Cost Benefit Analysis of Riparian Planting Options for Freshwater Coastal Streams in Horowhenua

Ngā utu kia piki te Mauri o ngā wai a Parawhenuamea

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Abstract

Freshwater ecosystem health is an important policy priority in New Zealand, recently highlighted by the government's launch of the 'Freshwater Reform 2013'. One practical way of improving freshwater ecosystem health is riparian planting. In this context, the aim was to develop and apply a cost benefit analysis (CBA) methodology to evaluate riparian planting options for restoring five freshwater coastal streams of importance to iwi/hapū in the Horowhenua, drawing on two distinct disciplines – freshwater ecology and economics.

Essential to this CBA methodology was an explicit evaluation of a desired policy outcome. Accordingly, attention was given to assessing what constitutes the desired policy outcome that is 'freshwater ecosystem health of coastal streams'. This assessment was based on developing a detailed understanding of the attributes that must managed to achieve 'freshwater ecosystem health' including: in-stream temperature, periphyton, sediment, water flows, ecological connectivity, nitrate and ammonia, key fish species and stream invertebrates. The CBA methodology then focused on developing a new systems framework (interrelated ecosystem 'biophysical structures', 'processes' and 'functions') for assessing the ecological role of riparian vegetation in improving freshwater ecosystem health.

Non-market economic values required for CBA calculations were then derived using a benefit transfer method. Data from three study sites (Karapiro South Waikato, Hurunui Canterbury, and Canterbury) based on 'choice experiment' values were evaluated for their suitability for use in the policy site (Horowhenua). The suitability of data from study sites for use in the policy site applied the Welch T test and Wilcoxon rank sum, using 'personal income' as the assessment criterion. Over 100 hundred planting scenarios were then tested by CBA, with almost all having positive net present values for both 5m and 10m width planting options.

The study concludes with a discussion of the practical and policy implications of these findings, and highlights the limitations of this study and how these can be overcome in future research.

Keywords: Indigenous, ecosystem health, freshwater coastal streams, riparian, environmental cost benefit analysis, benefit transfer

Dedication

I dedicate this thesis to my children

Hemi, Reggae and Ramaroa,

their children and their children's children

Figure 1: Carved pātaka (food store) 'Te Takinga' at Lake Waiwiri taken by George Leslie Adkin 1906 (Source: Alexander Turnbull Library, New Zealand)

Te koi a ngā Tīpuna, a vigilant observation of Ancestors

Maringi noa ngā roimata a Ranginui ki te umu a Papatuanuku
Tae atu ki Te-Wao-nui-a-Tāne rāua ko Hine-Pari-Maunga
Ara ko ngā mātua o Parawhenuamea te Atua o ngā manga me ngā awa
The tears of Ranginui fall to the chest of Papatuanuku
to the great forest of Tane and the Mountain Maiden
the parents of Parawhenuamea the Deity of streams and rivers

Heke ngā ua tae atu ki ngā rau a te maru a Tāne
Katahi ka whakaeto ki te kōhauhau
I te korenga a Tāne, he ua kei te whenua
hei ngaru kawea ngā kino ki ngā wai a Parawhenuamea
The rain stops at the leaves of the canopy of Tāne
then evaporates to the atmosphere
In the absence of Tāne much rain arrives at the land
a wave taking contaminants to the waters of Parawhenuamea

Ngā Mihi, Acknowledgements

Tuatahi, he whakaaro mo te koi a ngā Tipuna, nā ngā kōrero a neherā whakamarama ai ngā Atua me tō rātou ake rohe he tātai ki te taiao pērā ki Te-Wao-Nui-a-Tāne, a Hine-Pari-Maunga, ka puta ko Parawhenuamea.

First a thought for the vigilance of the Ancestors, reflected in the oratory for Atua and their domains a system within the natural environment like that of Te-Wao-Nui-a-Tāne, Hine-Pari-Maunga, produced is Parawhenuamea.

Nō hea tēnei Kaitito? Whānau mai ki te motu ko Mangaia ki Kuki Airani a Pāpā, he uri hoki no Scotland. He Māori a Māmā ko ētahi Iwi Te Ngare a Huia, a Tamatera, me Tūhoe. Ēngari hokihoki au ki a Kikopiri a Te Ngare a Huia; ki te raki o Kikopiri he roto ko Waiwiri, ki te tonga a Kikopiri he awa ko Ohau rere mai I ngā pae maunga ko Tararua tae atu ki te Moana-tāpokopoko-a-Tāwhaki.

From where is this Scribe? Father born in Mangaia one of the Cook Islands, he also a descendant from Scotland. Mother is Māori, Tribes include Te Ngare a Huia, Tamatera and Tūhoe. Yet I frequently return to Kikopiri of Te Ngare a Huia;to the north of Kikopiri is the lake called Waiwiri, to the south of Kikopiri is the river called Ohau running from the ranges of Tararua to the Tasman Sea.

I would like to acknowledge the MBIE-funded Manaaki Taha Moana (MTM) research team. Professor Murray Patterson and Derrylea Hardy at Massey University, I would like to thank for your guidance in organising my ideas in order for me to complete this milestone. I am particularly grateful Murray for the instruction to first understand the ecological processes of riparian vegetation at the interface of terrestrial and aquatic ecosystems, which led me (an accountancy and finance double major) to an acquaintance with freshwater ecology, tōku maioha. I would also like to thank Dr. Huhana Smith, Aroha Sphinks and Moira Poutama from Taiao Raukawa, for your counsel and tautoko during this journey.

Koutou ko ngā hoa mahi katoa he maha ngā hua a tō tātou mahi tahi whakaaro puawai, whakawhiti whakaaro, hei tātai mo tēnei kaupapa kia piki te Mauri o ngā wai a Parawhenuamea. Karawhiua!

Also to colleagues there are many benefits of our collaboration generating ideas and exchanging ideas, toward this issue to restore the life force of freshwater. Karawhiua!

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Chapter 1: Introduction

1.1 Background

Freshwater ecosystem health is essential to life on Earth. In spite of this, freshwater ecosystem health has declined due to the combined effects of deforestation, intense land use for farming and other uses, industrial discharges and urbanisation. In New Zealand as well as world-wide, economic activity has often taken priority where freshwater ecosystem health has suffered as a result, with declining water quality, loss of habitat, and reduced biodiversity.

In New Zealand, these issues concerning decline in freshwater ecosystem health have been recently addressed by the Ministry for the Environment's 'Freshwater Reform 2013 and Beyond' (hereafter the Freshwater Reform). This Reform sanctions two objectives for all water bodies, one of which is the focus of this study – "ecosystem health and general protection for indigenous species" (Ministry for the Environment, 2013). The Freshwater Reform acknowledges declining water quality, but doesn't explicitly suggest any solutions. Perhaps of more immediate importance to this thesis is the Horizon Regional Council's 'One Plan' for the Manawatū-Wanganui region, specifically Chapter 6 of the 'One Plan' which acknowledges for water quality improvement "enhancement and protection measures including fencing and planting of riparian margins" (Horizon Regional Council, 2013), yet delegates funding to third parties. Even more specifically, the Horowhenua District Council's (HDC) proposed District Plan includes a schedule (see Appendix 1) of priority water bodies with values of natural and ecological significance amongst other values.

One solution to the problem of freshwater degradation, which will be evaluated in this thesis, is riparian margin restoration and replanting. By replanting the riparian margin along the edges of freshwater bodies, freshwater ecosystem health will be improved. Riparian margins perform a variety of biophysical functions that can be managed to reduce the effects of land use on in stream habitat and water quality (Gregory, Swanson, McKee, & Cummins, 1991; Naiman & Decamps, 1997; Thompson & Parkinson, 2011). Existing riparian vegetation performs a variety of ecosystem functions, for example shading of the canopy mitigating in-stream temperature and eutrophication both attributes identified by the Freshwater Reform. The variety of ecosystem functions inherent of riparian vegetation, collectively improve freshwater ecosystem health and water quality of the freshwater bodies. Riparian margins deliver co-benefits such as habitat provision, flood mitigation, and enhanced aesthetics. These ecosystem function and co-benefits will take some time (up to 20-30 years) to reach their full potential, meaning riparian planting is required immediately in an effort for improved freshwater ecosystem health.

Also of relevance to this thesis is the Resource Management Reform Bill 2012 (RMA reform) emphasising robust and thorough cost benefit analysis (CBA). Environmental CBA is the economic appraisal of policies and projects that deliberately or indirectly impact on the environment. CBA uses benefits and costs including externalities with data in a monetary unit, to calculate a net benefit (or net cost) of a policy or more usually a project. Although project costs such as materials and labour are readily available, the valuation of externalities such as ecosystem functions is challenging and infrequently considered by CBA calculations. In this regard, non-market valuations are increasingly being used to overcome this problem of the valuation of externalities, using such methods as contingent valuation and choice modelling to elicit Willingness to Pay (WTP) values for co-benefits provided by ecosystem functions. However, the cost and time required for such non-market valuations are high and often considered impractical to undertake. Therefore, over recent years ‘benefit transfer’ methods have been more frequently used, whereby monetary valuations in the published literature are utilised as valuation proxies for a local study. In this study, monetary valuations associated with improving freshwater ecosystem health for another region in New Zealand (South Waikato, Hurunui and Canterbury region) are considered, to then be transferred to a CBA exercise for Horowhenua of this study. In benefit transfer studies, the sites where published data is drawn from are called the ‘study sites’, and the sites where the data as applied to are called the ‘policy sites’.

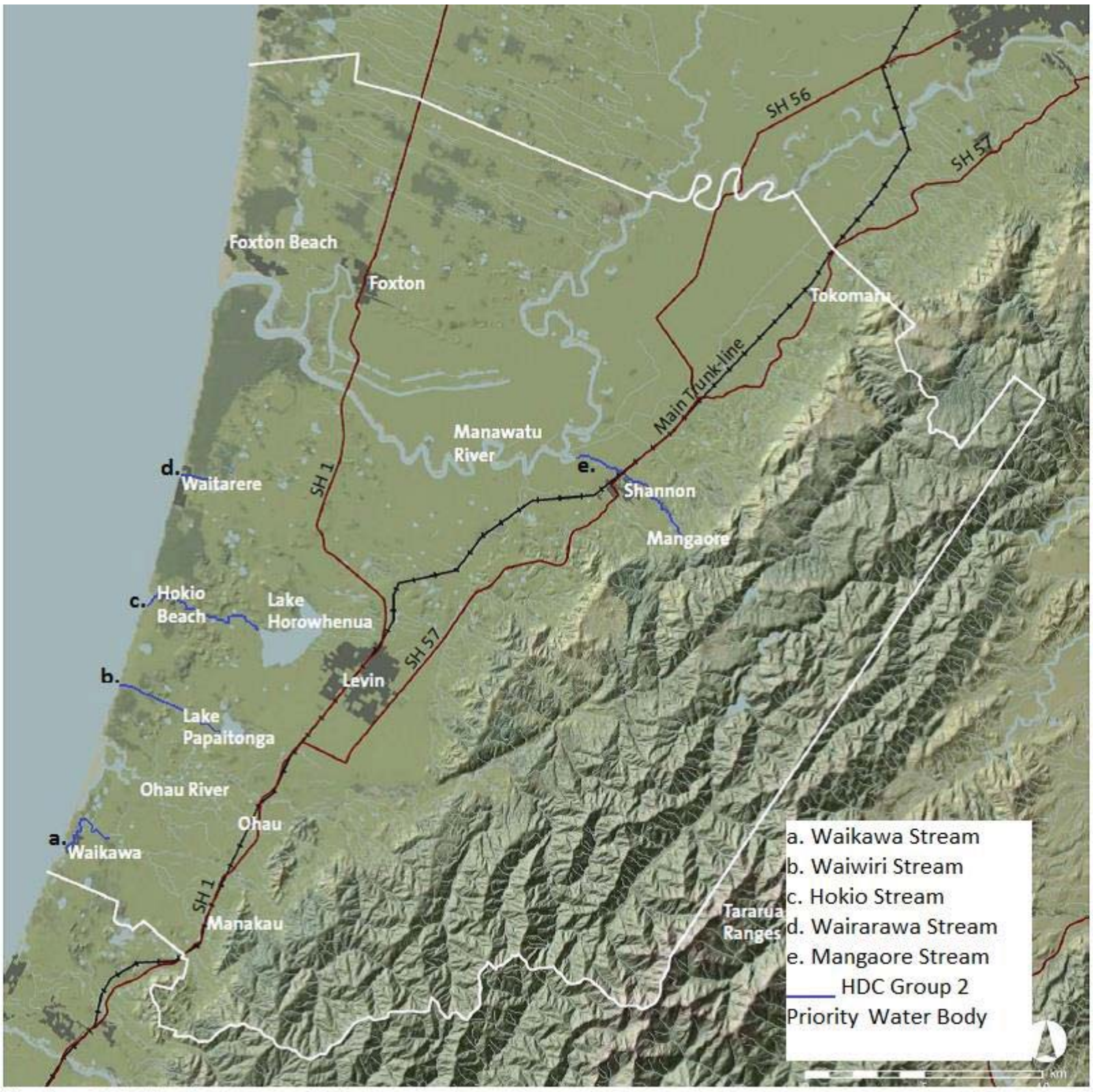
1.2 Horowhenua Case Study

In order to evaluate the net benefit of riparian planting, CBA will be used to assess riparian planting options in Horowhenua. These CBA evaluations will focus on selected freshwater coastal streams, with the expectation that the same type of methodology developed in this thesis could be applied to similar streams throughout New Zealand, and more broadly to other types of streams and other water bodies across the country. The policy sites of this thesis are Horowhenua Disctrict Council’s (HDC) Group 2 Priority Water Bodies (see Appendix 1), which are freshwater coastal streams in Horowhenua.

