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**Risks and Options Assessment**  
**for Decision Making (ROAD):**  
**An application to Lake Coleridge and the Rakaia River**

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A Dissertation  
submitted in partial fulfilment  
of the requirements for the Degree of  
Bachelor of Commerce (Honours)

at  
Lincoln University  
by  
Katie Ussher

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Abstract of a Dissertation submitted in partial fulfilment of the requirements for the Degree of Bachelor of Commerce (Honours).

Risks and Options Assessment  
for Decision making (ROAD):  
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The Risks and Options Assessment for Decision making (ROAD) model is a new decision making tool for the mitigation the impact of risk events. Unlike cost-benefit analysis where projects are approved when the benefits of a project outweigh the costs, the ROAD model process allows decision makers to identify projects that will reduce the negative impact of a risk event on stakeholders. This research is the first time that the ROAD model process has been applied to Lake Coleridge and the Rakaia River in Canterbury. Information gained from Environment Canterbury Regional Council has been applied to the steps set out in the ROAD model to identify how it can be applied to water management. As this is the first time the ROAD model has been applied, more information and data needs to be generated by Environment Canterbury and stakeholders. What is shown by applying the ROAD model process to Lake Coleridge and the Rakaia River is how stakeholders are impacted in the event of a drought event. Environment Canterbury are constrained in their decision making by the Canterbury Water Management Strategy (CWMS) and national legislation such as the Resource Management Act (1991). Despite the constraints on Environment Canterbury, the ROAD model can still be used to reduce the impact of risk. Stakeholders for Lake Coleridge and the Rakaia River include commercial irrigation companies, Trustpower who operate the Lake Coleridge hydropower station, farmers, Ngāi Tahu iwi and recreational river users. Strategies and projects to mitigate the impact of risk on these stakeholder groups can be developed through the ROAD model process. Further research should be conducted to continue the application of the ROAD model to Lake Coleridge and the Rakaia River once Environment Canterbury implement risk mitigation projects

**Keywords:** Risk analysis, Cost-benefit analysis, Water, Governance.

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# Chapter 1

## Introduction

Cost-benefit analysis has been used to assess water management projects for many decades. Since the 1930's in the United States, cost-benefit analysis has been applied to flood control projects as set out under the Flood Control Act (1936) (Brouwer & Pearce, 2005). Due to the nature of many water issues not having a market, this approach does not provide decision makers with accurate information. Cost-benefit analysis requires the costs and benefits to be valued in monetary units for the calculation of a project's net present value (Boardman, Greenberg, Vining & Weimer, 1996). Many of the costs and benefits relating to water management projects do not have a monetary value as there is no market for their valuation (Hanley & Black, 2006). The costs associated with a project are more than the construction costs of a dam on a river, for example. The environmental costs of changing water flows in the river also need to be taken into account. It is the environmental costs that are difficult to quantify in monetary terms (Hanley, 2011). Environmental costs include; changes to biodiversity, water pollution and reduced water flows restricting recreational opportunities (Hanley, 2011). The remediation of these environmental costs may be able to be valued in monetary terms (Hanley, 2011). The benefits of water management projects go beyond the economic benefits which can be valued in monetary terms. Some of the non-monetary benefits include; the ability to regulate river flows to respond to weather patterns, new recreation opportunities created with physical changes to waterways and improved ecological environments for wildlife (Hanley, 2011). A new decision making tool is needed that takes into account all the non-market costs and benefits of water management.

The Risks and Options Assessment for Decision making (ROAD) model provides a new tool for decision makers. The ROAD model is a risk-based approach that provides information for decision makers to address their 'worst-case' scenario and develop solutions to mitigate risk (Grafton, McLindin, Hussey, Wyrwoll, Wichelns, Ringler, Garrick, Pittock, Wheeler, Orr, Matthews, Ansink, Aureli, Connell, De Stefano, Dowsley, Farilfi, Hall, Katic, Lankford, Leckie, McCartney, Pohlner, Ratna, Rubarenzya, Raman, Wheeler, & Williams, 2015). The 'worst-case' scenario will differ depending on the water system the ROAD model is applied to. Changing weather patterns which lead to decreased rainfall and drought is a potential 'worse-case' scenario event. Drought reduces the water available to meet the demands on the water resource. The demands on the water resource as described by Grafton et al. (2015) span across the network of food production, energy generation, environment and water quality demands. Trade offs need to be made between these demands during adverse events. This is because water consumption for one use can prevent the consumption for another use



(Brouwer & Pearce, 2005). The advantage of using a risk-based approach to decision making allows decision makers to respond to adverse situations, such as a potential drought, and develop alternative sustainable solutions to these events (Grafton, et al., 2015).

This research project is the first time that the ROAD model has been applied to Lake Coleridge and the Rakaia River in Canterbury. As the ROAD model has yet to be published, exploratory research will be carried out to identify how the model can be applied to water management for Lake Coleridge and the Rakaia River. Information gathered from Environment Canterbury Regional Council (Environment Canterbury) will be used to apply the ROAD model to Lake Coleridge and the Rakaia River. Lake Coleridge and the Rakaia River have been selected because the river system is an example of the competing demands on the water resource. Lake Coleridge hydropower station generates electricity while regulating the flow of water into the Rakaia River. Irrigation companies utilise water in the Rakaia River to irrigate nearby farmland used for food production. The Rakaia River also is used for recreational activities that require high quality water for the health of users. Salmon anglers also rely on high quality water but also the river environment must be of a standard to ensure the future sustainability of the salmon fishery stock (Environment Canterbury Regional Council, 2011b). Environment Canterbury is responsible for the management of the water resources throughout the Canterbury region including Lake Coleridge and the Rakaia River (Environment Canterbury Regional Council, 2011b).

## **1.1 Current Water Management Constraints in Canterbury**

### **1.1.1 Canterbury Water Management Strategy (CWMS)**

The Canterbury Water Management Strategy (CWMS) provides information for the effective management of the water resource in Canterbury (Environment Canterbury Regional Council, 2011b). All of Canterbury's water resources are managed within the CWMS framework, including Lake Coleridge and the Rakaia River. The CWMS framework is an approach developed in collaboration with the Canterbury Mayoral Forum, Ngāi Tahu iwi, Environment Canterbury, stakeholders and industry groups (Environment Canterbury Regional Council, 2011b). The objective of the CWMS is to deal with the issues and constraints relating to water management throughout the Canterbury region. Issues facing Canterbury water management cover economic, environmental, social and cultural factors. Multiple targets are detailed to address the interrelated issues identified in the CWMS. These targets are used to assess progress on issues such as water use efficiency, biodiversity, water quality and recreational opportunities (Environment Canterbury Regional Council, 2011b). Underpinning the CWMS is a focus on the cultural importance of water to the Ngāi Tahu iwi in Canterbury. Ngāi Tahu has a holistic view of the environment with water being central to their resource management philosophy. They believe a collaborative approach between agencies,

legislation and management frameworks is required to achieve environmental goals (Environment Canterbury Regional Council, 2011b).

