Other Examples:

Exhaustion of a shared secretarial pool. Deteriorating reputation for a customer service after customers have had to listen to six different salespeople from six different divisions of the same corporation pitching competing products. The "shared resource" in this case was the firm's positive customer reputation.) A highly successful retail chain gives up on joint sales promotions with manufacturers after being deluged with proposals by enthusiastic manufacturers, or establishes terms for joint ventures that leave little profit for the manufacturers. Depletion of a natural resource by competing companies which mine it. And, of course, all manner of pollution problems from acid rain to ozone depletion and "the greenhouse effect."

Fixes that fail

Structure:



Description:

A fix, effective in the short term, has unforeseen long-term consequences which may require even more use of the same fix.

Early Warning Symptom:

"It always seemed to work before; why isn't it working now?"

Management Principle:

Maintain focus on the long term. Disregard short-term "fix," if feasible, or use it only to "buy time" while working on long-term remedy.

Business Story:

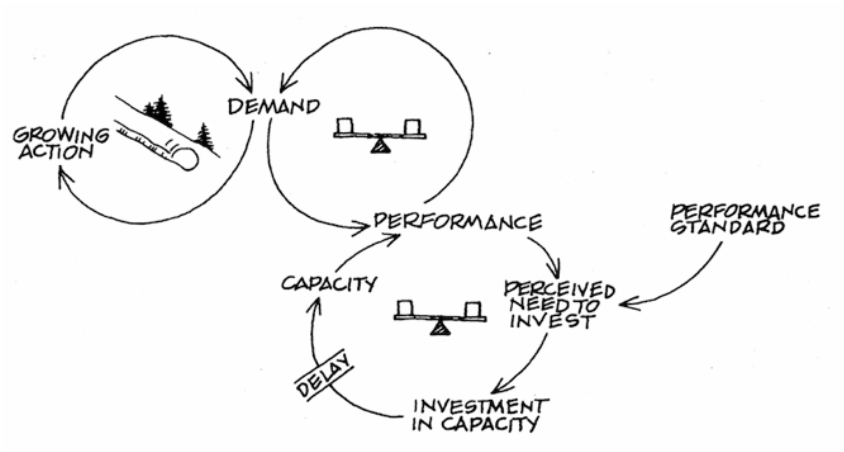
A manufacturing company launched a new set of high-performance parts, which were wildly successful at first. However, the CEO was driven by maximising ROI, so he deferred ordering expensive, new production machines. Manufacturing quality suffered, which led to a reputation for low quality. Customer demand fell off dramatically over the ensuing year, which depressed returns and made the CEO even more unwilling to invest in new production equipment.

Other Examples:

People and organisations who borrow to pay interest on other loans, thereby ensuring that they will have to pay even more interest later. Cutting back maintenance schedules to save costs, which eventually leads to more breakdowns and higher costs, creating still more cost-cutting pressures.

Growth and underinvestment

Structure:



Description:

Growth approaches a limit which can be eliminated or pushed into the future if the firm, or individual, invests in additional capacity.” But the investment must be aggressive and sufficiently rapid to forestall reduced growth, or else it will never get made. Oftentimes, key goals or performance standards are lowered to justify investment. When this happened, there is a self-fulfilling prophecy where lower goals lead to lower expectations, which are then borne out by poor performance caused by underinvestment.

Early Warning Symptom:

“Well, we used to be the best, and we’ll be the best again, but right now we have to conserve our resources and not over-invest.”

Management Principle:

If there is a genuine potential for growth, build capacity in advance of demand, as a strategy for creating demand. Hold the visions, especially as regards assessing key performance standards and evaluating whether capacity to meet potential demand is adequate.

Business Story:

People Express Airlines found itself unable to build service capacity to keep pace with exploding demand. Rather than putting more resources into training or growing more slowly (for example, through raising prices somewhat), the firm tried to “outgrow” it’s problems. The result was deteriorating service quality and increased competition, while morale deteriorated. In order to keep up with the continued stress, the company relied more and more on the “solution” of underinvesting in service capacity, until customers no longer found flying People Express attractive.

Other Examples:

Companies which let service quality or product quality of any sort decline, simultaneously blaming competition or their sales management for not pushing hard enough to maintain sales. People with grand visions who never realistically assess the time and effort they must put in to achieve their visions.