The Horowhenua is on the west coast of the North Island, approximately 80km north of the capital, Wellington. The five streams that will be evaluated include the Waikawa, Waiwiri, Hōkio, Wairarawa, and Mangaore streams. The total length of these streams to be considered by this thesis is 30.7 kilometres.

Descriptions of HDC’s Group 2 Priority Water Bodies are provided for in Chapter 5, and are briefly addressed here. Common to all the streams is a significant portion of adjacent land use in agricultural farming, other differences of significance are briefly noted. Waikawa Stream is the most southern of the streams, one of the larger watercourses of the region, flowing from the Tararua ranges through State Highway 1 to the Tasman Sea. North of Waikawa Stream and south of the Levin Township is Waiwiri Stream connecting Lake

Waiwiri (more commonly Lake Papaitonga) to the Tasman Sea. Much of the Lake Waiwiri was established as a reserve in 1901 and significant native vegetation still borders the lake.



Horowhenua District (boundary shown as a white line)

Figure 2: Map of Horowhenua coastal region (Adapted from: Horowhenua Open Space Strategy, 2012, p7)

North of Waiwiri Stream is Hōkio Stream connecting Lake Waipunahau (more commonly Lake Horowhenua) to the Tasman Sea. Lake Waipunahau previously was previously the recipient of sewage discharges from Levin for some decades since 1953. North of Hōkio Stream and Levin Township is Wairarawa Stream, a relatively dry stream flowing from the Wairarawa Lagoons to the Tasman Sea. Mangaore Stream is the most northern of the streams flowing from the Tararua ranges, through the Shannon Township to the confluence with the Manawatū River.

1.3 An Indigenous Perspective

An indigenous perspective is holistic considering accustomed environments as an extension of human identity (Durie, 2005), such as the five streams listed. Forest, freshwater and coastal are accustomed environments. Another term is ancestral environment because indigenous people are drawn to accustomed environments of their ancestors. This is true for Māori (indigenous people of New Zealand), such as myself. A short distance south of Lake Waiwiri at Muhunoa West Horowhenua, once lived my ancestors of Ngāti Kikopiri a sub tribe of Te Ngare a Huia. Ngāti Kikopiri and other sub tribes of Te Ngare a Huia, the wider tribe Ngāti Raukawa and the tribe Muaūpoko occupied Horowhenua and were sustained by accustomed environments - forest, freshwater and coastal.

I regularly return to the policy site Horowhenua. Iit is worth noting some other involvements in Horowhenua during the time of this thesis. Another cost benefit analysis of riparian planting for freshwater was conducted for the Manaaki Taha Moana[1] project, where the focus of that cost benefit analysis was the Waiwiri Catchment the stream, drains and tributaries. An additional project proposal to Raukawa ki te Tonga Trust funded a series of three wānanga (learning forums) that covered topics relevant to freshwater management. The ultimate aim of the three wānanga, was for riparian planting ancestral land and the application was granted. Two of the three wānanga (learning forums) have since been delivered. A priority on the agenda is the final wānanga, emphasising practical riparian planting. There have also been many presentations of this research. Audiences

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[1] There is a geographical overlap between the policy site of this thesis, and the case study area of the Manaaki Taha Moana (MTM), project which is Hōkio Beach to Waitohu Stream (south of Waikawa Stream).

have included fellow Kaitiaki and the tribe Ngāti Raukawa, Victoria University Landscape Architecture Students, the Department of Conservation; and the Manaaki Taha Moana teamof Massey University, Taiao Raukawa, Cawthron Institute, Waka Digital, and Manaaki Awanui.

Although this thesis does not reference an indepth indigenous perspective, it is reflected by the sub-title and the rendition - 'a vigilant observation of our ancestors'. This forms the conceptual framework of exchanges of riparian vegetation for freshwater ecosystem health. The sub-title 'Ngā utu kia piki te Mauri o ngā wai a Parawhenuamea' literally translates as 'the exchanges to increase the Mauri of the waters of Parawhenuamea'. According to Māori, Parawhenuamea is the deity of freshwater "springs, rivulets and streams we see issuing forth from the form of the Mountain Maid" (Best, 1923). An English equivalent for the concept of Mauri is drawn from the literature; Mauri is " a life principle or life essence" (Durie, 1998), "that force that interpenetrates all things to bind and knit them together" (Marsden & Henare, 1992). Mauri can be conceived as Exchanges which are addressed in *Chapters 2* and *3* as ecological exchanges and in *Chapters 4, 5* and *6* as economic exchanges. 'A vigilant observation of our ancestors' is a rendition of Māori cosmology which acknowledges the importance of Te-Wao-Nui-a-Tāne (the great forest) to Parawhenuamea (freshwater), which some decades later was observed by Western Science (Cooper & Thomsen, 1988).

In short, an indigenous perspective is holistic, drawing indigenous people to ancestral environments. The indigenous perspective is vigilant, with the potential to complement Western Science.

1.4 Aims and Objectives

1.4.1 Aim

The overall aim of this thesis is to develop and apply a cost benefit analysis methodology that evaluates the costs and benefits of riparian planting options for restoring freshwater coastal streams. This will be achieved by applying the methodology to the policy site of Horowhenua District Council's Group 2 Priority Water Bodies which are freshwater coastal streams.

1.4.2 Objectives

The specific objectives of this thesis that will support the overall aim are to:

1. Assess what is meant by the concept 'ecosystem health' as it is applied to freshwater coastal streams; and how this concept of ecosystem health is important in guiding the cost benefit analysis of riparian planting options.
2. Build on objective one to develop an operational framework (of quantitative indicators) for measuring freshwater ecosystem health, with a particular emphasis on the policy site.
3. Understand the ecological basis of the riparian planting of freshwater coastal streams, and appreciate how ecological processes contribute to the improvement of the freshwater ecosystem health.
4. Develop a cost benefit analysis framework for assessing the net benefits/costs of riparian planting options of the policy site, by reviewing the various methods of cost benefit analysis, and their limitations.
5. Evaluate the costs and benefits of riparian planting, informed from the Objective 4 findings, as well as the careful application of 'benefit transfer' methods, to obtain valuations for improving the freshwater ecosystem health at the policy site.

6. Discuss the findings of this research in order to draw out the implications for future research policy recommendations. How can the method be refined through further research and development, as well as being appropriately applied to other areas in New Zealand.

1.5 Thesis Structure

Figure 1 outlines the interrelationships between the different chapters and provides an overview of how this thesis is organised. *Chapters 2* and *3* focus on the ecology of riparian vegetation as it applies to freshwater coastal streams, with an explicit evaluation of freshwater ecosystem health using relevant attributes identified by the Freshwater Reform. Following the explicit evaluation, ecosystem functions that occur from riparian vegetation are described and situated within a conceptual framework, which links biophysical structures of riparian vegetation with ecosystem functions and processes. Once these ecosystem functions have been described and analysed, *Chapters 4, 5* and *6* then focuses on a CBA of riparian planting options. In *Chapter 4*, the CBA methodology is reviewed, which provides a backdrop to the application of CBA. In *Chapter 5,* the policy site Horowhenua and study sites are addressed for benefit transfer of data from the study sites to the policy site. In *Chapter 6,* are the actual CBA calculations and results reported for riparian planting options. The thesis concludes with *Chapter 7*, which discusses the methodological and conceptual contributions, empirical results and implications, the limitations and areas for future research and investigation.

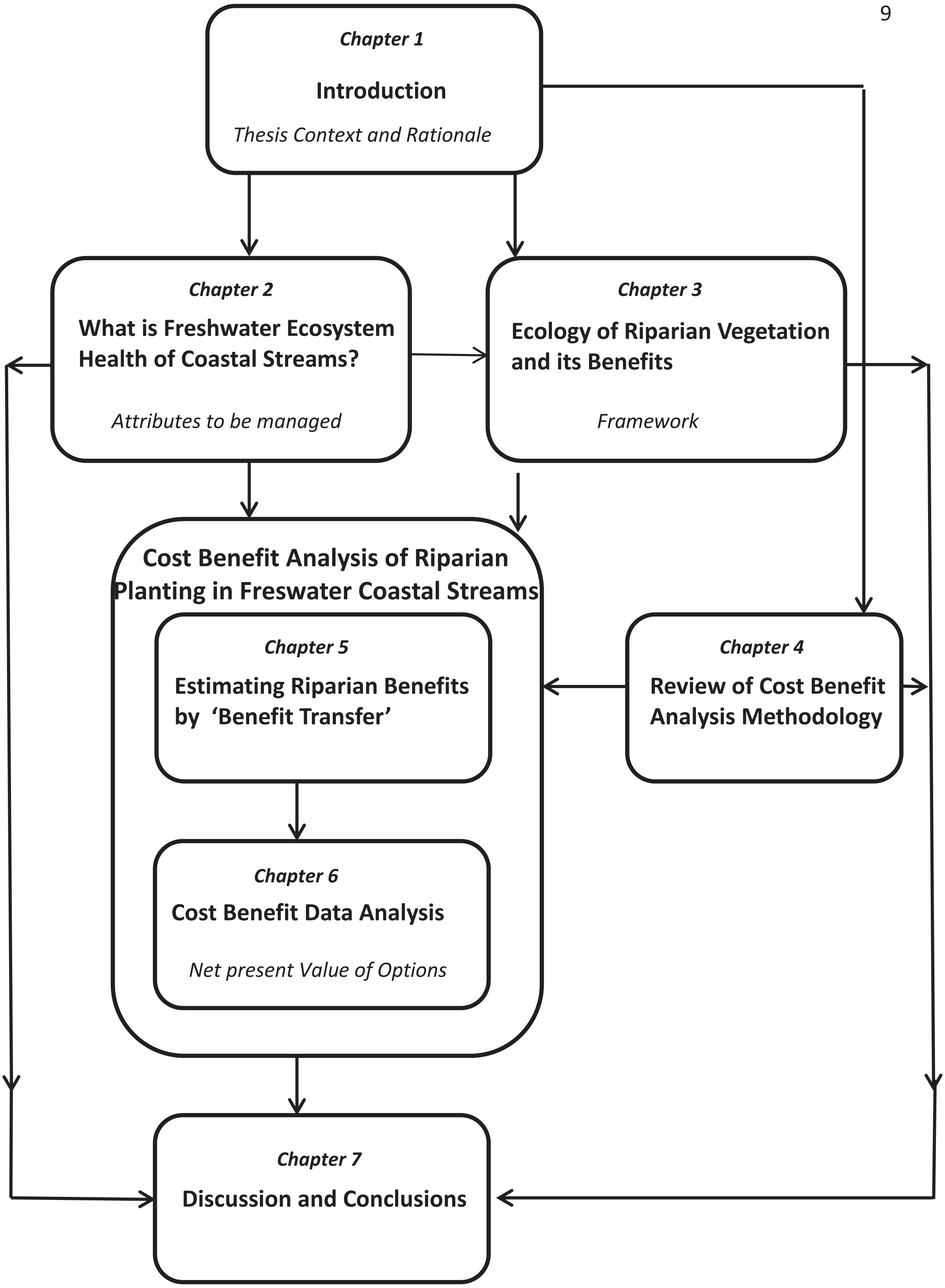

Figure 3: Thesis structure and steps

Chapter 2: What is Freshwater Ecosystem Health of Coastal Streams?

Freshwater management is a policy priority in New Zealand. Freshwater is “central to the environment, the economy and our identity” (Ministry for the Environment, 2013). In 2013 the Ministry for the Environment (2013) released *Freshwater Reform 2013 and Beyond* (2013) (hereafter referred to as ‘the Reform’). The Reform (2013, p5) explicitly acknowledges “water quality is declining in some areas”, and demonstrates some commitment to improving management of freshwater systems throughout New Zealand. The reform emphasises the National Objectives Framework (hereafter referred to as the Framework), as a means to achieving “freshwater objectives and limits”; these will be identified by collaborating Councils, Iwi/ Māori and local communities, then set into regional plans. Of the range of possible freshwater values that are identified by the Ministry for the Environment (2013), the Framework prioritises two and makes them applicable to all water bodies. These are ‘ecosystem health and general protection for indigenous species’ and ‘human health for secondary contact’.