The CWMS does not rely on economic decision making outcomes. Instead it outlines the issues facing water resource management in Canterbury (Environment Canterbury Regional Council, 2011b). A number of key water management activities outlined in the CWMS that Environment Canterbury need to manage including;

- Setting and maintaining environmental limits for water use
- Improve water quality and monitor the health of ecosystems
- Improve the cultural health of waterways using the Takiwā assessment framework
- Achieve greater water use efficiency at property, scheme and catchment levels
- Prepare for potential future challenges to the water supply from climate change
- Address issues relating to land use intensification, including investment in infrastructure
- Grow the Canterbury regional economy

The water management activities outlined in the CWMS offers an insight into the decisions Environment Canterbury need to make to manage the competing demands on water (Environment Canterbury Regional Council, 2011b). The CWMS can be seen as a framework to address the concerns of stakeholders in the Canterbury region (Environment Canterbury Regional Council, 2011b). To achieve the targets set out in the CWMS, investment from all stakeholders is required to ensure the sustainable management of the water resource in Canterbury.

### **1.1.2 Resource Management Act (RMA)**

The Resource Management Act 1991 (RMA) is legislation that governs how the environment should be managed in New Zealand (Ministry for the Environment, 2015a). The RMA was created to bring a number of different pieces of environmental legislation together into one Act of Parliament (Gow, 2014). The purpose of the RMA is to “promote the sustainable management of natural and physical resources” (Resource Management Act 1991, s 5). The natural and physical resources include water and ecosystems (Resource Management Act 1991). Prior to the implementation of the RMA, the central government provided technical guidance and assistance for local and regional councils to manage environmental issues. With the implementation of the RMA, local and regional councils were not longer given guidance that resulted in a diverse range of approaches to environmental management throughout New Zealand (Gow, 2014). More guidance is now being provided from central government to local and regional councils through initiatives such as National Policy Statements (Ministry for the Environment, 2015b).

The primary role of the RMA is to manage the effect that people's activities has on the environment. Regional Councils are responsible for the creation of regional policy statements and plans for the management of the environment in their region (Ministry for the Environment, 2015a). Environment Canterbury is responsible for the implementation of the RMA in the Canterbury region. To ensure people's activities are managed to reduce potentially negative effects to the environment, resource consents are required to be issued for certain activities. For example, a water permit would need to be issued by a regional council before water is taken from a waterway for an irrigation scheme (Ministry for the Environment, 2015a). The holistic view of the environment by Maori is reflected in the RMA legislation that was absent from existing legislation at the time (Gow, 2014). The intention of the RMA was to provide a framework for the sustainable management of the environment, including land, water and air (Gow, 2014).

The RMA also sets out a schedule of penalties for failure to comply with the requirements in the Act. Infringement or abatement notices can be issued under the RMA for activities that have a negative impact on the environment (Ministry for the Environment, 2015a).

## **1.2 Research Structure**

To answer the research question, how can the ROAD model be applied to water management at Lake Coleridge and the Rakaia River, this research is structured as follows. Chapter 2 begins with a literature review on the economic theory of Cost Benefit Analysis and its application to water resource management decision making followed by a brief overview of political and bureaucratic decision making strategies. Chapter 3 reviews the ROAD model and outlines the method for decision making. Chapter 4 applies the ROAD model process to Lake Coleridge and the Rakaia River to establish the framework for future research opportunities. Chapter 5 concludes by reflecting on how the ROAD model can be applied to Lake Coleridge and the Rakaia River.

## Chapter 2

### Literature Review

#### 2.1 Cost Benefit Analysis

Cost-Benefit Analysis is a decision making tool used to ensure the efficient allocation of scarce resources. The theory is used to evaluate the positive (benefits) and negative (costs) effects of a project for society as a whole (Boardman, et al., 1996). Costs of a project include opportunity costs associated with other projects that may not proceed. The monetary costs and benefits of a project are calculated, adjusted for time and summed together to calculate the Net Present Value (NPV) of the project. Projects with a NPV greater than zero (i.e. NPV is positive) should proceed (Boardman et al., 1996). This allows for multiple projects to be evaluated, determining a portfolio of projects that will provide efficient allocation of resources. The concept of Pareto efficiency underlies the theory of cost-benefit analysis. Pareto efficient allocation of resources is where additional allocations will make at least one consumer better off while not making any other consumers worse off (Boardman et al., 1996). This is an important concept for allocating the use of resources such as water.

Cost-benefit analysis has been used to evaluate water management projects since the 1930's in the United States (Brouwer & Pearce, 2005). Following a number of flooding events in the United States, including Mississippi, Pennsylvania and Ohio (Arnold, 1988), the United States Flood Control Act (1936) was enacted. The Act required evaluation of the costs and benefits of flood control projects (Arnold, 1988). A project could only proceed if the benefits exceeded the costs of a project, NPV greater than zero (Hanley & Spash, 1993). Projects such as levees and channels were constructed under the Flood Control Act (1936) to mitigate the risk of flooding in flood prone areas in the United States (Arnold, 1988). These projects were approved as the economic benefits outweighed the costs of constructing the levees and channels (Arnold, 1988). The risk of flooding may be the motivation for the construction of projects but it is not acknowledged in the cost-benefit analysis calculation. Brouwer and Pearce (2005) describe water as a quasi-public good as some of the competing demands for water may restrict the uses of water by other consumers. Water used for irrigation in the agriculture sector or water stored for hydroelectric generation reduces the amount of water available to ensure a healthy ecosystem or for recreational users (Brouwer & Pearce, 2005). Cost-benefit analysis can therefore be used to allocate water to those users that are the most willing to pay for the resource (Brouwer & Pearce, 2005). This could lead to water quality issues that are linked with efficient allocation of water resources. Inefficient allocation of water may not be Pareto efficient in terms of water quality (Brouwer & Pearce, 2005). This is because poor water quality would make

some consumers worse off if it impacts their health or their ability to use the water for recreational activities (Brouwer & Pearce, 2005).

Cost-benefit analysis is often used to analyse a specific project being considered. The United States Environmental Protection Agency (EPA) use cost-benefit analysis to assess proposed environmental legislation (Iovanna & Griffiths, 2006). The ecological benefits of proposed legislation are assessed which was not required under the Flood Control Act (1936). The ecological benefits that the EPA assesses relate to what humans value in the ecosystem (Iovanna & Griffiths, 2006). This includes the health of fishery stocks that are a benefit for recreational activities (Iovanna & Griffiths, 2006). The EPA has four categories of ecological benefits, which are; marketed products, recreation and aesthetics, non-use values, and maintaining health and prosperity (Iovanna & Griffiths, 2006). An issue with including ecological benefits into cost-benefit analysis is that the benefits are difficult to value in monetary terms. A monetary value for ecological benefits is still required for a cost-benefit analysis. Iovanna and Griffiths (2006) look at the use of the benefits transfer method by the EPA to estimate the monetary value ecological benefits. The EPA use data from previous studies and transfers it to the current analysis to estimate the ecological benefits of proposed environmental legislation (Iovanna & Griffiths, 2006). Given the time constraints imposed by legislation on the EPA to conduct the cost-benefit analysis, the benefit transfer method allows for sound decision making by the EPA (Iovanna & Griffiths, 2006).