Appendix 22 List of initial codes

Below is a table of the initial codes generated by the researcher, totalling 733.

A certain outcome may be impossible
A decision will need to be made
A written record of the info is important, to back up and explain the CLD
Ability to work together important
Achieved a lot within a limited time
achievements not celebrated
Action perceived as possibly inadequate
Active participation improved understanding
Advertised by council
Adverts placed for representation
Aligning on terminology can be difficult
All models limited, need to make assumptions in decision-making
Allows you to look at overall as well as focused parts
Already a rep on other council groups
Analysing by parts was useful
Analysing in sections provided clarity
Analysis of a part helped
Analysis of parts of diagram provided clarity
Analysis or breaking CLD into parts provided clarity
Analysis provided clarity
Applicability of process

Applicability of the process to different things
Applicable approach to a variety of problems
Applicable to different situations
Appreciate the gravity of decisions being made
Approach applicable across many problems
Approach different to traditional approaches/process
Approach improved shared understanding
Approach is holistic
Archetype too generic, needs more detail
Archetypes and analysis as a communication tool
Archetypes and analysis useful
Archetypes and partial analysis provide clarity
Archetypes as a communication tool
Archetypes as a useful tool
Archetypes difficult to understand
Archetypes help focus conversation moving forward
Archetypes helped focus discussion
Archetypes helped provide clarity & insight
Archetypes helped understanding of parts/provided clarity
Archetypes highlighted areas of intervention
Archetypes highlighted inter-connections and root causes
Archetypes may focus attention away from impacts across overall system
Archetypes not explained or interpreted correctly
Archetypes perceived as facilitator suggesting course of action
Archetypes provide clarity

Archetypes provided clarity
Archetypes provided clarity and understanding
Archetypes provided insight
Archetypes reinforced insights
Archetypes too simple
Archetypes useful for clarity
Archetypes were useful
Archetypes were useful, not a natural way of thinking
Archetypes/analysis provided better insight
Archetype didn't quite work for people
Attitude of group is important
Balance of participants needed
Balanced participation leads to best results
Balanced views required
Beginning was difficult
Being problem focused helped
Being problem focused was useful
Benefit to being involved and contributing
Best used with goal in mind
Better result
Better results from CLD than other processes
Better to be involved than not
Bigger groups harder to manage
Bring an active farming perspective
Brings together varying mental models
Broad mental model didn't change

Build diagram up in stages when presenting back
Building trust and familiarity
Built group relationships
Business person perspective
Can't keep evolving CLD
Can't/shouldn't be used for everything
Caretaker of land not owner
Cataloguing detail is important and will be a reference
Cautious about direction of council process
Challenge of discussing with varied intellects
Challenging to prioritise between influenced or influencers
Change in mental models
Change is difficult
Change is gradual
Change takes time
changing of mental models
Clarity from archetypes
CLD a possible tool to help manage issues of personality and politics
CLD aids coordinated thinking
CLD aligns with Māori worldview
CLD applicable across all sorts of applications
CLD approach quite democratic/representative
CLD as a communication tool
CLD as a decision-making support tool
CLD as an aid to support participants desired outcomes
CLD as an education tool

CLD as decision-making support tool
CLD as proactive tool not reactive
CLD can act as a framework for analysing changes later
CLD can help as a communication tool
CLD can help identify areas for focus later
CLD demonstrates inter-relatedness
CLD did NOT help de-politicise personality and politics
CLD enabled discussion relating to multiple factors
CLD enabled wider perspectives
CLD enables further learning
CLD enhances inter-connectivity of elements
CLD fit with Māori world view
CLD focuses conversation in the future
CLD focuses conversation moving forward
CLD has allowed time to consider issues
CLD has focused attention moving forward
CLD has focused conversation moving forward
CLD has not clear end-goal
CLD helped demonstrate different relationships
CLD helped focus conversation
CLD helped focus future conversation
CLD helped identify important factors to model
CLD helped increase understanding
CLD helped structure beliefs
CLD helps focus the discussion moving forward
CLD helps order thinking/impacts/relationships