This thesis focuses on the ‘ecosystem health’ value highlighted in the Reform, hereafter referred to as ‘freshwater ecosystem health’. In an effort for freshwater ecosystem health, the Reform identifies ten attributes to be managed, with each attribute having a minimum acceptable state on a scale of four bands - A, B, C and D. Attributes to be managed for freshwater ecosystem health in the Reform are listed, with added emphasis where attributes have been left open to interpretation:

- [In-stream] Temperature
- Periphyton
- Sediment

- [Water] Flow
- [Ecological] Connectivity
- Nitrate
- Ammonia
- Fish [Key Species]
- Stream invertebrates
- Riparian margin

The attributes to be managed for freshwater ecosystem health as determined by the Reform, were selected as an authoritative reference for optimum freshwater quality. However, the Reform only named attributes to be managed it did not provide any definitions or explanations as to the occurrence of those attributes. This omission was a topic of many submissions to the Reform[2]. This lack of clarity about the attributes to be managed for freshwater ecosystem health in the Reform is addressed in this thesis. This chapter discusses the concept of 'ecosystem health' and then provides comprehensive descriptions of the attributes to be managed for freshwater ecosystem health. The ecosystem functions of riparian vegetation are then addressed in *Chapter 4*.

2.1 Ecosystem health

For decades now, interpretation of ecosystem health has been the subject of cross-disciplinary debate. Amongst the debaters are, animal and plant science (Calow, 1992), environmental and hazardous materials (Cairns Jr, McCormick, & Niederlehner, 1993), 1993), ecology and resource management (Lancaster, 2000), ecological economics (Rapport, Costanza, & McMichael, 1998) and political science (Lackey, 2001). Of criticisms

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[2] To name a few who identified this lack of clarity about attributes are: New Zealand Conservation Authority, Royal Forest and Bird Protection Society of New Zealand Inc., Beef + Lamb New Zealand, Horizons Regional Council Manawatū-Wanganui.

for ecosystem health, is the reduction of an ecosystem to an analogy with an individual biological organism. Two assumptions surface from the organism analogy; an ecosystem has metabolic indicators (Lancaster, 2000), and an ecosystem is homeostatic or resilient when subject to perturbations (Calow, 1992). The irony of these assumptions is that it is known that ecosystems such as freshwater are not homeostatic when subject to perturbations caused by economic activity, hence the need to identify 'metabolic indicators' such as attributes to be managed for freshwater ecosystem health.

In practice ecosystem health is useful. It embraces a more holistic approach for environmental monitoring (Lancaster, 2000) by encompassing an entire ecosystem (Lackey, 2001), understood to be connected within larger systems (Rapport et al., 1998). Although a recent interest of Western science, the holistic approach of ecosystems within larger systems is not a new paradigm to Māori of New Zealand. According to indigenous knowledge human identity is an extension of accustomed environments (Durie, 2005). Genealogy is a reference system for Māori, entities such as peoples, environmental properties and land are interrelated and interdependent (Smith, 2007). Indigenous people are drawn to ancestral land.

An additional charm of ancestral land and accustomed environments, is that their condition manifests in its people. An example addressed in this thesis is Hōkio Stream, which once "had the capacity to provide sustainably for thousands of people" (Selby, Moore, & Mulholland, 2010). The water source of Hōkio Stream is Lake Waipunahau which was used for sewage discharge in 1953. Discharge to the lake affected the functioning of the stream to provide water for cleaning, cleansing and drinking, for cooking, food collection and storage as well as recreation. Living off the stream was no longer possible which manifested in temporary abandonment of ancestral land (Selby et al., 2010). Since at least

1998 restoration of Lake Waipunahau and Hōkio Stream resurfaces in policy where resilience of the lake and stream is yet to be observed.

2.2 In-stream Temperature

Stream temperature is critical to freshwater ecosystem health because it strongly influences what organisms can live in that freshwater ecosystem. At the Mangaore Stream in-stream temperature ranged between 5.8 ˚C and 14.9 ˚C (McEwan & Joy, 2011), which is ideal for most invertebrates and periphyton (Biggs, Kilroy, Mulcock, & Scarsbrook, 2002). Temperature tolerances vary among freshwater organisms but all have an optimal range for survival (Dodds & Whiles, 2010). For both freshwater fish and insects, changes in temperature can influence reproduction, rearing success and species competition. Temperature also effects freshwater life indirectly, as increased temperatures consequently reduce the saturation of dissolved oxygen (Collier et al., 1995).

The effects of water temperature on fish are well established and include fish distribution, abundance, behaviour, function, activity, growth, reproduction and survival. Fish actively pursue water with near optimal temperature. Ultimately, in-stream water temperature may influence whether or not adult fish return to a particular stream. At lower than optimum temperatures, the metabolism of fish declines and more energy is required for activity, reducing energy for growth. Temperature can affect gonad development, spawning, larval deformities and egg mortality (Richardson, Boubée, & West, 1994); thus changes in temperature are critical to survival of fish species. Fish require more oxygen as temperatures increase; however as noted earlier, increased temperature consequently reduces dissolved oxygen and “most fish will die if dissolved oxygen concentration becomes too low” (Dodds & Whiles, 2010).

Like fish, for stream invertebrates, temperature influences growth, metabolism, and survivorship (Quinn, Steele, Hickey, & Vickers, 1994). At higher temperatures invertebrates feed more actively elevating growth and metabolism; increased growth reduces energy for egg production, which then threatens survival. Many New Zealand invertebrates are sensitive to water temperatures greater than 20˚C (Parkyn, 2004); and are intolerant of increases in temperature (Quinn et al., 1994).

The temperature regime of a stream is influenced by tributaries joining or entering it. The resulting temperature of a stream is the individual temperatures weighted by their respective volume of discharge (Beschta, Bilby, Brown, Holtby, & Hofstra, 1987). When temperatures deviate from the norm or optimum, the event is known as thermal pollution. Economic activities that contribute to thermal pollution include discharges, industrial cooling, reduced stream flow, water withdrawals, hydroelectricity, and to a large extent removal of riparian vegetation (Dodds & Whiles, 2010).

2.3 Periphyton

Periphyton commonly referred to as the slime found on the streambed are freshwater algae and prokaryotes (e.g. cyanobacteria) that grow by photosynthesis. Algae are often observed at the Waikawa Stream[3], as is cyanobacteria[4]. Periphyton provide much of the energy for the maintenance of the rest of the ecosystem (Biggs, 2000). Periphyton are a primary food source for some invertebrates and fish, and are essential to freshwater ecosystem health. The amount of nutrients, light and other resources required by different periphyton species varies, but in general they need a combination of nutrients, light and temperature to provide the energy for cell growth.

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[3] Waikawa Stream downstream of SH1, January 2009; http://www.horizons.govt.nz/about-us/who-what-where/news/horizons-steps-up-algae-warnings/

[4] http://www.horizons.govt.nz/about-us/who-what-where/news/water-quality-top-priority/a-snapshot-of-water-quality-in-the-horizons-region/

Periphyton are warning systems for environmental degradation (Larned, 2010), by observing periphyton growth. Healthy streams are characterised by little obvious periphyton, scoured by water velocity and consumed by grazing invertebrates and fish. Thick slimy mats (Quinn & Meleason, 2002), otherwise known as eutrophication occurs when there is substantial periphyton growth. Eutrophication is often observed during summer as a nuisance growth of a dominating periphyton species, because of optimal nutrients, light and temperature. Land use has an effect on periphyton growth; for example agricultural farming has increased levels of nutrients to lowland water bodies, and the removal of riparian vegetation exposes periphyton to increased light and heat. The types of problems that nuisance growths of periphyton can impose on instream values are demonstrated in Table 1 as reproduced from Biggs (2000).

Table 1: In-stream values that can be compromised and associated problems that may arise as a result of periphyton proliferations

Instream Value	Problem
1. Aesthetics	Spoilt scenery and odour
2. Biodiversity	Habitat alteration, reduced invertebrates and benthic diversity
3. Contact recreation	Unsuitable for swimming and wading, odour
4. Industrial use	Distaste and odour, clogging abstraction structures
5. Irrigation	Clogging abstraction structures
6. Monitoring structures	Interferes with flow and sensor surfaces
7. Potable supply	Distaste and odour, clogging abstraction structures
8. Native fish conservation	Spawning an d living habitat impaired
9. Stock and domestic animal health	Toxic blooms of cyanobacteria
10. Waste assimilation	Reduced functioning: stream flow, ability to absorb ammonia, ability to process organics
11. Water quality	Suspended waste, anoxic (low oxygen) streambed, fluctuations in dissolved oxygen, alkalinity, acidity and toxicity
12. Whitebait fishing	Clogging nets

Source: Biggs (2000). ***New Zealand Periphyton Guideline: Detecting, Monitoring and Managing Enrichment of Streams.***

2.4 Sediment

Increased sediment degrades the freshwater ecosystem affecting stream habitat and water quality. At the Mangaore stream, suspended sediment concentrations ranged from 0.60 to 160 mg/litre (Brown, 2009). Sediment is a product of erosion, occurring when soil particles become detached from the ground to enter water as sediment. Erosion loss is a natural process, however intense land use has accelerated erosion consequently generating higher levels of sediment. Addressed here are sheet and channel erosion which are effects of land use, and the effects of sediment on freshwater ecosystems.

Both sheet and channel erosion are heaviest during flood flows. Sheet erosion is the diffuse loss of soil from a catchment during a rain event; a process of splash detachment, splash transport, run off detachment and run off transport (Walling, 1976). Channel erosion relates to high volume channel flows with increased erosive power, consequently scouring the stream bank, dislodging soil and entering water bodies as sediment.

Variation in the amount of sediment in streams is influenced largely by soil properties of the land and adjacent land use. Deforestation, conversion to agriculture and the direct effects of livestock in water bodies, have increased erosion and consequently the amount of sediment ending up in freshwater coastal streams and rivers. Almost all forms of farming result in increased erosion, with suspended sediment being higher in waterways in land areas that have been drained for farming, than in that of native forests (Quinn, Cooper, Davies-Colley, Rutherford, & Williamson, 1997). Pasture land is also characterised by pugging or soil compaction, caused by stock damage and decreased groundcover. Soil compaction reduces the capacity of the soil to absorb rainfall increasing volume of runoff, with inadequate groundcover to intercept and slow down the movement of sheet erosion.

Increased sediment degrades the freshwater ecosystem affecting stream habitat and water quality. Bullies and invertebrates use interstitial spaces between stones (Jowett, Richardson, & Boubee, 2009; Parkyn, 2004), but are unable to do so when those interstitial spaces are filled by sediment. Thus sediment consequently reduces habitat quality and biodiversity. Suspended sediment also reduces visual clarity for both sighted freshwater organisms (Collier et al., 1995), and humans who use streams and rivers for recreational swimming. Reduced water clarity can thus become a human safety issue. Suspended sediment also reduces light penetration for optimum growth of periphyton and bryophytes (mosses and liverworts).

2.5 Water Flows

Water flow or more strictly channel flow (Q) is cross sectional area (A) multiplied by velocity (V). Units of measurement are either cubic meters per second (m^3/s) or litres per second (L/s). The cross sectional area is channel height multiplied by channel width. Ideally stream channels would remain unchanged, however many streams have been subject to channel erosion. Velocity depends on channel slope, frictional resistance differing between sandy and stony substrates, and the wetted perimeter which relies on a water source. Water flow of Hōkio Stream ranged from 0.3 to 2 cubic metres per second (Gibbs, 2011); the source is Lake Waipunahau (more commonly known as Lake Horowhenua), that used to receive sewage discharges from Levin. Wairarawa Stream is ephemeral, dry during summer with no flow, but its main sources of water are the Wairarawa Lagoons.

Water flow is critical to “sustaining native biodiversity and ecosystem integrity” (Poff et al., 2010). Some definitions for flow in pursuit of ecosystem integrity are, the natural flow regime (Poff et al., 1997), environmental flow (Global Environmental Flows Network, 2007), and ecological flow (Beca Infrastructure Limited, 2008). The effect of flow on ecological integrity is summarised by Poff et al. (1997) as primary regulators, three of which are addressed here: water quality, energy sources and physical habitat.

When reporting on water quality in New Zealand, the Ministry for the Environment measures bacteria, nutrients, visual clarity, and water temperature, dissolved oxygen, and stream invertebrates – all of these factors are affected by low water flow which occurs due to decreased water volume. Decreased water volume is accompanied by an increase in concentration of bacteria and nutrients in-stream. Increased nutrients contribute to increased periphyton biomass, which reduces visual clarity. Streams with low water flow are more sensitive to heat increasing the water temperature, which consequently decreases dissolved oxygen and impinges on stream life.

Energy sources of in-stream food webs are periphyton, leaf litter, invertebrates and fish. Hence an energy flow by trophic relationships where invertebrates and fish consume periphyton and leaf litter, and some invertebrates and fish consume other invertebrates and fish. Flood events and very low flow conditions, have a potentially cascading effect on in-stream trophic relationships. Primary sources of energy periphyton and organic matter are scoured and washed out during flood events. During low flow, periphyton has the potential to proliferate decreasing biodiversity, which changes the invertebrates community to one dominated by grazers.

Aquatic species have well-defined preferences for habitat. The flow regime affects pools, runs, riffles and rapids. These habitats differ by water velocity, depth and substrate. Pools are deep areas with low velocity and have a fine sandy substrate. In contrast, runs are characterised by moderate decrease in depth and increase in velocity. Riffles are shallow areas with higher velocity, with a substrate of gravel and small rocks. Rapids are the most turbulent being shallow with increased velocity of water over exposed rocks. Pools and runs are the habitat of lamprey, and shortfin and longfin eels (Jowett & Richardson, 2008).