Much of the recent literature has focused on how cost-benefit analysis has been adapted to be more useful in decision making under different political structures. The Water Framework Directive (WFD) is legislation applying to all European Union countries (Hanley & Black, 2006). Through a cost-benefit analysis framework, the WFD incorporates environmental considerations into river basin management policy (Hanley & Black, 2006; Dehnhardt, 2014). As with the use of cost-benefit analysis as a decision making tool in the United States, risk mitigation may be a motivator for decision makers. However, risk is not included in cost-benefit analysis as described by the WFD. The WFD does require investment and participation from stakeholders in the management of river basins (Hanley & Black, 2006). How the requirements of the WFD are implemented in each European Union country differs. Hanley and Black (2006) analyse the implementation of the WFD in water management initiatives in Scotland. Cost-benefit analysis was conducted at both the local river system level and national level for the implementation of hydroelectric schemes. The environmental considerations included the impact to fisheries stocks in the river basin from hydroelectric generation schemes. The costs of potential restoration of fisheries stock were included in the analysis as well as the environmental cost of degraded water quality (Hanley & Black, 2006). Through their analysis, Hanley and Black (2006) found that valuing environmental costs and benefits are an issue for conducting analysis as set out in the WFD. This is due to the nonmarket value of environmental

costs and benefits that leads to uncertainty in the analysis (Hanley & Black, 2006). Dehnhardt (2014) looked at how the WFD framework is applied in Germany. Research showed how the political structure of a country could impact on the implementation of policy. German policy makers have not favoured environmental cost-benefit analysis for policy analysis (Dehnhardt, 2014). This is due to the multiple beliefs and interest groups that are involved in water resource policy (Dehnhardt, 2014). Involving stakeholders in the decision making process, which is a requirement of the WFD (Hanley & Black, 2006), is problematic in Germany. This has implications not only for policy implemented in multiple countries, such as the WFD, but also the impact of special interest groups in environmental policy implementation. Cost-benefit analysis is used in the context of the WFD as analytical tool to inform policy choices, improve economic efficiency and inform policy makers as to the net benefit to society as a whole of the policy (Dehnhardt, 2014). The political interests and beliefs of policy makers impact the implementation and economic valuation of environmental policy. The WFD does attempt to change beliefs of policy makers but this is difficult to achieve (Dehnhardt, 2014). Case studies of how the WFD has been applied in the United Kingdom are analysed by Balana, Vinten and Slee (2011). They looked at the role WFD provided in decision making for river basin management. Provisions in the WFD require the use of a cost-effectiveness analysis as opposed to cost-benefit analysis (Balana, et al., 2011). Cost-effectiveness analysis differs from cost-benefit analysis in that the benefits are expressed in physical units rather than monetary units. It does not compare the costs and benefits of a project but rather it is used to assess the most cost effective project options (Balana, et al., 2011). This variation of cost-benefit analysis overcomes the issues identified by Hanley and Black (2006) relating to the difficulties of valuing environmental benefits that are outside the market.

Cost-utility analysis extends cost-benefit analysis by measuring intangible benefits with a utility score (Hajkowicz, Spencer, Higgins & Marinoni, 2008). The intangible benefits identified by Hajkowicz et al. (2008) include; human health, the physical landscape, recreational activities, and biodiversity. Costs are still measured using the standard cost-benefit analysis approach with discounted cash flows. The method described by Hajkowicz et al. (2008) in their article looking at water quality enhancement projects in Western Australia offers another approach to address the difficulties of measuring environmental benefits in monetary terms. Cost-utility analysis is also an extension of cost-effectiveness analysis, which was used by Balana et al. (2011) to study river basin management in the United Kingdom. Cost-utility analysis allows for multiple qualities to be analysed at the same time in a utility function. The qualities identified by Hajkowicz et al. (2008) related to the Swan and Canning River systems in Western Australia include environmental and societal benefits. Hajkowicz et al. (2008) found that the cost-utility analysis was a useful framework for analysing water quality enhancement projects in Western Australia where there were multiple outcomes being measures with different units. Cost-utility analysis allows for multiple projects to be ranked and approved,

subject to a budget constraint, in order to address water quality issues (Hajkowicz et al., 2008). For the Swan and Canning River systems projects to improve water quality relate to the reduction of nitrogen and phosphorus in the water, flood mitigation, and cultural significance for Aboriginal communities (Hajkowicz et al., 2008). Cost-benefit analysis can be used to rank and approve multiple projects. This is achieved by making multiple separate calculations. The advantage of using cost-utility analysis is that only one utility calculation is required. Once again risk is external to the analysis being conducted.

The literature has shown that the standard cost-benefit analysis approach to decision making has been adapted to address the complexities of environmental management. While the analysis method has evolved, the data required for analysis is still based on the cost-benefit analysis approach which is to assign a monetary value to environmental costs and benefits. Also the literature has shown the difficulties of valuing benefits in the absence of a market for environmental benefits. Risk is not addressed by any of the methods mentioned in the literature. Projects being analysed may be to mitigate a risk event, for example flooding, but there is no acknowledgement of how likely the risk event is to occur. There is the potential for a risk mitigation project to be approved when there is a low likelihood of the risk event occurring.

## **2.2 Political and Bureaucratic Decision Making**

International organisations provide a number of guidelines for governments and environmental agencies to follow in regards to environmental protection. The guidelines do not explicitly recommend the use of economic decision making tools, such as cost-benefit analysis. However it is important to acknowledge the recommendations of international organisations as political organisations, including Environment Canterbury, incorporate their recommendations into planning and decision making processes. The United Nations Educational, Scientific and Cultural Organization (UNESCO) provide information and guidelines on various water management issues, including water resource sustainability and governance.

Water is seen as being a vital component for sustainable economic growth. UNESCO (2015b) identifies the growing demand for water as one of the issues facing economic development. Issues such as water quality and infrastructure need to be addressed in order for equitable development to occur (UNESCO, 2015b). UNESCO operates the United Nation's water science programme, the International Hydrological Programme (IHP) (United Nations Educational, Scientific and Cultural Organization (UNESCO, 2015a). The programme began in the 1960's with the establishment of the International Hydrological Decade. The IHP began as a way to co-ordinate research to improve how water resources are used (Nace, 1969). Since the start of the first Hydrological Decade in 1975, the IHP has evolved from having a hydrological research focus to now focusing on education and

enhancing the governance and management of water resources (UNESCO, 2012). The IHP is a multi-disciplinary programme that facilitates education and works to improve water resource management and governance (UNESCO, 2015a). Since 1975 there have been eight phases of the IHP. Each phase has built on the previous phase to develop a deeper understanding of water resources management issues. These water resources management issues include sustainable development and environmental changes (UNESCO, 2012). The eighth phase of the International Hydrological Programme (IHP-VIII) has been adopted for the eight-year period from 2014 to 2021. The aim of the eighth phase is to gain a deeper understanding of the linkage between water, energy and food in order to improve integrated water resource management (UNESCO, 2012). This approach is similar to the work being carried out by the Food, Energy, Environment and Water (FE2W) Network who are researching the connections between food, energy, environment and water and the importance of these factors for the future sustainability of the water resource (Food, Energy, Environment and Water Network [FE2W], 2014). The holistic approach to identifying the interconnections between water, energy and food allows for a deeper understanding of the trade offs that need to be made when addressing the competing demands on the water resources. The purpose of IHP-VIII is to safeguard water resources for human health and mitigate risk events including floods and droughts (UNESCO, 2012). This is addressed at local, regional and global levels, as the challenges are complex and diverse (UNESCO, 2012). Political, financial and information challenges are faced in IHP-VIII with the aim of identifying issues and developing solutions (UNESCO, 2012). The information gathered by the research in IHP-VIII is likely to be influential in the planning and decision making processes of water resource managers. New Zealand is an active member in the IHP since the 1960's (UNESCO, 2015a). Information gained from the earlier phases of the IHP has been incorporated into water resource management plans including the CWMS (UNESCO, 2015a). IHP-VIII is consistent with the current water resource management beliefs of the New Zealand government, which is a holistic approach that incorporates the interests of Maori (UNESCO, 2015a).