CLD helps structure and focus conversation
CLD helps with wider understanding of an issue
CLD helps you be proactive with problems
CLD highlighted less obvious connections
CLD in entirety is overwhelming
CLD in its entirety is daunting
CLD is suitable even though culture is evolving
CLD leads to action
CLD needs further development
CLD not detailed enough?
CLD not suitable for incorporating spiritual components
CLD presents existing knowledge in a different format
CLD provides simple representation of many discussions
CLD provides structure
CLD represented entire group
CLD structure does not provide a weighting component
CLD suits complex problems
CLD useful as a communication tool
CLD useful as a decision-making support tool
CLD was a reflection of common sense
CLD wasn't completed on first day
CLD will be a good communication tool
CLD will probably always be able to evolve
CLD/Archetypes as decision-making support tool
Clear descriptions/understanding of factors and relationships is important

Close to original understanding but refined
Collective understanding is complex, not binary
Combined existing knowledge
Commonality of objectives
Communication tool
Community culture
Communication tool
Complete CLD overwhelming
complex nature of problems
Concept of same/opposite straight forward
Confusing at beginning
Contributions of participants improves output
Conversation lead to understanding
Conversation leads to understanding
Coordinated/holistic discussion
Correct pace is important
Could continue evolving the diagram
Could continue to evolve
Could dispel myths
Could share knowledge
Could relate to archetypes
Could see diagram developing as group talked
Council advertised for participants
Council not coordinating/linking
Councilor perspective
Curiosity for learning about process

Current approaches do not provide best results
Current practice possibly not aligned with desired outcomes
Dairying interests
Dairying is part of rural culture
Decision-making is difficult
Decision-making is subjective
Decisions need to be made eventually
Defining and understanding the direction of influence was important
Defining factors is difficult
demystify some concepts
Desire for additional decision-making support tools
Desire for alternative approaches
Desire for different ways to do things
Desire for more and different tools
Desire for tools to assist decision-making
Desire to continue
Desire to discover different tools
Desire to ensure balanced group
Desire to explore new approaches and tools
Desire to implement actions
Desire to increase understanding of situation
Developing a common language was difficult
Developing trust
Diagram evolved visually as process evolved
Diagram evolved with discussion
Diagram grew/evolved with discussion

Didn't expand personal understanding
Didn't highlight new issues
Didn't improve personal understanding
Didn't understand archetypes were patterns they described
Didn't want to miss out
differing perspectives on dairying/farming
Different aspirations
different drivers of participants
Different group, different diagram
Different group, different result
Different group, different result (both good and bad thing)
Different group/ different diagram
Different group/ different outcome
Different names for the same thing
Different outcomes sought by participants
Different people have different world views/ mental models
Different understandings of participants can be difficult
Differentiating between contributors and flow on effects difficult
Difficult to achieve work/life balance
Difficult to brainstorm initial factors
Difficult to change linear thinking
Difficult to get representation right
Difficult to get representation/ interest
Difficulties communicating technical info to public
Difficulty comprehending the overall system
Difficulty identifying three main factors

Direction of council process unknown
Disconnected approach
Discussion creates understanding
Discussion enabled understanding
Discussion enables understanding
Discussion has enabled understanding
Discussion has helped focus further conversation
Discussion in person important
Discussion lead to insight
Discussion leads to clarity and understanding
Discussion leads to greater shared understanding
Discussion leads to improved understanding
Discussion leads to understanding
Discussion main benefit
Discussion was important
Discussion was useful
Discussion went well
Discussion/process increased/enabled learning
Discussions better because an existing group
Divergent discussion leads to greater discovery
Diversity added value
Diversity difficult to model
Diversity leads to better result
Diversity of representation important
Diversity of views important
Diversity resulted in better output

Diversity strengthened output
Documenting thought process important
Don't want group too big
Drawing lead to understanding
Easier with existing group relationships
Easy process once started
Economics models often leave out qualitative factors
Efficiency of process
Efficient process
Efficient use of time
Enabled participation
Enabled wide range of perspectives to be heard
Enjoyability of process
Entire CLD overwhelming
Entire CLD was overwhelming
Environmental interest
Environmental interests
Environmental perspective
Everybody able to contribute
Everything is connected
Evolution of individual mental models
Evolution of mental models
Evolved visually with discussion
Existing processes don’t provide optimal results
expanded knowledge of system
Expectations were that workshop would be action orientated