Riffles, however, are observed to have higher fish densities than runs (Jowett & Richardson, 1995). Flooding increases depth, increasing pool habitats and a loss of riffle habitats. Low flow and the extremes of drought, result in patchiness of water and fragmented stream continuum.

2.6 Ecological Connectivity

Ecological connectivity is fundamental to species distribution. Ecological connectivity is defined as "the flow of organisms and ecological processes across landscapes" (Krosby, Tewksbury, Haddad, & Hoekstra, 2010). The streams Hōkio and Waiwiri connect the lakes respectively Waipunahau and Waiwiri, to the sea. These two streams have been identified as priority outflow stream habitats for fish passage (James & Joy, 2009). In addition to connections between lakes and sea, freshwater rivers and streams connect various landscapes that interact through processes that are essential to some species and ecosystem functions. Hydrological connectivity is "water mediated transfer of matter, energy and/or organisms within or between elements of the hydrologic cycle" (Pringle, 2003). Often cited (Amoros & Bornette, 2002; Jansson, Nilsson, & Malmqvist, 2007; Pringle, 2003) are four-dimensions of hydrological connectivity identified by Ward (1989). They are longitudinal, lateral, vertical and temporal which are considered as follows.

The longitudinal dimension of hydrological connectivity integrates upstream-downstream linkages. Longitudinal connections are fish migration, the colonisation cycle (Müller, 1982) and river continuum concept (Vannote, Minshall, Cummins, Sedell, & Cushing, 1980). Many of New Zealand's native fish are migratory and spend parts of their lifecycle in freshwater and at sea. However, in-stream barriers hinder the ability of those migratory fish to colonise and persist in suitable habitats (James & Joy, 2009). The colonisation cycle of stream insects, demonstrates upstream-directed flight behaviour when pursuing optimal conditions during the eggs and nymph stages. The river continuum concept theorises that stream invertebrate communities minimise energy loss, with downstream invertebrates consuming processed resources from upstream communities.

The lateral dimension of hydrological connectivity occurs between the channel and the riparian area of the waterway. This dimension includes the movement of organisms and exchange of organic matter. Riparian vegetation also provides habitat diversity for both terrestrial and aquatic species (Collier et al., 1995). Most aquatic insects spend only larval and nymph stages in water, leaving as winged adults to the riparian area in preparation for reproduction. The riparian margin provides energy inputs including leaf litter and terrestrial insects. Leaf litter is consumed by stream invertebrates during larval and nymph stages and terrestrial insects that enter the water are consumed by fish.

The vertical dimension of hydrological connectivity is the hyporheic zone which incorporates interactions between ground waters and the receiving water body. Important functions of organisms that inhabit the hyporheic zone are bioturbation and litter breakdown (Jansson et al., 2007). Bioturbation is the reworking of soils and sediments important for soil processes and shape of the channel (Meysman, Middelburg, & Heip, 2006). Aquatic hyphomycetes (fungi) disperse within the hyporheic zone (BÄRlocher, Seena, Wilson, & Dudley Williams, 2008). The significance of hyphomycetes, is that they breakdown and enhance the quality of leaf litter, which is subsequently consumed by stream invertebrates.

2.7 Nitrate and Ammonia

Nitrate and ammonia are interdependent through the nitrogen cycle. Both are reactive nitrogen compounds received by freshwater ecosystems from associated catchments. Total nitrogen and ammoniacal nitrogen in excess of guidelines have been observed for the Waiwiri Stream (Allen, Sinner, Banks, & Doehring, 2012). According to Land Air and Water

Aotearoa (LAWA)[5], Waikawa stream is in the worst 25% of sites for nitrogen, total nitrogen (1.2g/ m^3), total oxidised nitrogen (0.866g/ m^3), and ammoniacal nitrogen 0.032g/ m^3)[6].

Biological nitrogen fixation was once the only significant process creating reactive nitrogen (Marino & Howarth, 2010). Prior to the agricultural and industrial revolutions, nitrate and ammonia were naturally received by water bodies as biological degradation products of organic matter. Intense land use however, has caused an increase in concentrations of ammonia and nitrate to freshwater ecosystems, threatening freshwater ecosystem health. The sources, processes and implications of nitrate and ammonia to freshwater ecosystems are addressed below.

Nitrate leaching to freshwater is a consequence of animal waste, fertiliser, agricultural runoff, and sewage effluents (Alonso & Camargo, 2003; Arango et al., 2007; Vitousek et al., 1997; R. J. Wilcock et al., 1999). Animal waste is a significant cause of nitrate leaching. The concentration of nitrogen in animal waste exceeds plant requirements, with excess nitrogen then leaching through soils to streams and groundwater. Nitrate accumulates in the topsoil during dry periods with little movement. As soil moisture increases nitrate is flushed from the soil to associated water bodies. When nitrate is absorbed by living organisms, haemoglobin is converted to methomoglobin which is ineffective in carrying oxygen to cells, thereby resulting in a depletion of oxygen and death.

Ammonia is commonly absorbed onto clay and other particulate matter then carried by water as suspended sediment. Livestock waste that is stored, treated, applied to land and discharged to water, is associated with ammonia losses (Alonso & Camargo, 2009; Bussink & Oenema, 1998; Hickey & Vickers, 1994; Wilcock, McBride, Nagels, & Northcott, 1995).

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[5] www.lawa.org.nz

[6] http://www.lawa.org.nz/explore-data/manawatu-wanganui-region/waikawa/waikawa-stream-at-huritini/

Total ammonia is the sum of ionised (NH_4^+) and unionised (NH_3). For aquatic animals, NH_4^+ is only toxic at high concentrations and low pH (Alonso & Camargo, 2009). More toxic is NH_3, which increases with increases in pH and temperature (Emerson, Russo, Lund, & Thurston, 1975). For fish, NH_3 causes an increase in gill ventilation, hyperexcitability, convulsions and finally death (Alonso & Camargo, 2003). For stream insects, the effects of ammonia on behavioural endpoints are considered of more interest, indicative of physiological and ecological processes preceding mortality (Alonso & Camargo, 2009).

2.8 Key fish species

In their field study, (McEwan & Joy, 2011) collected 130 fish in a 100-m reach of the Mangaore Stream; most commonly Redfin bully (*Gobiomorphus huttoni*), and *Galaxias* species shortjaw kokopu and koaro (McEwan & Joy, 2011). In a study for prioritising restoration of out-flow stream habitat on the west coast of New Zealand which includes the Horowhenua area of this research, James and Joy (2009) identify key fish species including eels (*Anguilla* genus), and inanga and giant kokopu (both of the *Galaxias* genus). Key species have demonstrated positive associations for co-occurrence (Minns, 1990), and are addressed below.

2.8.1 Eel

Eels are found at almost all habitats with access to the sea. Eels live long and catadromous lifecycles. Catadromous lifecyles involves eels spawning and hatching at sea, returning to freshwater as juveniles, developing to adults then returning to the sea to spawn and die. Eel species in New Zealand are shortfinned (*Anguilla australis)* and longfinned *(Anguilla dieffenbachii)*; the longfinned eel are the endemic species. Each of these species differ in habitat preference (Glova, Jellyman, & Bonnett, 1998), diet (Hicks, 1997; Jellyman, 1989), and growth (Chisnall & Kalish, 1993).

Eel habitat is dependent on water velocity and substrate. Small longfinned eels (<30cm) are most common in riffles. Larger eels prefer low velocity habitat such as pools associated with a variety of cover macrophytes, banks, in stream debris and shade (Baillie, Hicks, den Heuvel, Kimberley, & Hogg, 2013).

Eels are opportunistic and feed intermittently on a wide range of food items. Food items have been observed to have correlation with the size of the eel. In an analysis of the gut contents of fish Hicks (1997) observed that longfinned eels consume both aquatic and terrestrial insects. Jellyman (1989) observed a change in diet with size of eel. At <30cm the longfinned eels ate both land and stream invertebrates, and crustacean. At larger sizes their diet was dominated by the consumption of fish perch, other eels and bullies.

2.8.2 Inanga and Giant Kokopu

Inanga (*Galaxias maculatus*) and giant kokopu (*Galaxias argenteus)* are native to New Zealand, two of five species in the New Zealand whitebait fishery. Horowhenua streams of focus for this thesis are within the jurisdiction of the Horizons Regional Council (HRC), and HRC's regional plan the "One Plan". The One Plan includes a water policy that identifies the management of native fish spawning sites, as an issue of importance. Both inanga and giant kokopu have an amphidromous life cycle, spawning in rivers or estuaries, moving to the sea as hatched larvae and returning as juveniles to freshwater to complete their lifecycle.

The preferred habitat of both whitebait species is characterised by deep gently flowing pools water with shelter from overhanging riparian vegetation (Bonnett & Lambert, 2002; Jowett & Richardson, 2008; Richardson, 2002). Both species feed on land and stream organisms. Inanga feed remaining in the current and taking from the drift, or feeding where the current has concentrated food. Giant kokopu are generalist feeders, feeding on both land and stream insects as well as fish (Bonnett & Lambert, 2002).

2.9 Stream Invertebrates

Stream invertebrates have significant functions in freshwater ecosystem processes. Invertebrates process and consume in-stream and terrestrial organic carbon, subsequently influencing periphyton growth, nutrients, and food available for higher order consumers fish and birds. Freshwater crayfish rely on invertebrates for growth. However with age, freshwater crayfish change to a diet dominated by detritus (Brown, 2009). A healthy invertebrate community is indicative of optimum freshwater ecosystem health. The following paragraphs describe the physical and biological variables that influence invertebrate community structure, invertebrate communities as biotic indices, with a brief description of pollution-sensitive invertebrate species.

Invertebrate community structure and diversity is controlled by a number of physical and biological variables (Death & Joy, 2004). Physically a healthy community is supported by wadeable, hard bottomed or stony streams with native vegetation in the riparian margin. Biologically, invertebrate communities are altered by organic pollution a consequence of organic waste, entering water bodies via non-point (e.g. run off) and point (e.g. drains) sources. Organic waste is used or converted mainly by micro-organisms such as bacteria, fungi and protozoa, which consequently compete with invertebrates for oxygen.

A healthy invertebrate community is indicative of optimum freshwater ecosystem health, hence the use of invertebrate communities as biotic indices of water quality and freshwater ecosystem health. Invertebrate community structure can change over different scales of time and distance due to the stresses that occur in the aquatic environment; therefore, such changes in invertebrate community structure are a better indicator of water quality than chemical water quality data for one single moment in time. Two common biotic indices measuring invertebrate communities are Macro Invertebrate

Community Index (MCI) and percentage of invertebrate species Ephemeroptera, Plecoptera and Trichoptera (%EPT).

The MCI considers all species present in a sample collected, and is based on the density of all invertebrate species collected. The %EPT measures the abundance and diversity of only pollution-sensitive invertebrate species Ephemeroptera (mayfly), Plecoptera (stonefly) and Trichoptera (caddisfly), hence the acronym %EPT. Some New Zealand pollution-sensitive species that are therefore good pollution indicator species are:

Acanthophlebia cruentata, a mayfly - these have demonstrated sensitivity to high water temperatures, low dissolved oxygen and increased sediment. *Acanthophlebia cruentata* is endemic to New Zealand and is common at the pre-mentioned hyphorheic zone of forested streams, with terrestrial organic matter the main source of nutrition in the form of fine particulate matter (FPOM).

Auestroperla cyrene, a stonefly - these colonise all types of fresh water habitats in New Zealand from near sea-level to alpine streams. Unique to this stonefly is the presence of hydrogen cyanide, rendering it unpalatable to potential predators (McLellan, 1995). This stonefly consumes both coarse and fine particulate organic matter (respectively CPOM and FPOM), and is an opportunistic feeder with a varied diet decomposing wood, dead mayfly nymphs, leaf litter and associated fungal hyphae.

Aoteapsyche raruraru, a caddisfly - these are most common at lake outlets, declining in abundance with increasing distance from the lake. Decreasing abundance is associated with food quality, temperature change, flow variability, substrate instability, competition and predation. *Aoteapsyche raruraru* have demonstrated an increase in density with an increase in current velocities on upper surfaces of small boulders as optimal feeding sites consuming FPOM (Harding, 1997).

2.10 Ecosystem health a holistic methodology

This chapter first addressed ecosystem health as a holistic approach with ‘metabolic indicators’. Indicators such as attributes to be managed for freshwater ecosystem health, demonstrate that ecosystems operate within larger systems. This holistic approach is of relatively recent interest for Western science, as it is an approach traditionally experienced and observed by indigenous people such as Iwi and Hapū of Māori in New Zealand. The chapter proceeded to provide comprehensive descriptions of the attributes to be managed for freshwater ecosystem health adapted from New Zealand’s Freshwater Reform. It has described the incidence of attributes and potential effects throughout freshwater coastal streams; the holistic approach characteristic of ecosystem health. The detail for attributes provided in this chapter, serves interested lay end users to appreciate freshwater ecosystem health of coastal streams.