The New Zealand National Infrastructure Unit was established in 2009 to support the delivery of the government's infrastructure objectives (National Infrastructure Unit, 2014). The creation of the New Zealand Infrastructure Plan 2015 provides guidance to local governments, including Environment Canterbury, to ensure infrastructure decision making is done in accordance with the objective of the national government (National Infrastructure Unit, 2015). Water infrastructure networks are included in the New Zealand Infrastructure Plan 2015. The purpose of the New Zealand Infrastructure Plan 2015 aligns with the purpose of IHP-VIII in identifying the challenges facing infrastructure networks and developing solutions. The challenges for water infrastructure networks identified in the New Zealand Infrastructure Plan 2015 including the financial constraints of local authorities and the impact of climate change on the water resources (National Infrastructure Unit, 2015). The impact of climate change includes both potential flooding and drought events (National



Infrastructure Unit, 2015). Over the next 30 years, the New Zealand Infrastructure Plan 2015 aims to strengthen the management of water resources and infrastructure by developing a framework for decision making that can be used for future planning (National Infrastructure Unit, 2015). The framework will provide a holistic approach to infrastructure management to benefit all New Zealanders (National Infrastructure Unit, 2015). The benefits from infrastructure investment should include social, fiscal and environmental benefits (National Infrastructure Unit, 2015). The New Zealand Infrastructure Plan 2015 does not include guidance on the management of natural waterways such as the Rakaia River. The productive water sector is included in the plan, which includes irrigation schemes (National Infrastructure Unit, 2015). As water from the Rakaia River is used for the irrigation of nearby farmland on the Canterbury Plains an awareness of the guidelines in the New Zealand Infrastructure Plan 2015 for the future decision making process of Environment Canterbury must be considered. The benefits of projects need to be identified and incorporated into infrastructure decisions (National Infrastructure Unit, 2015). How the costs of infrastructure projects are incorporated into decisions is not stated in the New Zealand Infrastructure Plan 2015. It can be assumed that costs will be addressed in some form of cost-benefit analysis before infrastructure projects are implemented.

Much of political and bureaucratic decision making addresses the planning of projects rather than if a particular project should be accepted. The identification of challenges and risks appears to be a new approach by organisations, such as UNESCO. Once the challenges and risks have been identified, projects to mitigate risk can be developed. Cost-benefit analysis may then be used to determine if the benefits outweigh the costs of each proposed project.

## Chapter 3

### Risks and Options Assessment for Decision making (ROAD) Review

The Risks and Options Assessment for Decision making (ROAD) model presents a new way of approaching water management decisions. The ROAD model has been developed to address the risks associated with global food security threats as the global population increases (Grafton et al., 2015). As the global population increases, more food will need to be produced to feed the growing population. If the risks related to food security are not mitigated, there is the potential for negative impacts on water, energy and environment systems which are needed to support food production systems (Grafton et al., 2015). By following the ROAD model process, decision makers are able to create a holistic overview of the potential risks and opportunities related to the area of risk and threat assessment. The impact of the decisions on stakeholders is considered in the ROAD model process, which is an improvement on the traditional cost-benefit analysis approach. The ROAD model process bring together three of the dominant discourses in food security. The dominant discourses identified by Grafton, et al. (2015) are; sustainable intensification, the 'nexus' approach and resilience thinking.

Sustainable intensification relates to the increase in agricultural production to produce more food for consumption (Grafton et al., 2015). As agricultural production increases there is often an associated increase in demand for water and energy resources and a negative impact on the environment from nutrient run off, for example (Grafton et al., 2015). Sustainable intensification aims to increase agricultural production while using fewer resources, including water resources, while reducing the negative impact on the environment. The aim is to optimise the available resources to increase production (Grafton et al., 2015). For sustainable intensification, the trade offs between the demands for food, water, energy and environmental resources need to be managed to reduce the negative impact from favouring one demand over another (Grafton et al., 2015).

The 'nexus' approach brings together the competing trade offs on natural resources including water. These trade offs cover the four demands on water identified by the FE2W network, food, energy, environment and water (Grafton et al., 2015). The trade offs between the competing demands on water relate to the quasi-public good nature of where the consumption for one use prevents its consumption for another use (Brouwer & Pearce, 2005). The 'nexus' approach allows for the impact on each of the four demands to be assessed when one demand is prioritised over the others. It is therefore important to gain an understand of how the four demands are interconnected to be able to predict impact of trade offs (Grafton et al., 2015). An advantage of the 'nexus' approach is that multiple demands can be analysed at the same time (Grafton et al., 2015). Governance issues are a

key feature of the 'nexus' approach as they can be both part of the problem and the solutions to resource management issues (Grafton et al., 2015). The political rationale of decision making and the development of solutions to resource management issues need to be understood as this could lead to institutional reform as part of addressing risk (Grafton et al., 2015). Stakeholder investment and participation is important in any institutional reform, which aligns with the approaches of UNESCO in IHP-VIII and the New Zealand National Infrastructure Unit.

Resilience thinking relates to the ability of the decision making process to be able to respond and adapt to the changing threats on the resource (Grafton et al., 2015). It also relates to how well a system, such as water systems, can respond and adapt to shocks while continuing to deliver benefits to stakeholders (Grafton et al., 2015). An example of a shock to water systems is climate change. Climate change can cause flooding and droughts that have the potential to impact the ability of water systems to continue to deliver benefits to stakeholders. Resilience thinking offers a new approach to address threats and risks as there is not the need to accurately predict future events but rather develop strategies for systems to respond and adapt to a range of potential scenarios (Grafton et al., 2015). The systems orientated approach allows for the development of risk mitigation solutions and can reduce the impact of shocks to communities and ecosystems (Grafton et al., 2015).

### **3.1 ROAD Model Method**

The ROAD model provides a process for the assessment of risks that incorporates sustainable intensification, the 'nexus' approach and resilience thinking for the long-term planning of decision makers. The risks that are assessed in the ROAD model, span multiple time periods depending on how quickly the impact of the risks could be felt. Grafton et al. (2015) define these time periods as; rapid onset, slow onset and prolonged onset. Rapid onset risks relate to sudden shocks to a system such as floods or wildfires. Slow onset risks impact a system gradually such as a drought or water degradation. Prolonged onset risks impact a system in the long term. Climate change is an example of a prolonged onset risk (Grafton et al., 2015). Individuals, businesses and governments are able to factor in these identified risks at differing time periods into their decision making (Grafton et al., 2015). The advantage of this is that solutions can be developed that are flexible and have the ability to respond to multiple risks. Through this long-term planning approach, decision makers have the opportunity to identify how risk mitigation solutions could impact on the trade offs on natural resources including water resources.

The steps in the ROAD model process builds on each previous step to assist decision makers. As Grafton et al. (2015) describe, the ROAD model process consists of five steps which are summarised in Table 1.