Experience leads to understanding
Explanation with CLD important
Face-to-face discussion useful for understanding
Facilitation and interpretation is important
Facilitation helped with efficiency of process
Facilitation important
Facilitation is important
Facilitation was a key component
Facilitation was important
Facilitation was very important
Facilitator probed a deeper understanding
Facilitation good
Facilitation was important
Facilitation was done well
Farmers not portrayed well, wanted to ensure balanced perspective
Farming business is complex
Farming getting a hard time in media
Feeling attacked as a farmer
Feeling pressure of decision-making responsibility
Feeling responsibility of decision-making
First time use a little challenging
Flexibility in approach required in solving problems
Focus of discussion in future
Focus on problem detracted from exploring wider issue?
Focused conversation in a way not expected
Focuses attention moving forward

Focuses attention on areas of importance/difference
Focusing on a problem was useful
Frustration with council
Frustration with council?
Frustration with traditional approach
Frustration with traditional council process
Frustration with traditional process
Frustration with traditional processes
Frustration with council
Full benefits of process may only be realised in the future
Further evolution of CLD necessary
Further refinement necessary
Get better at process with practice
Gets to a result quicker
Getting aggregation level correct was difficult
Getting participants is important
Getting people together was part of the benefit
Getting scale of problem is important
Getting started with process was difficult
Good communication tool
Good discussion
Good group
Good process
Great tool
Greater detail desired in some areas
Greater prep for meetings might help?

Grew personal understanding slightly
Group dynamic important
Group dynamics important
Group guided through the process
Group ownership of outcome
Group participation in important
Group participation important
Group participation is important
Group relationship important
Group relationships important
Group representation difficult
Group representation important
Group representation is important
Group shared understanding improved
Group size important
Group size important, bigger perhaps?
Group tended to jump to solution
Group understanding improved
Group was good
Guides future conversations
Had to concentrate on links (same/opposite)
Hadn't come across this approach before
Happy with process
Heading in same general direction but different specific direction
Helped guide future discussion, policy interventions
Helps highlight different world views

Helps visualise factors that are difficult to model
Highlighted major drivers of the system
Highlighted the rate of change of the system
Highlighted weighting of drivers and factors
Highlighted weighting/importance of some factors over others
Identification of levers
Identified more than the obvious factors
Importance of being involved
Importance of being involved in the process
Importance of being involved to understand
Importance of face-to-face discussion
Importance of facilitation
Importance of group dynamic
Importance of group representation
Importance of participant frame of mind
Importance of problem focused action
Importance of tailoring 'soft' side of process to the audience
Importance of visual tool
Improved personal knowledge
Improved personal understanding
Improved shared understanding
Improved understanding through discussion
Improvement of collective understanding
Improvements/ differences are relative over time
In Māoridom there is no ownership, only kaitiaki
Incorrect data as an input

Increase in shared understanding
Increased shared understanding
Increased understanding
Increased understanding of system from low level to begin
Independent facilitation is impotent
Insight provided was daunting
Inspired more detailed learning
Inter-connectedness consistent with Māori world view
interested in learning a new tool
Interested in new ways/curiosity
Intergenerational involvement in the area/issues
Intergenerational problem
Invisibility of issues
Involvement important for understanding
Issues are complex and inter-generational
Issues are generational
Issues are large and complex
Issues are long term
It was a good group
Job changes caused migration
Keen to learn about CLD
Key influences highlighted
Lack of economic data
Lack of judgement
Lack of technical background in the issue
Lack of trust from those not involved

Lack of understanding of rural issues
Land management perspective
Learned about issues
Learned from other people
Learning about loops & archetypes required focus
Learning of cultural concepts
Legislation can create difficult and confusing reality
Less technical knowledge was difficult for participant
Less technical knowledge a limitation
Likes the outdoors
Limitation of existing system
Limitations to people's ability to contribute
Literacy a barrier to involvement
Literacy a barrier to understanding
Local government perspective, engineering
Local identity
Local perspective
Long term issues
Long term problem
Long term remedies
Looking to improve ways of thinking
Maintaining focus is important
Makes the complex accessible and clear
Māori is a living practice, not just a language
Māori more than a language, it's a way of life
Māoridom lends itself towards complex mental models

Map of area would be useful
Mauri a major learning
Mental model didn't expand
Mental models evolved
Misunderstood a part of archetype
Model as decision-making support tool
Modelling is not reality
Modelling needs to be integrated
Modern life is affecting Māori world view
Modern life is compartmentalised
Modern world is busy
Modern world is task focused
Momentum possible once change initiated
More comfortable with process the more its done
More detail desired
More detail required
More discussion of detail required
More in common than we think/was thought
More time important
More time is important/useful
More time required
More time would be beneficial
Multiple levers identified
Need a long-term vision
Need more time
Need time to discuss