Chapter 3: Ecology of Riparian Vegetation and its Benefits

The riparian margin is the interface between land and water ecosystems, the land adjacent to a water body such as a stream. Before human-induced changes to land cover, the riparian margin was vegetated, characterised by well-functioning ecosystems and suitable for human contact. Riparian vegetation is widely recognised as a means to maintaining water quality for ecosystem health. The purpose of this chapter is to demonstrate how riparian vegetation contributes to attributes to be managed in the pursuit of freshwater ecosystem health. This is considered by a conceptual framework[7] (see Figure 4) which compartmentalises riparian vegetation into three conduits identified in Te Reo Māori (the Māori language) which is a novel contribution to the literature. The framework in Figure 4 is original, identifying riparian vegetation at the macro level, and at the micro level the biophysical structures of the vegetation function as three conduits of exchange: te marumaru (the canopy), ngā pararopi (detrital inputs), and whenua (the riparian floor).

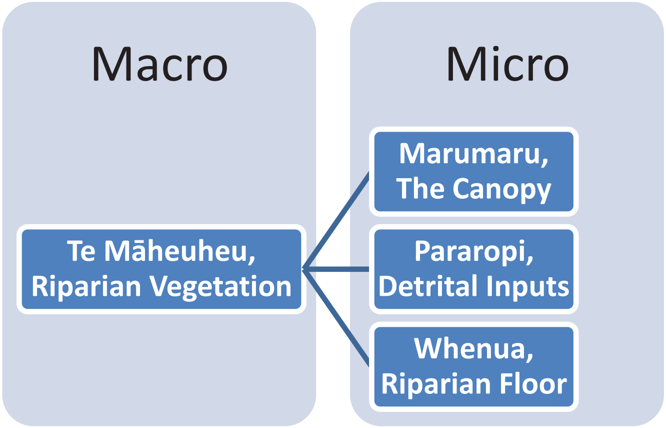

Figure 4: Compartmentalising riparian vegetation as conduits of exchange

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[7] Similar to the framework is PuseyA and ArthingtonA (2003) conceptual model depicting how the riparian zone impacts on riverine fish. Rather than riparian vegetation, the macro level of PuseyA and ArthingtonA (2003) model is the riparian zone, at the micro level are resources exchanged: transfer of solar energy, exchange of inorganic material, and exchange of organic material.

3.1 Maru, The Canopy

“Most of New Zealand was originally forested with small native streams characterised by dense shade” (Parkyn, Davies-Colley, Halliday, Costley, & Croker, 2003). The dense shade provided a canopy, under which animal and plant communities had evolved. Lowland stream habitats dominated by indigenous vegetation providing dense shade, are now uncommon in New Zealand. When solar radiation levels increase particularly during summer, there are significant effects of shading by a forest canopy intercepting light reducing the energy exchange at the stream. Collier et al. (1995) differentiate total solar radiation as photosynthetically available radiation (PAR) and near infrared radiation (NIR), the effects of which are addressed below.

Ahotakakame, Photosynthetically Available Radiation

Photosynthetically available radiation (PAR), is light available for primary production such as growth of periphyton. Quinn, Cooper, Stroud, and Burrell (1997) mimicked the effects of shading from PAR, in Whatawhata New Zealand where periphyton blooms are common during summer in unshaded channels. The Whatawhata study demonstrated a decrease in periphyton growth with increasing shade. As previously mentioned, higher production of periphyton renders many implications for freshwater. It is therefore favourable for streams to have a canopy from PAR.

It has also been observed that increased exposure to light is significantly correlated with the growth of macrophytes (James & Joy, 2009; Parkyn et al., 2003; Sand-Jlnsen et al., 1989). Macrophytes are commonly referred to as aquatic weeds. These weeds prefer fine substrates where roots can establish. Some macrophytes are noxious plants because of their potential to block water bodies (Wilcock, Champion, Nagels, & Croker, 1999);

characterised by daily variations in dissolved oxygen, temperature and pH, with consequences for habitat suitability and the abundance of invertebrates and fish.

Pūngao Hihi, Near-infrared radiation

Near-infrared radiation (NIR) is not used by plants for growth but influences the stream temperature regime. Light transmitted to the water is absorbed by water, suspended particles and dissolved materials, then converted to heat (Dodds & Whiles, 2010). This results in an increase in temperature. Beschta (1997) argues "solar radiation as the singularly most important radiant energy source for heating streams during daytime". Furthermore, change in temperature is inversely proportional to mean depth, reduced depth increases light penetration consequently increasing temperature (Snelder et al., 1998).

It has so far been established that increases in temperature affect the metabolism of periphyton and ammonia concentrations. Increased temperature also increases metabolism, reproduction and survival of stream insects and fish. In addition, it has been observed that large changes in daily temperature during the summer are significant in reducing afternoon stream flows (Constantz, Thomas, & Zellweger, 1994).

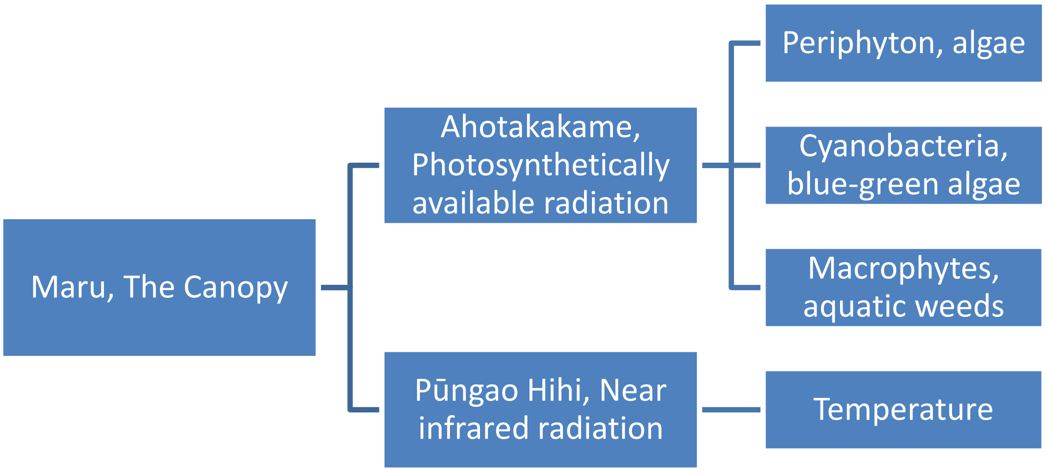

Figure 5: Marumaru the canopy, and attributes to be managed for freshwater ecosystem health

3.2 Pararopi, Detrital Inputs

The exchange of detrital inputs such as leaf litter and woody debris from riparian vegetation to a receiving water body, is a dimension of lateral connectivity. These detrital inputs are considered here as well as the contribution to the biodiversity of freshwater.

Rākau - Woody Debris

The loss of riparian forests has resulted in a reduction of natural wood loadings in streams. Woody debris enter streams in different shapes and sizes including whole trees, logs, chunks of wood, roots and branches. Wood entering streams have a significant structural and functional role that is integral to stream ecosystems (Baillie et al., 2013; Meleason, Quinn, & Davies-Colley, 2002; Naiman & Decamps, 1997). In-stream processes considered in this study are material movement and habitat diversity.

When large wood enters a stream and lodges, it forms a dam. The dam/s retain organic matter (smaller wood and leaves), subsequently increasing the time for biological processing of organic matter, and for leaf litter processing. Wood dams can also create backwater pools with low water velocity. The wood pools accumulate sediment, controlling its movement and mitigating the consequences of sediment in stream systems with implications of sediment previously mentioned in section 2.4 (page 16).

Woody debris affect the flow, diverting and obstructing stream flow, which in turn influences depth, current and substrate, creating a diverse range of wooded pools (Evans, Townsend, & Crowl, 1993). Wooded pools increase habitat diversity and complexity and provide refuge for aquatic organisms from predators and flooding. Despite being a small portion of total habitat, the removal of wood from New Zealand streams has consequently decreased the density of two of New Zealand’s larger native fish (Baillie et al., 2013): the longfin eel and banded kokopu. When there are no other stable substrates, woody debris provides habitat stability for both terrestrial and aquatic invertebrate communities, in order to feed, pupate, or lay eggs (Meleason et al., 2002).

Rau popo - Leaf litter

Detritus is a major carbon source sustaining most ecosystems, including freshwater coastal streams. Leaf litter is a primary energy supply for all freshwater food webs (Cummins, 1973; Lecerf, Dobson, Dang, & Chauvet, 2005; Power, Sun, Parker, Dietrich, & Wootton, 1995; Vannote et al., 1980). Leaf litter is thus an important food source for New Zealand stream invertebrates. Stream consumers rely directly or indirectly on leaf litter with the potential to increase biodiversity; this occurs by the transfer of energy from primary consumers of leaf litter to higher order consumers such as fish and birds. The significance of leaf litter to a freshwater food web is addressed by considering feeding groups as consumers of leaf litter. In recalling the river continuum concept, downstream and middle reach invertebrate communities consume energy entrained in the water lost by upstream communities.

The consumption of leaf litter is often demonstrated by considering feeding groups: aquatic microbes (fungi and bacteria); shredders; collector-gatherers; and filter feeders. When leaf litter enters the stream, it is colonised by aquatic microbes that breakdown and condition the leaf, "enhancing leaf palatability" (Gessner, Chauvet, & Dobson, 1999). The remaining feeding groups all have a nutritional dependence on the colonising microbes (Dodds & Whiles, 2010; Quinn, Smith, Burrell, & Parkyn, 2000; Vannote et al., 1980).

The next group to consume the leaf litter are shredders, insect larvae, decapod consumers such as crayfish and shrimps. The pre-mentioned larvae of *Austroperla cyrene* is a known shredder (Winterbourn, 1982). Shredders are generally found at the headwaters where the riparian margin is most vegetated, consuming leaf litter as coarse particulate organic matter (CPOM >1mm). Shredders play a significant role for stream food webs, extended to processing the leaf litter, engulfing and tearing the leaf litter reducing particle size. Shredders' consumption of leaf litter results in a continuous contribution of leaf litter: particulate organic matter (FPOM), ultrafine particulate organic matter (UPOM) and dissolved organic matter (DOM).

Both collector-gatherers and filter feeders consume FPOM and UPOM. Collector-gatherers occur where FPOM and UPOM has been deposited (Anderson & Sedell, 1979), settled out, trapped by vegetation, or entrained into the streambed. The pre-mentioned *Acanthophlebia cruentata* is a potential collector gatherer with terrestrial FPOM being a main source of nutrition (Collier, Wright-Stow, & Smith, 2004). To capture FPOM-UPOM, filter feeders use morphological structures such as specialised head fans or behavioural activities such as net building (Anderson & Sedell, 1979), to retrieve suspended matter from water drift. The pre-mentioned *Aoteapsyche raruraru* is a filter feeder that uses different methods for constructing nets depending on the velocity of the current.

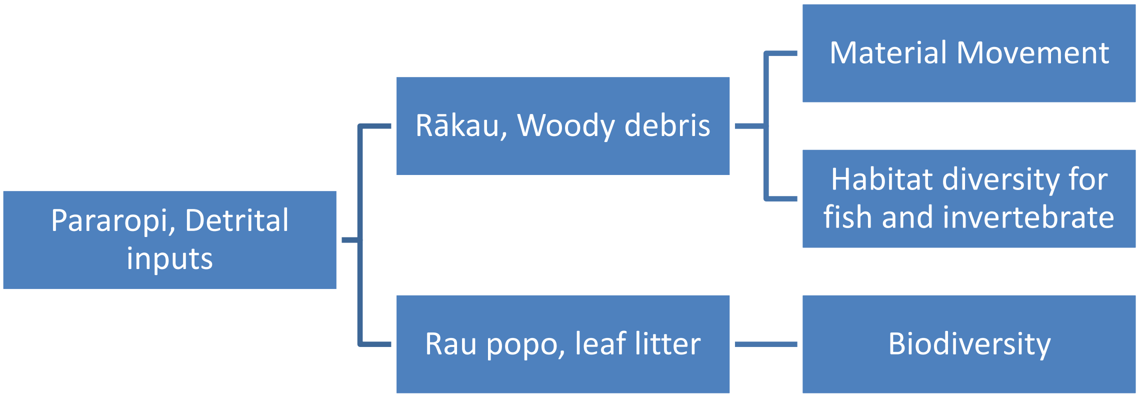

Figure 6: Pararopi detrital inputs, and attributes to be managed for freshwater ecosystem health

3.3 Whenua - The Riparian Floor

The riparian floor provides a physical barrier to sediments and nutrients being carried into streams. The spatial distribution of vegetation on the riparian floor influences stream water chemistry through diverse processes (Dosskey et al., 2010; Hickey & Doran, 2004). These processes will be considered by addressing pūrei a New Zealand sedge species, as well as paraumu humus and weri rootlets.

Pūrei - Sedge

Riparian vegetation is a proven practice of reducing sediment loads in surface runoff (Daniels & Gilliam, 1996; Pinay, Roques, & Fabre, 1993; Schmitt, Dosskey, & Hoagland, 1999). Particulate settling removes sediment and sediment-bound contaminants from runoff flow, such as ammonium adsorbed to trapped runoff sediment (Ettema, Lowrance, & Coleman, 1999), and *e. coli* attached to soil particles (National Institute of Water and Atmospheric Research, 2006). Numerous stems, sedges, thatch and grasses slow the flow of runoff, promoting the settling of suspended sediment transported by runoff.