**Table 1: ROAD Model Process Summary**

<b>ROAD Model Step</b>	<b>Dominant Discourse</b>	<b>Key Points of ROAD Model Process</b>
1. Scope	Sustainable Intensification	<ul style="list-style-type: none"> <li>• Definition of:               <ul style="list-style-type: none"> <li>• Decision makers and their objectives</li> <li>• Risks</li> <li>• Stakeholders and their objectives</li> <li>• Baseline and thresholds for food, energy, environment and water systems</li> <li>• Manageable internal and external parameters</li> <li>• Available financial and non-financial resources</li> </ul> </li> </ul>
2. Trigger	Resilience Thinking	<ul style="list-style-type: none"> <li>• Identify trigger events</li> <li>• Select trigger events for assessment</li> </ul>
3. Causal Risk Assessment	The 'Nexus' Approach	<ul style="list-style-type: none"> <li>• Identification of:               <ul style="list-style-type: none"> <li>• Consequences of risks</li> <li>• Causal links between events</li> <li>• Portfolio of controls and mitigants</li> </ul> </li> <li>• Define causal model</li> </ul>
4. Control and Mitigant Options Assessment	Sustainable Intensification	<ul style="list-style-type: none"> <li>• Estimation of:               <ul style="list-style-type: none"> <li>• Likelihoods of events</li> <li>• Consequences and their impact</li> </ul> </li> <li>• Compare consequences to objectives of decision makers and stakeholders</li> <li>• Select investment decision</li> <li>• Conduct sensitivity analysis of decisions</li> <li>• Document decisions and their rationale</li> </ul>
5. Implementation and Review	Resilience Thinking	<ul style="list-style-type: none"> <li>• Implement decisions</li> <li>• Compare outcomes to objectives of decision makers and stakeholders</li> <li>• Re-evaluate causal pathways and consequences</li> <li>• Review controls and mitigants</li> <li>• Document review and make recommendations for subsequent assessment</li> </ul>

The concept of sustainable intensification is reflected in step 1, definition of scope, which consists of defining the structure within which decisions will be made. Firstly, the decision makers and their objectives need to be identified. The risks that need to be assessed by decision makers are also identified (Grafton et al., 2015). The stakeholders in the decision must be identified along with their needs and objectives in the process. Data on the baseline and key thresholds for the sustainability of food, energy, environment and water resources is gathered. Finally the internal and external parameters are defined as well as the identification of the financial and non-financial resources which are available for implementing any outcomes (Grafton et al., 2015). The internal and external parameters are the options decision makers have to mitigate risk. As these can be managed, changes to parameters can be made by decision makers in response to risk events occurring.

The second step of the ROAD model is to identify the events that can trigger the risks identified in step 1. This is a reflection of the concept of resilience thinking. All the risks and their triggers are identified before the specific risks are selected that will be assessed. The selected risks and trigger events include the 'worse case' scenario which allows decision makers to better prepare for all possible events (Grafton et al., 2015). The 'worse case' scenario is the worst possible event that would negatively impact most if not all stakeholders. Planning for this event would be beneficial for decision makers as they can prepare strategies and projects to mitigate the impact of the event for stakeholders.

The 'nexus' approach is reflected in step 3 through a causal risk assessment where the consequences and causal links between risks in food, energy, environment and water systems are identified (Grafton et al., 2015). Food systems are the agriculture industry that produces food for consumption. Water is needed for irrigation to increase productivity. Energy systems respond to the demand for electricity. Hydropower stations use water to generate electricity which can be used to operate irrigation equipment. Environment systems relate to the biodiversity and ecosystems of waterways. This includes wildlife habitats which require a minimum amount of water to be sustainable. Water systems require a level of water quality for human and ecosystem health. This also includes the recreational activities that are carried out on waterways such as fishing. Controls and mitigants are also identified step 3 of the ROAD model (Grafton et al., 2015). The controls and mitigants relate to the actions that can be taken to reduce the negative impact to stakeholders from the risk event occurring. Step three ends with the definition of a causal model that links the key trigger events, risks, controls and mitigants (Grafton et al., 2015).

Step 4 is the assessment of control and mitigant options identified in step 3. This step utilises the concept of sustainable intensification. Step 4 begins with an estimation of the qualitative or quantitative likelihood of the events in the causal model will occur (Grafton et al., 2015). By estimating the likelihood of a risk event occurring, decision makers can prioritise risk mitigation strategies and projects. Projects that mitigate a risk event that is unlikely to occur do not need to be implemented. Only strategies and project to mitigate risk events that will occur should be implemented. An estimation of the consequences and their impact to stakeholders is also required. These consequences are then compared to the needs and objectives of decision makers and stakeholders as well as the baseline thresholds identified in step one (Grafton et al., 2015). Investment decisions are selected that relate to the application of controls and mitigants of the trigger events. A sensitivity analysis is then conducted on the investment decisions to estimates of the key likelihoods and consequences. Finally the decisions made and the rationale behind those decisions are documented for implementation (Grafton et al., 2015).

Resilience thinking is incorporated into step 5 which concludes the ROAD model process by implementing risk mitigating strategies and projects and reviewing those decisions. After the decisions are implemented, the outcomes are compared to the needs and objectives of the decision makers and stakeholders (Grafton et al., 2015). They are also compared to the baseline thresholds identified in the earlier steps of the process. The causal risk pathways and the consequences for stakeholders estimated in steps three and four are re-evaluated. The controls and mitigants are also reviewed before the review process is documented and recommendations are made for future assessment of the decision making process (Grafton et al., 2015). Step five allows for the decision making process to be adapted in the future as new risks and threats to the water resource are identified which follows the resilience thinking discourse.

## Chapter 4

### Application of ROAD Model

The ROAD model process will be applied to Lake Coleridge and the Rakaia River in Canterbury. The waterways are managed by Environment Canterbury under the CWMS. Fed by inflows from the Southern Alps, Lake Coleridge is a water storage lake for the Lake Coleridge hydropower station operated by Trustpower (Environment Canterbury Regional Council, 2011a). The Lake Coleridge hydropower station generates electricity that is feed into the national electricity grid. Trustpower are able to regulate the flow through the hydropower station that regulates the water levels in the Rakaia River. The braided river environment of the Rakaia River is significant for the ecology of the river and also local Ngāi Tahu iwi. The Rakaia River is the habitat for native fish and bird species including rare river bird species such as the banded dotterel (Environment Canterbury Regional Council, 2011a). As the Rakaia River flows across the Canterbury Plains, irrigation companies and farmers utilise water for irrigation on dairy and crop farms (Environment Canterbury Regional Council, 2011a). At the mouth of the Rakaia River where the river meets the Pacific Ocean, anglers fish for salmon. Along with salmon fishing, other recreational activities are conducted on the Rakaia River, including jet boating and kayaking (Environment Canterbury Regional Council, 2011a).

Lake Coleridge and the Rakaia River in Canterbury is an example of how the four competing demands on water; food, energy, environment and water, interact. Table 2 below summarises the four demands on water in the context of Lake Coleridge and the Rakaia River.

**Table 2: Summary of the Four Demands on the Rakaia River**

Water Demands	Lake Coleridge / Rakaia River Demands
Food	Dairy farming Crop farming
Energy	Lake Coleridge hydropower station
Environment	Braided river environment Biodiversity
Water	Water quality Salmon angling

The demand for water from dairy and crop farming in the production of food comes from the need to irrigate farmland to increase production. Commercial irrigation companies take the water needed for irrigation from the Rakaia River with the use of a resource consent restricting the amount of water that can be taken from the river. As production increases on dairy and crop farms, more water is needed for irrigation. More electricity needs to be generated to operate irrigation systems putting pressure on the Lake Coleridge hydropower station to increase electricity generation. As more water is taken from the Rakaia River, there is a negative impact on the braided river environment as there

is less water in the river to support biodiversity. Also, nutrient runoff into the Rakaia River from increased irrigation would negatively impact the ecosystem by reducing water quality. A negative impact on salmon fishery stocks would impact recreational salmon anglers. Other recreational activities would also be impacted with a reduced water flows in the Rakaia River. It is important for these trade offs to be recognised and incorporated into decision making processes. Solutions can then be developed to mitigate the negative impact of an increase in water resource demand.