Need to have enough time
Need to live to understand
Need to make assumptions in decision-making
Need to understand detail before making decisions
Need to validate choice of archetypes
Needs to be problem focused
Next step is proritising things
No expectations
Non-verbal signals in the group are important
Not all contributions are verbal
Not all divergent discussion is useful
Not enough time
Not familiar with CLD
Not knowing where diagram was going made it difficult
Not usually a visual person
Only some archetypes focused on
Open discussion due to divergent/exploratory nature of conversation
Open minded/curiosity
Other projects - more time has been useful
Other projects - time allocated for in-depth discussion useful
Other residents not interested
Outcomes owned by citizens get more traction
Output reflects participants
Output reflects those involved
Output restricted by problem being focused on

Output was tangible
Outputs reflect participants
Overall CLD was daunting
Overwhelmed by entire CLD
Ownership of CLD output
Ownership of outcome
Ownership of output
Ownership of outputs
Pace of process built well
Partial analysis of diagram in parts was useful
Partial analysis useful
Participant and systems thinker
Participant contributions is important
Participant focused on action rather than understanding?
Participant is goal orientated
Participants see their input in the outcome
Participants wanted same things
People able to contribute and share perspectives
People grew more comfortable as the process continued
People motivated to be there
People's perspectives different to assumed/perceived
Perceived solution already known?
Personal mental models changed
Personal perspective grew
Personal perspectives
Personal perspectives as well

Perspective of a landowner/manager
Physical presence helped
Physical presence is important. Meeting in person
Planning perspective
Positive experience
Possible communication tool
Possible good communication tool
Possibly improve briefing before the event
Potential for process to be applied in other ways
Preconceived ideas already broken down by council process
Preparation was important
Prioritises action
Problem focus was good
Problem still evolving
Process allowed discussion
Process an efficient use of time
Process an improvement
Process applicable across many areas
Process better if it results in action
Process better represents people
Process better than traditional procedures
Process develops respect for others
Process easy to follow
Process enabled development of understanding
Process enabled discussion
Process enabled output

Process enabled reflection/introspection
Process enabled robust discussion
Process expanded their personal perspective
Process got easier as it progressed
Process has changed potential action
Process has enabled momentum
Process has focused attention moving forward
Process has value longer term
Process helped build relationships
Process helped engage all types of people
Process helped ensure balanced discussion
Process helped keep conversation balanced
Process helps build trust
Process helps manage discussion
Process helps various agencies interact
Process is accessible
Process is common sense
Process is robust
Process kept momentum once started
Process leads to understanding
Process not easy or hard
Process not really easy or hard
Process started slow
Process useful in various applications
Process very versatile
Process was educational

Process was good for engaging people in discussion
Process was important
Process will become better the more it is used
Process not as controversial as expected
Progress/output was tangible
Progressed quickly
Prosperity underpins vibrancy
Protecting interests
Provided insight to policy levers
Provides structure to conversation and ideas
Public health perspective
Qualitative modelling is difficult and little understood
Quicker than traditional methods
Ran out of time
Ranking factors difficult
Real world is complex, a mix of objective and subjective
Records of conversations important
Reflect back on CLD later
Reinforced important decisions/factors already realised/highlighted
Reinforces connectivity of issues
Relationships and trust developed
Relationships within group were important
Rep on other council groups
Representation not complete
Representing company interests
Representing tribal interests

Resident perspective
Right level of detail is important
River co-management
Safe environment
Same meaning, different words
Same things different words
Same things, different words
Satisfaction from involvement
Schools are hub of rural community
Science perspective
Scope of process important
Seeking information versus telling information
Seeking process to be as practical as possible
Seeks an environmental outcome
Self-selection bias
Shared understanding grew
Shared understanding perceived to improve but to be tested
Similarity to some other processes
Simple focus of the discussion made it useful
Simplicity is important
Size of council task
Size of group important
Small group better
Small group enabled discussion
Small group encourages engagement
Small group was good