Paraumu - Humus

Soil in the riparian margin, can provide ideal conditions for nitrogen conversions and be important sites of nitrate removal. In a study of a New Zealand headwater stream, the majority of nitrate loss (56-100%) occurred in riparian organic soils (Cooper, 1990). Interacting directly with surface runoff, vegetation and roots on the riparian floor are decomposed by microbial organisms producing humus, organic matter-rich surface soils. These micro-organisms also perform denitrification converting nitrate to nitrogen gases, “a permanent loss of nitrogen from the system” (Fennessy & Cronk, 1997).

Weri - Rootlets

Root systems interact with soil water and groundwater, with the potential to remove nitrogen by plant uptake for growth. When leaf, stem and root tissues of vegetation are experiencing vigorous growth, the rate of nutrient uptake from the root zone is greatest. Riparian vegetation has demonstrated large removals of nitrogen from shallow groundwater (Daniels & Gilliam, 1996), with this nitrogen removal being more significant in New Zealand compared to other countries (Cooper, 1990).

The roots of riparian vegetation can bind the soils, effectively reducing vulnerability of soils to erosion. The roots provide reinforcement, resisting increased flow volume and velocity, especially during flooding. With reduced vulnerability and increased reinforcement, there is a decrease in sediment inputs to the stream.

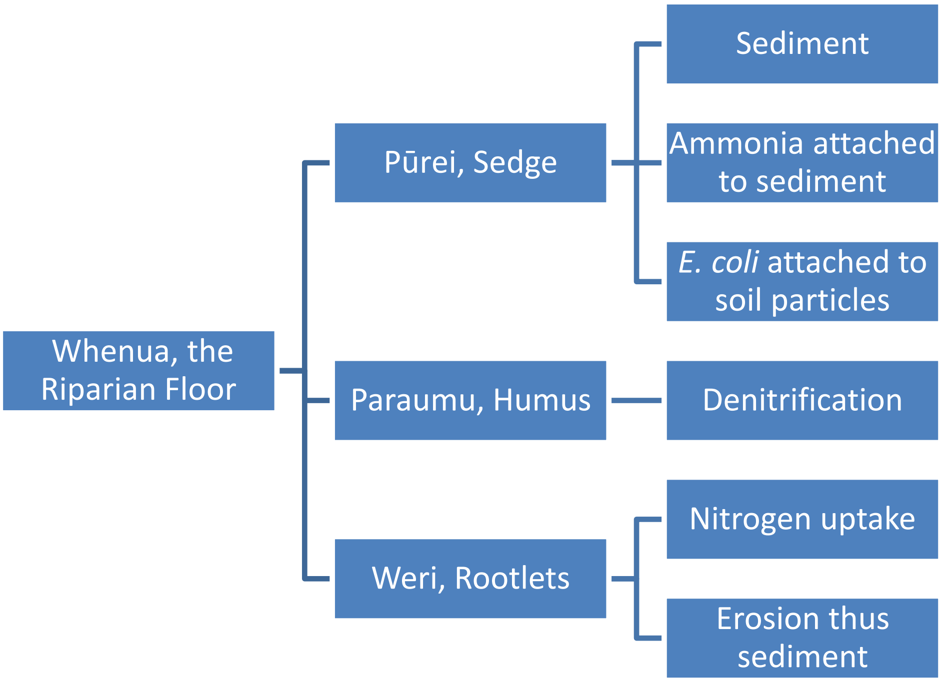

Figure 7: Whenua the riparian floor, and attributes to be managed for freshwater ecosystem health

3.4 A conceptual framework of the exchanges of riparian vegetation for freshwater ecosystem health

This chapter demonstrates that riparian vegetation serves significant ecosystem functions (ecological processes and ecosystem structures) for freshwater ecosystem health. Better organisation of the ecosystem functions (which are significantly complex) is demonstrated by Figure 8.

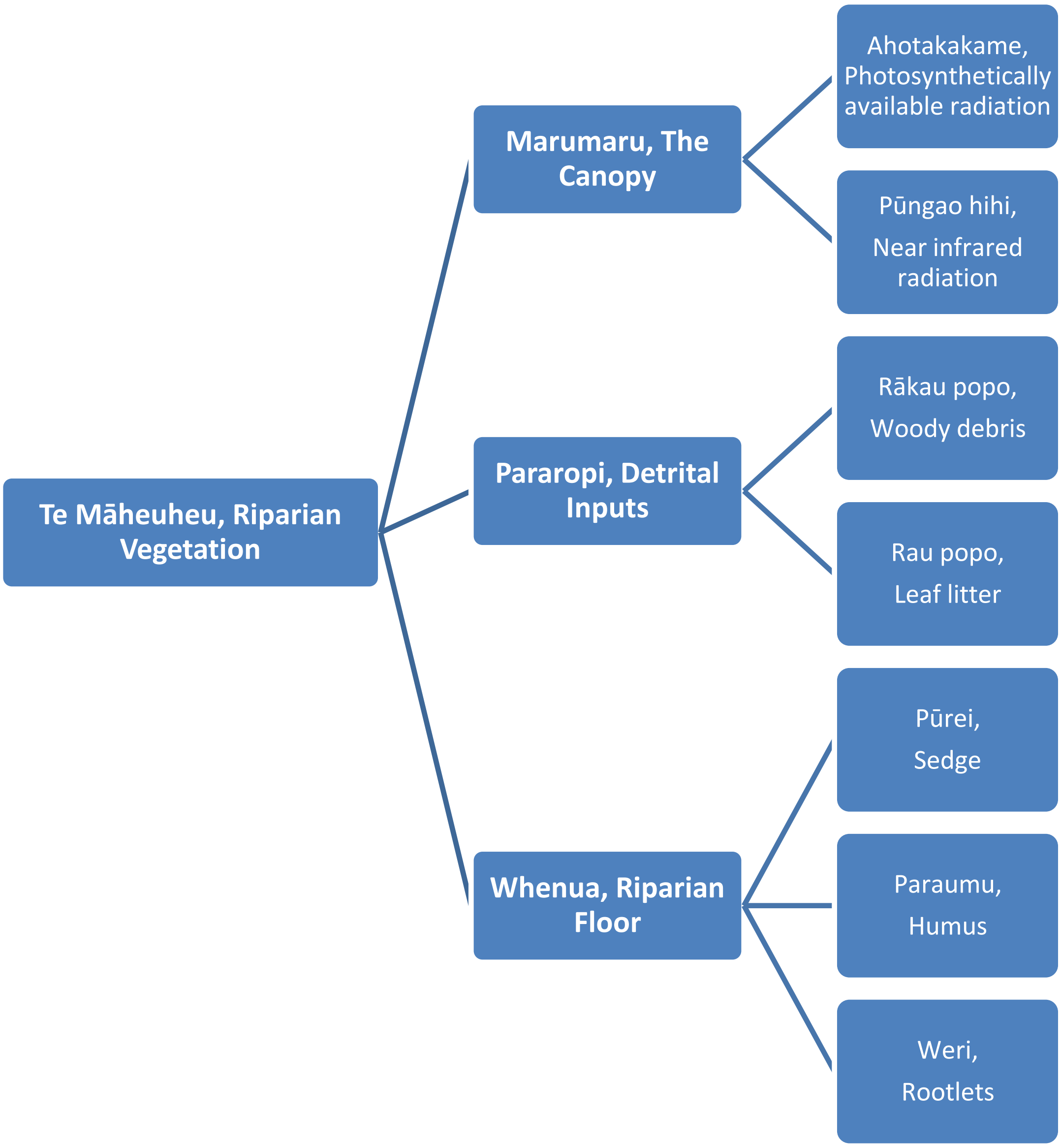

Figure 8: A conceptual framework of the exchanges of riparian vegetation for freshwater ecosystem health

Chapter 4: Review of Cost Benefit Analysis Methodology

The cost benefit analysis (CBA) methodology is widely accepted as a tool to improve the quality of decisions about the allocation of scarce resources, for either private or public benefit. CBA is a methodology that relies on monetary values. In its most simple form CBA is an equation of net-benefits ($); that is benefits less costs, anticipated of resource allocation. The CBA criterion is to proceed with investment if net-benefits ($) are positive. The purpose of this chapter is to describe the CBA methodology that was developed during this study by addressing the following components of CBA methodology: desired policy outcome; impact assessment; valuation; sites of significance and calculation methodology. Prior to addressing the CBA methodology adopted by this study, this chapter firstly provides a comparison of financial analysis for private benefit versus cost benefit analysis for public benefit, both of which adopt the net present value methodology.

Financial analysis measures private benefit of an investment of private capital. Alluded to by Campbell and Brown (2003), “private benefit” is for a specific entity. The specific entity could take many forms including but not limited to, an individual, a private corporation, or public enterprise. When an investment of private capital is being evaluated by an entity, input to the analysis is restricted to changes in capital, costs and benefits expected to accrue to only that entity. However, private investment often results in effects beyond the private investor, which are referred to as the externalities, impacts, costs and benefits that affect other entities. Financial analysis is only concerned with private benefit; such analysis does not account for externalities and it is therefore of limited value in analysing many public policy issues.

Cost benefit analysis (CBA) evaluates an allocation of resources to programmes, projects and policies, estimating public benefit or net value to the wider public. A significant foundation of CBA dates back to the Flood Control Act (1936) in the United States, which legislated for water resource projects, an evaluation of costs and benefits “to whomsoever they accrue” (United States Flood Control Act (1936)). To whomsoever remains to be true of contemporary CBA, increasing relevant stakeholders from private to public, anyone potentially affected by a proposed allocation of resources. CBA has evolved to a “general discipline” (Sen, 2000) and is now the subject of much greater criticism, debate and innovation, since the Flood Control Act conducted almost 80 years ago. It is beyond the scope of this study to analyse the 80 years of CBA criticism, debate and innovation in the literature. However, this chapter contrasts CBA and financial analysis revealing the contribution of ‘public benefit’ CBA, as is applied in this research. CBA embraces environmental, economic, social and cultural impacts (Murray, 2013); taking into account externalities ignored by financial analysis. Accepted definitions for costs and benefits are changes in human wellbeing (utility) (Pearce, Atkinson, & Mourato, 2006); rather than strictly changes in capital. CBA is much more robust and far broader in scope than financial analysis; CBA is extended to include the wider stakeholders, externalities and changes in human wellbeing.

There have been significant enhancements to the CBA method since the Flood Control Act, particularly non-market valuation methods that have become the focus of study in their own right. Given that CBA relies on data in monetary units, valuation methods are used to convert externalities and changes in human wellbeing to data in monetary units for input to CBA calculations. The use of innovative methods of valuation is becoming increasingly accepted. Methods of valuation addressed in this chapter include opportunity costs, contingent valuation and benefit transfer.

The following sections of this chapter explore the CBA literature reviewing the following steps that need to be considered when conducting a CBA; desired policy outcome, impact assessment, valuation, sites of significance, and the calculation method.

Step 1: Desired Policy/Project Outcome

This first step of the CBA methodology used (and essential to any policy analysis methodology) is clarity about the desired policy/project outcome, and the time horizon. According to Hanley and Barbier (2009), this step requires a general policy/project definition; Sen (2000) goes further stating that an explicit evaluation is required including a full account of reason and logic as input to the CBA. An essential, first step for this CBA is an explicit evaluation of the “desired policy outcome”.

For this particular study, the desired policy outcome is freshwater ecosystem health for coastal streams, as explored in Chapter 2. This desired policy outcome applies to freshwater coastal streams, but also demonstrates some universal characteristics for an explicit evaluation. First, policy statements are sometimes ambiguous and open to interpretation, potentially providing foundations for an explicit evaluation as endorsed by Sen (2000). Second, if desired policy outcome is environmental it is recommended that explicit evaluation is holistic, considering many attributes of an ecosystem. Third, descriptions of attributes increase awareness of the relative ecosystem, potentially revealing sensitivities to perturbations and impacts.

Step 2: Impact assessment

Subsequent to explicit evaluation of the desired policy outcome, the next step in the CBA process is to identify and characterise impacts of the project. Environmental CBA includes characterisation of the deliberate or indirect impacts on the environment (Atkinson &

Mourato, 2008), which is environmental impact assessment (EIA). To conduct an environmental impact assessment (EIA) it is necessary to be familiar with the ecosystem and ecosystem functions for which the CBA is being conducted. Ecosystem functions are best conceived as a subset of ecological processes and ecosystem structures (De Groot, Wilson, & Boumans, 2002). As demonstrated in *Chapters 2* and *3,* with increased understanding of the relevant ecosystem, it is then possible to organise the ecosystem functions into a comprehensive framework that clarifies ecological processes and identifies important components of the ecosystem. The environmental CBA conducted in this thesis required consideration of the deliberate impacts on the environment essential to achieve the desired policy outcome, namely freshwater ecosystem health for coastal streams. In this project, designated actions such as riparian planting are designed to deliberately impact on and improve ecosystem functions.

Indirect impacts on the environment are revealed by methods of EIA. Interaction matrices were amongst the earliest methods of EIA. Leopold’s matrix attempts to identify significance and magnitude of environmental impacts as a result of designated actions in a project. In the Leopold matrix developed for this CBA, along the horizontal axis are 100 potential project actions, and down the vertical 88 environmental variables; this matrix is thorough, revealing 8,800 possible impacts to be considered on two scales: significance and magnitude. Specifying this number of project actions and environmental variables is a significant undertaking, requiring both time and a high level of knowledge. Leopold’s matrix has also been criticised for a lack of guidance in determining significance (Thompson (1990). These criticisms are mitigated by reducing the scope of the matrix and focusing on the most likely impacts.