As the ROAD model is a new tool for decision makers, some of the data and information required to complete all the steps in the process is not yet available. In applying the ROAD model to Lake Coleridge and the Rakaia River the aim is to identify the data and information that needs to be collected. This will allow Environment Canterbury decision makers to use the ROAD model in future decision making. Environment Canterbury and Trustpower are currently working on gathering relevant data and information before implementing the ROAD model process as a decision making tool.

#### **4.1 ROAD Model Step 1: Scope**

Step 1 of the ROAD model defines the scope within which decisions are made. A summary of how step 1 of the ROAD model relates to Lake Coleridge and the Rakaia River can be found in Table 3. The decision makers for Lake Coleridge and the Rakaia River are Environment Canterbury and commercial parties, which include irrigation companies and Trustpower. Ultimately Environment Canterbury is responsible for making decisions for Lake Coleridge and the Rakaia River, as they are the only regional government authority for the area. Environment Canterbury is responsible for achieving the multiple target objectives and vision of the CWMS framework. Decisions made by Environment Canterbury in relation to Lake Coleridge and the Rakaia River will be constrained by the requirements in the CWMS and the RMA. Their objective is to manage the waterways in accordance with the CWMS and national government initiatives. Commercial parties make decisions as they relate to their commercial operations. Their objectives are to operate within existing water consents and Water Conservation Orders (WCO) conditions while maintaining profitability. The commercial parties are also stakeholders in the decision making process of Lake Coleridge and the Rakaia River. Irrigation companies and farmers require sufficient water to allow for efficient irrigation of farming areas to reduce nutrient loss. Trustpower are also stakeholders, as they require water to meet hydroelectric power generation needs. Additional stakeholders are the Selwyn District Council, which is the local council for the area including Lake Coleridge and the Rakaia River. The Selwyn District Council's objectives relates to local council governance and supporting the needs of local residents. Recreational users, such as the salmon anglers at the mouth of the Rakaia River, are also stakeholders. The needs of salmon anglers include high water quality for biodiversity and the safety of the salmon fisheries stock. Ngāi Tahu iwi are also stakeholders in Lake Coleridge and the Rakaia



River due to the cultural significance of the waterways. The beliefs of Ngāi Tahu are incorporated into the decision making process of Environment Canterbury as seen with the CWMS.

**Table 3: ROAD Step 1 Lake Coleridge and the Rakaia River Summary**

<b>Step 1: Scope</b>	
1.1 Decision makers undertaking the assessment	<ul style="list-style-type: none"> <li>• Environment Canterbury – policy and regulation</li> <li>• Commercial Parties – Trustpower, multiple irrigation companies</li> </ul>
1.2 Objectives of the decision makers(s)	<ul style="list-style-type: none"> <li>• Environment Canterbury: Achievement of multiple targets in the CWMS</li> <li>• Commercial Parties: Manage within consents and Water Conservation Order conditions</li> </ul>
1.3 Risks(s) to be assessed	<ul style="list-style-type: none"> <li>• Inflows to Lake Coleridge and irrigation demand</li> <li>• Impact on irrigation, hydropower and recreation (Salmon angling)</li> </ul>
1.4 Stakeholder groups and their needs and objectives	<ul style="list-style-type: none"> <li>• Selwyn District Council – local council governance</li> <li>• Irrigation companies and farmers – demand for water, need to irrigate efficiently to minimise nutrient loss</li> <li>• Trust Power – demand water for hydropower generation to met commercial needs</li> <li>• Recreational Users – water needed to meet WCO requirements</li> <li>• Ngāi Tahu – Management of water for cultural importance</li> </ul>
1.5 Baseline for food, energy, environment and water systems	<ul style="list-style-type: none"> <li>• Irrigated areas influenced by Coleridge/Rakaia supply</li> <li>• Generation from Coleridge hydropower station</li> <li>• Flow suitability along Rakaia River for recreational activities</li> <li>• <i>Further information on baselines needed for future research</i></li> </ul>
1.6 Key thresholds for sustainability of energy, water, environment, food resources	<ul style="list-style-type: none"> <li>• <i>Data needed for future research</i></li> </ul>
1.7 Internal and external parameters that can be managed	<ul style="list-style-type: none"> <li>• Commercial Arrangements between irrigation companies and Trustpower</li> <li>• Consent conditions irrigation companies and consequences for their water use agreements with individual irrigators</li> <li>• Take consents to ensure WCO mandated flow sharing in river</li> </ul>
1.8 Financial and non-financial resources available for implementing options	<ul style="list-style-type: none"> <li>• Commercial investment by Trustpower</li> <li>• Commercial investment by irrigation schemes</li> </ul>

The identification of risk events that are to be assessed in the ROAD model process forms part of step one. There are three risk scenarios that face Lake Coleridge and the Rakaia River that can be assessed

by the ROAD model. Each of these risk scenarios relate to the inflow of water into Lake Coleridge and the demands of water from irrigation companies. Each scenario is determined by weather conditions in the Southern Alps and the Canterbury Plains and has an impact of the amount of water that flows in the Rakaia River. The three scenarios are listed in Table 4.

**Table 4: Risk Scenarios for Lake Coleridge and the Rakaia River**

<b>Lake Coleridge Inflow</b>	<b>Irrigation Demand</b>
High inflow (wet)	High demand (dry)
Low inflow (dry)	Low demand (wet)
Low inflow (dry)	High demand (dry)

Wet weather conditions in the Southern Alps will increase the inflow into Lake Coleridge whereas dry conditions will reduce the inflow. On the Canterbury Plains, where there is a need for irrigation, dry weather conditions will cause an increase in the demand for irrigation as there is less water supply coming from rain on farmland. Wet weather therefore reduces the demand for irrigation. The ‘worst case’ scenario is when there are dry weather conditions in both the Southern Alps and the Canterbury Plains. This scenario results in low inflow into Lake Coleridge and high demand for irrigation on farmland. Each risk scenario will have an impact on the stakeholders relating to irrigation, hydropower generation and recreation.

Environment Canterbury is currently working on determining baselines and thresholds for the sustainability of the water resource in Lake Coleridge and the Rakaia River. It can be assumed that the baseline for food, energy, environment and water systems will relate to the minimum water level in the Rakaia River that will support the needs of stakeholders including irrigation companies, Trustpower for hydropower generation and recreational users. The baseline level will ensure that all the activities carried out on Lake Coleridge and the Rakaia River will still be able to be conducted in the future. By identifying key thresholds for stakeholders, risk mitigant projects can be implemented before stakeholders are negatively impacted. This could include implementing projects to improve water quality or increase the water flows in Lake Coleridge and the Rakaia River during a drought making more water available for irrigation and biodiversity needs.

The parameters that can be managed involve agreements with commercial parties. Irrigation companies require consents for water to be taken from the Rakaia River. These consent conditions can be changed to ensure the water flows in the Rakaia River continue to meet WCO requirements. This could reduce the amount of water that can be taken from the Rakaia River, which would decrease the productivity of the agriculture sector. As agricultural productivity needs to increase to supply food to more people, water infrastructure would need to be changed to improve efficiencies in the network. This could involve changing irrigation equipment to ensure the water that is allocated

for irrigation is used effectively. Environment Canterbury needs to work with stakeholders to identify additional parameters that can be managed.