Small groups enabled learning
Smaller group better
Smaller group size was better
Smaller groups better
Smaller groups more productive
Some confusion around colours used
Some of the conversation wider than the problem
Sought out to participate
Specialist CLD knowledge important
Specialist explanation was important
Speed of modern life doesn't allow us to slow down
Start was hardest part
Starting is important
Starting strong is important
Still differences in mental models
Strong start important
Strong start was important
Structure enabled discussion
Structure of process helped conversation
Structure of process helped with discussion
Success of process dependent on skill of facilitator
Successful journey
Succession planning important
Suggested alternative courses of action
Support from subject matter experts might help
Synthesise rather than analyse

Talking through CLD relationships helped
Technology used was important
There is always more to do
Time a limited factor
Time a limiting factor in traditional processes
Time commitment was important
Time is limited in modern world
Time is required for discussion and understanding
Time required to use tool
Time was limited
Time was required to absorb and process, when receiving information
Timing of process steps is important
Timing was good
Tool builds trust and understanding
Tool helped increase shared understanding
Tool helps coordinate thinking
Tool suits complex problems
Tool to assist decision-making
Traditional approaches less successful
Traditional communication methods not accessible for some
Traditional processes not optimal
Trust the process
Turning understanding into action
Two workshop process useful
Unable to please expectations

Unaware of extent of issue
Understand because involved in process
Understanding directions of factors and relationships was challenging
Understanding does not mean agreement
Understanding nature of relationships (same/opposite) was challenging
Understanding of issues grew
Understanding of system developed
Unfair stigma on dairying
Unrealistic expectations
Unsure of all aspects of shared understanding
Unsure of overall value of process
unsure what outcome to expect
Use different words but mean same thing
Use of clear language made it accessible
Using process helped it make sense
Variety of input is important
Variety of interaction in process was engaging
Variety of participants widened discussion
Variety of perspective to incorporate
Variety of perspectives
Variety of perspectives improves outcome
Visual aid
Visual aid helps with complexity
Visual component necessary

Visual component of output powerful
Visual image important
Visual output was important
Visual record important
Visual representation aided understanding
Visual representation of discussion
Visual representation of factors is useful
Visual representation was important
Visual tool is useful
Visual tool made it easier to understand/engage
Visual tool useful
Visual tool was accessible
Visual tool was important
Visual tool was useful
Want to stay up to date
Wanted to contribute according to standards
Wanted to ensure a balanced perspective
Wants to restore river
Was curious to see what it was
Water is core to productive livelihood
Water makes or breaks productive livelihood
Water user
We are good at fixing solutions not problems
We deal with problems piecemeal
We have many tools for modern life
We tend to focus on immediate problems

Weighting of factors
Weighting of factors and relationships important
Weighting of factors difficult
Weighting of factors important
Weighting of factors next step
Weighting of factors unknown
Weighting of relationships missing
Why not dealing with problem known already?
Wide range of applications
Wider input required
Widespread issues
Will these discussions influence outcomes?
Willingness to discuss
With CLD we would focus on detail
Would be easier if repeated

Appendix 23 Joseph Luft's 11 principles of change

The 11 principles of change outlined by Joseph Luft in his influential 1969 work *Of Human Interaction* are reproduced below. They can be found on page 14 of his book and the reader is referred to his book for a full discussion of these principles.

Eleven principles of change are outlined:

1. A change in any one quadrant will affect all the other quadrants.
2. It takes energy to hide, deny, or be blind to behaviour which is involved in interaction.
3. Threat tends to decrease awareness; mutual trust tends to increase awareness.
4. Forced awareness (exposure) is undesirable and usually ineffective.
5. Interpersonal learning means a change has taken place so that quadrant 1 is larger, and one or more of the other quadrants has grown smaller.
6. Working with others s facilitated by a large enough area of free activity. It means more o the resources and skills of the persons involved can be applied to the task at hand.
7. The smaller the first quadrant, the poorer the communication.
8. There is a universal curiosity about the unknown area, but this is held in check by custom, social training, and diverse fears.
9. Sensitivity means appreciating the covert aspects of behaviour, in quadrants 2, 3, and 4, and respecting the desire of others to keep them so.
10. Learning about group processes, as they are being experienced, helps to increase awareness (enlarging quadrant 1) for the group as well as for individual members.
11. The value system of a group and its membership may be noted in the way *unknowns* in life of the group are confronted.