Step 3: Valuation

The next step in the CBA process involves the valuation of the identified impacts. To be considered as input to CBA calculations, all impact measures must be converted to data in monetary units – this is achieved through valuation of impacts. Valuation of some impacts is relatively straightforward, for example, project costs observed in an active market; however, some project costs are not immediately available. Other impacts are difficult to value in monetary terms. This is particularly challenging when trying to value ecosystem functions. For example, shading by the canopy mitigating in-stream temperatures and eutrophication both which are attributes previously described. There is a plethora of research into valuation methods that attempt to address the complexity of monetary valuation. This chapter addresses the following topics relevant to valuation methods: total economic value, direct market valuation, contingent valuation and benefit transfer.

4.3.1 Total economic value

Total Economic Value (TEV) is the sum of the total monetary value of environmental impacts. TEV provides a framework for valuation by categorising environmental impacts. A variation of this framework is provided by Sharp and Kerr (2005) in Figure 7.

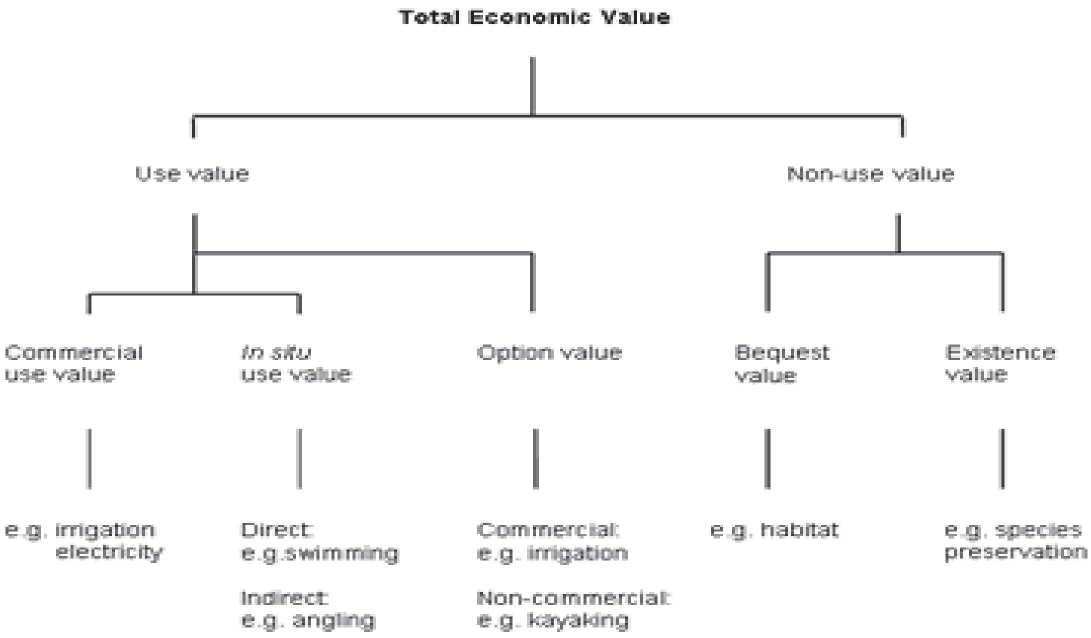

Figure 9: Total economic value (Source: Sharp and Kerr, 2005)

Another variation of the TEV framework is provided by Pillet (2006), which differentiates between three categories of values: use, option and existence. 'Use values' are distinguished between direct and indirect values: direct use values are immediate inputs, and indirect use values are functional advantages provided by the environment. Common to an interpretation of "option value" is the concept of irreversibility (Hanemann, 1989; Pascual et al., 2010), which refers to the value of ensuring that the environment or an ecosystem is not impacted by irreversible damage, preserving the option to be of service in the future. "Existence value" is the satisfaction of just knowing that the environmental unit is maintained in a condition of personal preference.

4.3.2 Direct-market valuation

Direct market valuation relies on production or cost data (Pascual et al., 2010). This is an observation of real or estimated values within an active market. This valuation method is suited to use values within the TEV framework. The thesis considers direct market valuation of labour and materials, as well as opportunity costs for land.

Monetary values for labour can be approximated by quarterly updates on income by Statistics New Zealand, and from the multiple sources for potential pay earned by various occupations from Careers NZ. Observed values of labour have also been used to reflect the value of leisure to workers (Hanley & Barbier, 2009). Materials are another impact observed in an active market, as simple as a no obligation quote from the appropriate supplier. For land, the opportunity cost is estimated by land acquisition costs estimated by land market values (Adams, Pressey, & Naidoo, 2010). Opportunity costs are the next best alternative use rejected for the chosen action.

4.3.3 Non-market valuation

Some impacts, however, are subject to market failure; that is "wider social and environmental impacts" (The Treasury Business Analysis Team, 2005). These impacts are either not actively traded, or overwhelmed in difficulty for approximation. They include some ecosystem services, and option and existence values of the TEV framework. As a result, non-market valuation methods have been developed. Non-market valuation is a defining feature of environmental CBA (Atkinson & Mourato, 2008). Non-market techniques include contingent valuation (CV), choice experimenting (CE) and benefit transfer (BT). Contingent valuation is a catalyst for CE and BT techniques. Contingent valuation and CE are the "first best strategy" (Patterson & Glavovic, 2008), however these two primary research methods are resource intensive, demanding significant technical expertise, time and money.

Contingent valuation

Assuming an impact is a commodity and not traded in an active market, contingent valuation (CV) elicits an economic value for the commodity. A rationale of CV for economic valuation of the environment, is to see elements of the environment traded as a "normal private commodity purchased and consumed" (Sen, 2000).

CV defines the commodity in varying conditions. For demonstration purposes consider one commodity with three "commodity conditions" current, satisfactory and desirable. A hypothetical market for the commodity is created by surveying people to identify their preferred "commodity condition" at a cost. Assuming a change in condition from current to desirable, this change is indicative of an improvement in the commodity. The cost is in the form of "willingness to pay" (WTP), which is, an indication of the "change in well-being that an individual enjoys" (Atkinson & Mourato, 2008). WTP is generally through the payment vehicle per household per year, sometimes proposed as an increase in rate payments. The use of WTP in this thesis is proposed as an allocation of current rate payments, rather than an increase in rate payments.

CV is not without criticism – at the root of criticism is study design, but "without a specific focal point of attack" (Boyle, 2003). Values elicited by CV and subsequently used in environmental CBA are "not well described" (Richard A. Posner, 2000). Certainly an observation of this study is poor description of the ecological change in the commodity, which is perhaps an outcome of public interest for a salient description of environmental impact noted by Tait, Baskaran, Cullen, and Bicknell (2011). Atkinson and Mourato (2008) suggest that the most recurring criticisms of CV are "constructing rigorous test of robustness", presenting yet another challenge of interpreting test methods and results. Despite these criticisms, CV is increasingly used worldwide. For example, the New Zealand Environment Court noted the value of "such estimates and the cautions that come with them" (Counsell, Evans, & Mellsop, 2010).

Choice experimenting

Like contingent valuation (CV), choice experimenting (CE) is a survey method eliciting economic value for a "set" of commodities (commodities are better known as 'attributes' in New Zealand (Marsh, 2012; Marsh & Phillips, 2012; Tait et al., 2011). CE is based on the work of Lancaster (1966) and (Atkinson & Mourato, 2008). CE assumes that a good is made up of multiple attributes which collectively generates consumer utility or satisfaction. CE is used to estimate what people might be willing to pay for a collection of preferred impacts. However the technique is noted for "cognitive difficulty" (Atkinson & Mourato, 2008), demonstrated by the following narration and Table 2 over leaf. Assuming competing goods and three competing policy alternatives, each alternative with a set of attributes anticipated impacts A and B, as well as WTP per household per year with each impact (A and B) at varying levels. From the three policy alternatives, respondents are asked to select their most preferred policy alternative based on the combination of attributes, impacts A and B, at a cost of WTP.

Table 2: Choice experimenting and potential cognitive difficulty for interpretation

	POLICY ALTERNATIVES		
	One	**Two**	**Three**
Impact A	No change	Satisfactory	Desirable
Impact B	No change	Satisfactory	Desirable
WTP/ household/ year ($)	0	2	3

Despite criticism of cognitive difficulty, CE is "perhaps the most widely used variant in environmental economics" (Atkinson & Mourato, 2008). CE is increasingly used in New Zealand, a fact that is demonstrated in the CBA conducted in this thesis which makes reference to three CE studies for freshwater published in 2011 and 2012. One policy proposal can often have multiple impacts, and CE can cater for multiple impacts. The New

Zealand studies considered in this research also provide a WTP estimate for individual impacts of potential policy alternatives, which is useful where there is a specific interest such as in this study. Finally, like CV, CE considers preferences of the tax payer and rate payer.

Benefit transfer

As noted earlier, contingent valuation (CV) and choice experimenting (CE) are methods of primary research that are ‘first best strategies’. However, they are also resource intensive and this limitation is often prohibitive to them being conducted for the purposes of a CBA ‘Benefit transfer’ is widely regarded as essential (Pearce, 1998), reducing demand on limited resources. Considered to be secondary research, benefit transfer (BT) still requires technical expertise, but demands less time and money. BT is the adaption of existing information or data to new contexts (Rosenberger & Phipps, 2007). BT takes data from primary research conducted in a particular study site, and applies it in an exercise such as CBA for a policy site. A study site is “an original survey site from which to transfer values to other sites”, “whereby site values are transferred to the policy site from the original survey site” (Baskaran, Cullen, & Colombo, 2010). It goes without saying that the “adaption of existing information” is an activity exercised by everyone on a daily basis; on the other hand, BT is the subject of technical criticism and innovation for the quality of the primary research, and the validity of transfer.

Poorly designed primary research produces poor quality information for a study site. It is highly questionable why poorly generated data would be used in subsequent research for exercises such as CBA. Thus, when identifying appropriate data sources for a CBA, it is critical to assess the quality of primary research, to determine whether the policy alternatives of the original study were realistic. There must be adequate description of the market area of the original study, both geographically and demographically so that unit of economic valuation (WTP) and the payment vehicle are comparable.

Limitations related to validity of value transfer can be mitigated by comparing the study site with policy site. Comparisons are made between the environmental good/service, and time between primary research and transfer (Spash & Vatn, 2006), site characteristics

(Baskaran et al., 2010), experiences and attitude of populations (Loomis & Rosenberger, 2006), and per capita income (Atkinson & Mourato, 2008). If there are multiple primary studies for the potential use in BT, preceding indicators can also be a method of elimination, eliminating those least comparable to the policy site.

Examination of the significant debate about the methods used to test the transfer of data in valuation studies is beyond the scope of this study. However, the following is a brief acknowledgement of some of these tests. Meta-analysis (MA) provides statistical summaries "concerned with understanding the influence of methodological and study-specific factors on research outcomes" (Rosenberger & Loomis, 2000). Kristofersson and Navrud (2005) recommend equivalence tests, with the null hypothesis WTP "values are different" between study and policy site within a defined or acceptable interval. Muthke and Holm-Mueller (2004) use t-tests to compare WTP and demand functions for similar environmental goods of contingent valuation studies from Norway and Germany. Such sophisticated techniques, however "might largely become the preserve of the highly trained specialist rather than a tool that can be routinely used by a broader assortment of practitioners" (Atkinson & Mourato, 2008).

BT is subordinate to CV and CE; BT will always be inaccurate as there is a need to define acceptable error (Kristofersson & Navrud, 2005). BT relies on design quality of original studies, comparability between study and policy sites, and sophisticated testing of data. Despite the preceding challenges, there is significant support for BT, and this technique is routinely used. BT has the advantages of relatively low cost and time requirements. For a policy site, it provides useful information for input to initial assessment of the value of policy options (Baskaran et al., 2010). The advantages of BT are demonstrated in the study described in the following chapter, which compares population personal income of the policy site with that of three study sites to identify the site most similar with the policy site.

The WTP data from sites found to be the most similar to the policy site of this study was thus subsequently used for benefit transfer and in cost benefit analysis.

Other economic valuation methods

Contingent valuation, choice experimenting, and benefit transfer, elicit WTP. For the CBA conducted in this research, WTP was applicable. There are, however, other economic valuation methods that can be used to establish WTP – these are identified in Table 3.

Table 3: Economic valuation methods used to establish WTP or WTA

Avoided Cost (AC): services allow society to avoid costs that would have been incurred in the absence of those services. For example, flood control provided by barrier islands avoids property damages along the coast.
Replacement Cost (RC): services could be replaced with man-made systems. For example nutrient cycling waste treatment can be replaced with costly treatment systems.
Factor Income (FI): services provide for the enhancement of incomes. For example, water quality improvements increase commercial fisheries catch and income of fishermen.
Travel Cost (TC): service demand may require travel, the costs of which can reflect the implied value of the service. For example, recreation areas attract distant visitors whose placed on that area must be at least what they were willing to pay to travel to it.
Hedonic Pricing (HP): service demand may be reflected in the prices people will pay for associated goods. For example, housing prices along the coastline tend to exceed the prices of inland homes.
Marginal Product Estimation (MP): service demand is generated in a dynamic modelling environment using production function to estimate value of output in response to corresponding material input.
Group Valuation (GV): This approach is based on principles of deliberative democracy and the assumption that public decision making should not result from the aggregation of separately measured individual preferences, but from open public debate.