Financial resources for implementing risk reduction options are limited. Commercial investment from Trustpower and the various irrigation companies on the Canterbury Plains would be required to finance possible projects. Currently there are no proposed projects to mitigate risks to Lake Coleridge and the Rakaia River. Projects that may be developed to reduce the impact of drought conditions could include irrigation systems. In this case, irrigation companies would be required to finance improvements to the irrigation network.

## 4.2 ROAD Model Step 2: Trigger

Step 2 of the ROAD model identifies the trigger that can lead to the risk event occurring. A summary of this step for Lake Coleridge and the Rakaia River can be seen in Table 5. As identified in step one, the trigger for the risk scenarios for Lake Coleridge and the Rakaia River in Table 3 relate to changes in weather conditions in both the Southern Alps and the Canterbury Plains. Different combinations of the weather patterns in the Southern Alps and the Canterbury Plains will necessitate different responses from Environment Canterbury and stakeholders. By identifying the ‘worst case’ scenario, risk-mitigating projects can be developed that could also mitigate less risky scenarios. The ‘worst’ case scenario is a combination of dry weather in the Southern Alps and also dry weather on the Canterbury Plains. This would indicate drought conditions and would trigger the ‘worst case’ scenario event. Drought conditions would result in less water being available to meet all the demands on the resource.

**Table 5: ROAD Step 2 Lake Coleridge and the Rakaia River Summary**

<b>Step 2: Trigger</b>	
2.1 Identification of trigger event(s) that can lead to risks	<ul style="list-style-type: none"> <li>• Decreased rainfall in mountains and low lake inflow</li> <li>• Decrease rainfall over farming area – high irrigation demand</li> </ul>
2.2 Selection of trigger events to be considered in the assessment, including a ‘worst case’ scenario	<ul style="list-style-type: none"> <li>• Low inflow to Lake Coleridge and High irrigation demand</li> </ul>

## 4.3 ROAD Model Step 3: Causal Risk Assessment

The causal risk assessment is the third step in the ROAD model process. A summary of step 3 of the ROAD model as it relates to Lake Coleridge and the Rakaia River can be seen in Table 6. The consequences of changing weather conditions relate to a reduction in the productivity in the agriculture and energy sectors. The consequences for the environment have a negative impact for biodiversity and recreational users. Minimum water levels in the Rakaia River are controlled by WCO

that ensure there is sufficient water flow for the health of the ecosystem. Causal links between events are currently being identified by Environment Canterbury. The controls and risk mitigants relate to the possible changes that can be made to existing water consents and commercial arrangement. There is potential to change consent conditions and commercial arrangements when these agreements are renegotiated.

**Table 6: ROAD Step 3 Lake Coleridge and the Rakaia River Summary**

<b>Step 3: Causal Risk Assessment</b>	
3.1 Identification of consequences from risks across food, energy, environment and water	<ul style="list-style-type: none"> <li>• Decreased rainfall in mountains and low lake inflows</li> <li>• Decreased rainfall over farming area – high irrigation demand</li> </ul>
3.2 Identification of causal links between events across food, energy, environment, water systems	<ul style="list-style-type: none"> <li>• Does increased irrigation demand substantially reduce hydropower?</li> <li>• Is reduced water supply for irrigation likely to lead to substantially reduced farm productivity?</li> </ul>
3.3 Identification of a portfolio of controls and mitigants	<ul style="list-style-type: none"> <li>• Consent conditions</li> <li>• Commercial arrangements</li> <li>• WCO changes</li> </ul>
3.4 Definition of a causal model linking key triggers, risks, controls and mitigants	<ul style="list-style-type: none"> <li>• Trigger <ul style="list-style-type: none"> <li>• Drought</li> </ul> </li> <li>• Risks <ul style="list-style-type: none"> <li>• Inflow to Lake Coleridge</li> <li>• Demand for Irrigation</li> </ul> </li> <li>• Controls and Mitigants <ul style="list-style-type: none"> <li>• Consent conditions</li> <li>• Commercial arrangements</li> </ul> </li> </ul>

As part of the ROAD model process, a diagrammatic representation of the decision making process can be developed. The diagram shows how the trigger events, risks and consequences identified in steps 3 and 4 link together. Figure 1 below is a diagram of the risks relating to Lake Coleridge and the Rakaia River from the perspective of a farmer on the Canterbury Plains. Information on the consequences, which would be identified in step 4, are based on assumptions as Environment Canterbury are currently working on identifying these and other information that comprises step 4 of the ROAD model. The weather patterns for the Southern Alps and the Canterbury Plains flow into the drought trigger event. It is interesting to note the two-way arrow between low inflow into Lake Coleridge and the drought trigger event. Low water levels in Lake Coleridge can be caused by reduced rainfall in the Southern Alps or drought conditions requiring more water to be released into the Rakaia River. This highlights the importance of Lake Coleridge as a water storage lake and the potential for the lake to act as a risk control mechanism. As the diagram shows, the potential consequences are identified including consequences for individual farmers. There are a number of potential options available to mitigate the risks of a drought, which include reducing water use and

improving water use efficiency. Presenting the ROAD model in diagrammatic form helps decision makers to rationalise their decisions to stakeholders. Environment Canterbury is one of the decision makers that would need to present the results of the ROAD model process to any stakeholders that are impacted by implemented changes. By presenting diagrams of the ROAD model process that are targeted to each of the stakeholders, Environment Canterbury can rationalise the need for change as it effects each of the stakeholders in the Rakaia River.

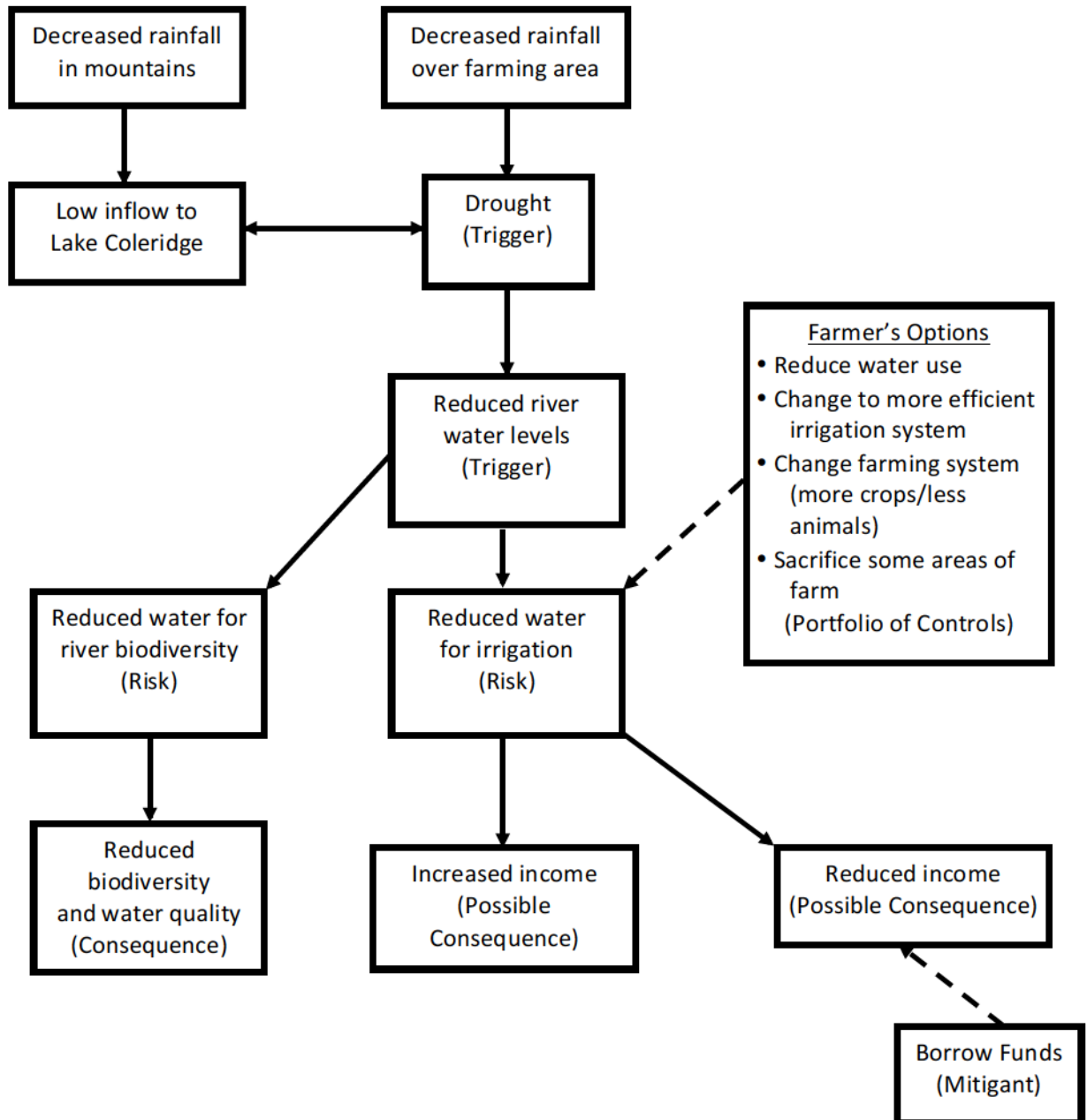


Figure 1: ROAD Model Diagram for Lake Coleridge and the Rakaia River

#### 4.4 Future Research Opportunities

As the ROAD model is a new tool for decision makers, there are a number of gaps where more information and data needs to be gathered. To complete step 1 of the ROAD model for Lake Coleridge and the Rakaia River, baseline and key thresholds for food, energy, environment and water

systems need to be identified. To complete step 3, further research needs to be conducted to identify causal links between events across food, energy, environment and water systems. Assumptions have been made based on Environment Canterbury's current data. However their links need to be confirmed before a causal model can be finalised. Current thinking by Environment Canterbury and Trustpower is that while low inflow into Lake Coleridge and high irrigation demand would be the 'worst case' risk event, the likelihood of that occurring is low. Much of the information and data for step 4, Control and Mitigant Options Assessment, needs to be gathered. This includes estimating the likelihood events will occur, such as the likelihood weather patterns will change. The consequences of events need to be estimated and how these will impact stakeholders. These consequences also need to be compared to the objectives of decision makers, Environment Canterbury and commercial parties, and stakeholders, irrigation companies, Trustpower, recreational users and Ngāi Tahu iwi. Once information becomes available from Trustpower and Environment Canterbury this can be completed. Step five can be completed once projects have been selected, as this step requires projects to be implemented and reviewed. Hydrological data has not been analysed that relates to the 'worst case' scenario event triggered by drought.

## Chapter 5

### Conclusions

The literature on cost-benefit analysis showed that there was a need for a new approach to evaluating water resource management projects. There are a number of cases where cost-benefit analysis is not flexible enough to address all the risks and demands on the water resource. The cases include; the United States (Brouwer & Pearce, 2005; Iovanna & Griffiths, 2006), European Union countries under the WFD (Balana et al., 2011; Dehnhardt, 2014; Hanley & Black, 2006) and Western Australia (Hajkowicz et al., 2008). In all of the cases the difficulty of valuing the benefits of water resources in monetary terms was the major issue. A greater awareness of how human activities impact the environment has necessitated the inclusion of environmental costs and benefits in to the evaluation of water resource management projects (Hanley, 2011). The ROAD model offers a new tool for decision makers to implement effective water management projects. The risk-based approach allows decision makers to develop strategies and implement projects to mitigate risk events (Grafton et al., 2015). Following the steps of the ROAD model decision making process as set out by Grafton et al. (2015), decision makers can identify not only the risk events but also the trigger events that could lead to the risk event occurring. This allows decision makers the opportunity to implement strategies to mitigate risk before the event occurs. By developing the ROAD model to incorporate the three discourses; sustainable intensification, the 'nexus' approach and resilience thinking, decision makers are able to gain a deeper understanding of the impact risk events would have on stakeholders. Also incorporation of the 'nexus' approach into the ROAD model forces decision makers and stakeholders to acknowledge the competing trade offs and demands on the water resource. The consequences of changing one or more of the food, energy, environment and water quality demands are acknowledged as the impacts to the other demands are identified. This does not address the issues with a cost-benefit analysis but does allow decision makers to better plan projects to mitigate risk events.

The purpose of this research is to identify how the ROAD model can be applied to Lake Coleridge and the Rakaia River system. This was achieved by working with Environment Canterbury to identify what information and data was available and what still needed to be gathered. The interaction between the competing demands on the Lake Coleridge and Rakaia River water resource are evident through farming (food), Lake Coleridge hydropower station (energy), biodiversity (environment) and recreational activities (water). Environment Canterbury decision makers and key stakeholders including commercial parties, Ngāi Tahu iwi, Selwyn District Council and recreational users, need to work together to achieve their individual objectives. Many of the objectives of stakeholders in Lake

Coleridge and the Rakaia River span across the competing demands which further highlights the need to manage the trade offs in water resource management so that one group is not adversely disadvantaged. The risk events already identified by Environment Canterbury relate to potential changes in weather patterns in the Southern Alps and the Canterbury Plains. A reduction in rainfall in drought conditions would increase the demand for water to meet the needs of stakeholders. The risk of drought conditions is the 'worst case' scenario that Environment Canterbury and Lake Coleridge and the Rakaia River stakeholders have found that there is a need to plan for. Strategies can be developed to mitigate the impact of a drought. The trigger for action from Environment Canterbury in the event of a drought will be a reduction in rainfall levels as identified in step 2 of the ROAD model. If the trigger event of a reduction in rainfall occurs, it is possible for changes in resource consent conditions to occur to reduce the amount of water being removed from the Rakaia River for irrigation. The causal risk assessment model created in step 3 of the ROAD model links together the information gained so far. This includes risk events, triggers for risk events and the controls and mitigants of risk for Lake Coleridge and the Rakaia River.

While these risks are so far not conclusive, in applying the ROAD model to Lake Coleridge and the Rakaia River in Canterbury, the areas where more information needs to be gathered have been clarified to assist future research opportunities. Further information is needed to confirm the causal risk assessment in step 3 and its components. Also data needs to be collected from Environment Canterbury and Trustpower to estimate the likelihood of risk events occurring and the potential impact on stakeholders. Environment Canterbury and Trustpower are currently working to generate this data that can be included in future research. Once collected, this will allow Environment Canterbury to use the ROAD model process to mitigate the risk of drought, and any other perceived risk, in Lake Coleridge and the Rakaia River area. Any decisions made by Environment Canterbury would need to be made within the constraints of the CWMS and the RMA legislation. The ROAD model does not replace cost-benefit analysis as a decision making tool, but rather it is a process for decision makers to follow to develop new strategies to mitigate the impact of risk events. Risk mitigation projects developed through the ROAD model process could still be subject to a cost-benefit analysis before approval if it is required by government authorities.



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