Source: Wilson and Liu (2008)

Step 4: Sites of significance

The most significant site of any environmental CBA is the policy site - the site for which the CBA is intended. In the absence of primary data, application of benefit transfer necessitates the information collected from other sites. Information collected for a policy site must be consistent and comparable to the relevant factors of the study sites. A common source of information providing data for each site is advantageous, for example geographical boundaries, such as area units per Statistics New Zealand, which were used in this study. A description of like values between study sites, for example commodity definitions for which WTP was elicited at study sites are provided in section 5.2. To address sites of significance, information for sites must be comparable and consistent, a comparable description of primary studies such as size and location, and a common source of information assumes the information was collected in the same way.

Step 5: Calculation methodology

Net-benefits

Once data is collected and processed to monetary units of costs and benefits, the net benefits calculated over a time horizon. For each year of the time horizon net benefits can be calculated (*Cf*): benefits less costs, as demonstrated in Table 4. In Table 4 impacts are changes in utility in the form of costs and benefits. The costs are *A* initial investment, and *B* ongoing costs from year 1. Benefit *C* is WTP per household per year multiplied by the relevant population, and *D* the benefit of forgone costs as a result of the investment. Both benefits are ongoing from year 1.

Table 4: Calculating net benefits of resource allocation

		Year (t)										
		0	1	2	3	4	5	6	7	8	9	10
Costs	***A***	1000										
($)	***B***		100	100	100	100	100	100	100	100	100	100
Benefits	***C***		150	150	150	150	150	150	150	150	150	150
($)	***D***		90	90	90	90	90	90	90	90	90	90
Net Benefits (E) ($)		-1000	140	140	140	140	140	140	140	140	140	140

Discounting

Net benefits have been calculated for each year of the time horizon, demonstrating that net benefits are anticipated at several different points in time. Net benefits must be discounted. Discounting is the opposite of compounding interest on an investment (Kotchen, 2010), converting net benefits to their present value (PV) at a discount rate. The discount rate is a reflection of both time preference and uncertainty or risk (The Treasury Business Analysis Team, 2005). Time preference suggests that most kinds of benefits are more highly valued the sooner they are received; any kind of cost, seems less onerous the further away in time (Hanley & Barbier, 2009). The discount rate also reflects the risk of the investment, where one will require a return at least as high as they can obtain from any other investment of equal risk (The Treasury Business Analysis Team, 2005). A higher discount rate indicates a preference for benefits sooner rather than later, and this carries a higher risk. A low discount rate is indicative of decreasing preference for timing of benefits and low risk. Thus, it is not appropriate to treat net benefits in year 1 the same as net benefits in year 10 because of time preference and risk.

The present value (PV) of a net benefit (FV for future value) is provided by equation 1.

Equation 1: Present value of future net benefits

$$PV = FV/((1 + \boldsymbol{i})^t)$$

The discount factor is $(1 + \boldsymbol{i})^t$, is a product of i the discount rate and t the relevant year of the net benefit. The discount factor is between 0 and +1, as either $\boldsymbol{i}$ or $\mathbf{t}$ increases the discount factor decreases. Dividing the net benefit (FV) by the appropriate discount factor for year t produces PV. PV for net benefits of table 2 are presented in the following table, assuming a discount rate of 10%.

Table 5: Present value of future net benefits over a ten year time horizon

	Year (t)										
	0	1	2	3	4	5	6	7	8	9	10
Net Benefits (E) ($)	-1000	140	140	140	140	140	140	140	140	140	140
PV(NetBenefits) ($)	-1000	127	116	105	96	87	79	72	65	59	54

New Zealand Treasury uses a 10% discount rate whenever there is no other agreed sector discount rate for policy proposals. For analysis at the level of the organisation, the department capital charge rate is used, which is an estimate of the government's average cost of capital (The Treasury Business Analysis Team, 2005). The capital charge rate for 2011/12[8] was 8%.

Net Present Value

Net present value (NPV) is the sum of the present value of net benefits over the time horizon. For the example in Table 5, it is -$139.76. NPV is a relatively objective method of calculating a change in collective utility as a result of investment for desired change. When

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[8] http://www.treasury.govt.nz/publications/guidance/mgmt/capitalcharge

NPV is the exclusive criterion, an investment will proceed if NPV is greater than zero because that reflects a potential “improvement to social welfare” (Hanley & Barbier, 2009). In the preceding example, an NPV of -$139.76 would be deemed to be unacceptable. As input for policy formation in government, a negative NPV does not rule out proceeding with a proposal (The Treasury Business Analysis Team, 2005) because, in addition to the CBA, other information inputs are considered for optimum welfare and living standards. NPV is just one output of CBA. Others are the internal rate of return (IRR), the benefit cost ratio (BCR), and the payback period.

Sensitivity Analysis

The output of CBA (NPV, IRR or BCR) is an indication of the economic efficiency given initial assumptions and data. However, “none of these predictions can be made with perfect foresight” (Hanley & Barbier, 2009). Hence, sensitivity analysis, which is an “assessment of variability in output variables and importance of input variables” (Cacuci, 2003) is conducted. Variability in output is a consequence of variability in input Variability in input can surface through the proposed discount rate, time horizon, under/ over estimating costs, discrepancy in WTP data, and uncertainty about which input are costs and benefits.

The benefits of sensitivity analysis are notable. It “is a non-confrontational way to handle controversy about key assumptions, calculation methods and projected data” (Merrifield, 1997). It reduces bias, and increases accountability and transparency. It has the potential to “discover and quantify the most important features of the model under investigation” (Cacuci, 2003), features which may require scrutiny, assessment or management.

4.6 A cost benefit methodology

This chapter has described the CBA methodology, which was adopted in this thesis. The methodology begins with an explicit evaluation of the desired policy outcome, endorsed as an essential step of policy analysis. The methodology then aligns literature: impact assessment, valuation, identifying sites of significance, and the calculation methodology.

Chapter 5: Estimating Riparian Benefits by 'Benefit Transfer'

As outlined in Section 4.3.3, commonly used terms in benefit transfer are 'study site' and 'policy site'. The study site is the site of primary research, and the policy site is the site of interest where the primary research is transferred to for use. Study sites of this research are Karapiro, Hurunui and Canterbury. These sites will be further elaborated on later in this chapter. The policy site of this research is Horowhenua - more specifically the group 2 priority water bodies of the Mangaore, Hōkio, Waiwarara, Waiwiri and Waikawa Streams. A brief description is provided for each of the priority streams in Section 5.1.

To compare study sites with a policy site, a common source of information for each site is advantageous. Increased accuracy for benefit transfer is achieved when data has been collected and processed in the same manner. Increased accuracy for this research is achieved by the use of data for area units from the 2006 Census (Statistics New Zealand), which provides area units consistent with both study and policy sites.

All studies of primary research to be addressed here were New Zealand choice experiments for changes in freshwater. As choice experiments, these surveys were used to elicit economic value of a set of commodities. In these studies, however, rather than using the word 'commodities', the term 'attributes' is used. Each of the three study site surveys used a commodity/attribute for freshwater "ecological health" or "ecology" that is comparable to freshwater ecosystem health described in Chapter 2.

This chapter concludes by comparing personal income of the study sites with that of the policy site, to identify which study site is most comparable to the policy site for benefit transfer of WTP data for cost benefit analysis. Briefly, comparison of personal income was achieved by using the statistic programme *R*. For each site a population of personal incomes was generated based on the frequency of occurrence of relevant income brackets; populations and samples (N=250, N=1,000) of study sites were compared with policy site.

5.1 Policy Site: Horowhenua

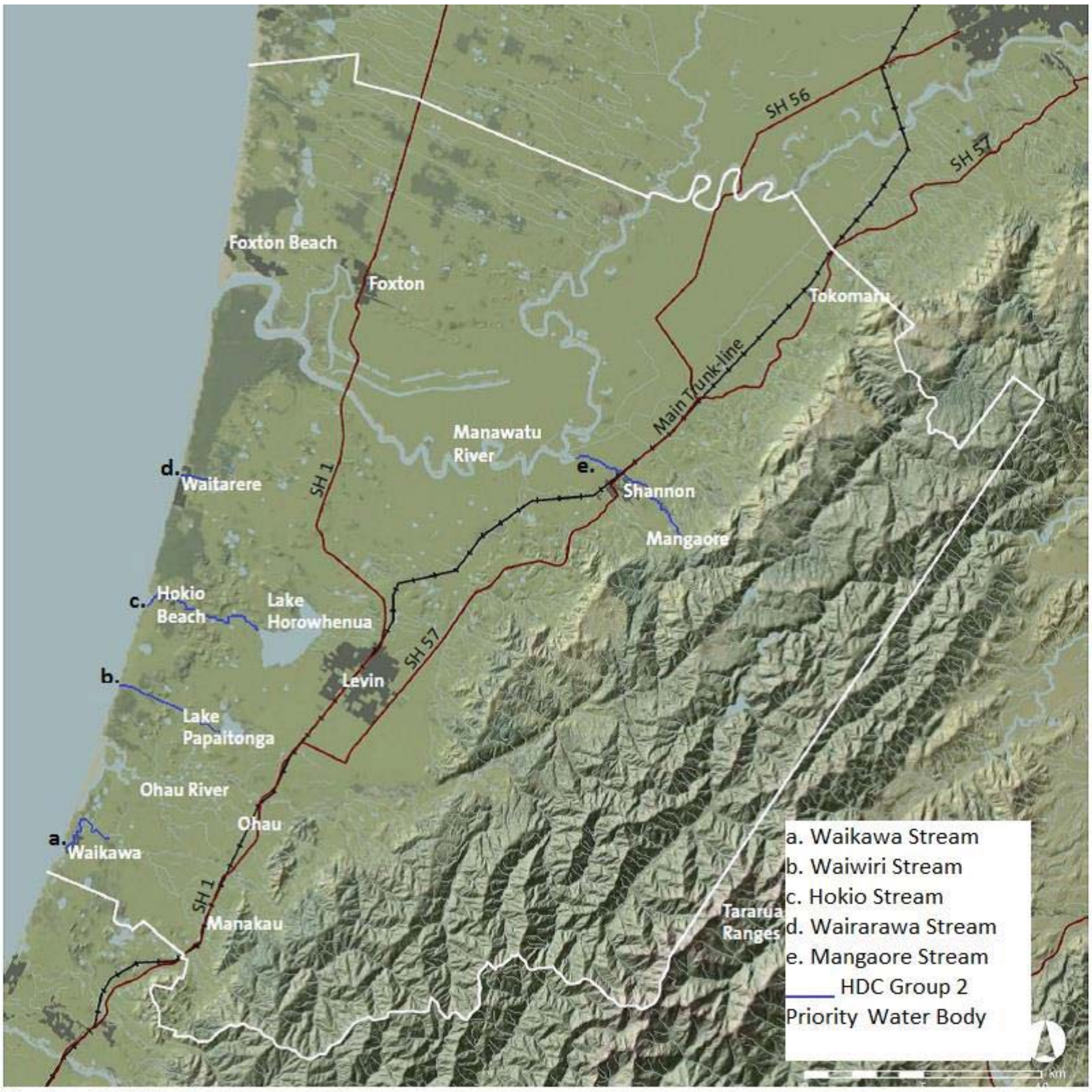
The Horowhenua district is in the Manawatu-Wanganui region on the west coast of the North Island of New Zealand, north of the capital city of Wellington. Horowenua is made up of a total of 16 settlements. From the south is Waikawa, to the north is Moutoa and to the east are Tokomaru and Ōpiki.

Horowhenua District Council identified priority water bodies in Schedule 12 (see Appendix 1) of its most recent district plan review in 2013. Group 2 priority water bodies included the policy site of this research, which are reproduced in Table 6, which also lists the length of each stream. These streams have been identified for open space connections between the Tararua ranges and the coast (Boffa Miskell Ltd, 2012).

Table 6: Horowhenua District Council's group 2 priority water bodies

Stream	Area of priority	Length (km)	Source of Length data
Mangaore	Between Manawatu River and Tararua Forest Park	13.7	*Correspondence with Horizons Regional Council*
Hōkio	Between Tasman sea and Lake Horowhenua	8	James and Joy (2009)
Waiwarara	Between Tasman Sea and 2km upstream	2	*Schedule 12 Priority Water Bodies (HDC, 2013)*
Waiwiri	Between Tasman Sea and Lake Papaitonga	5	James and Joy (2009)
Waikawa	Between Tasman Sea and 2km upstream	2	*Schedule 12 Priority Water Bodies (HDC, 2013)*

Adapted from Horowhenua District Plan Schedule 12, version October 2013



Horowhenua District (boundary shown as a white line)

Figure 10: Map of Horowhenua coastal region (Adapted from: Horowhenua Open Space Strategy, 2012, p7)

Landuse for the Manawatū-Wanganui region was taken from Statistics New Zealand's Agricultural Production Statistics (2003)[9] (see Appendix 2). The highest use of land is grassland (77%), generally associated with agriculture – consequently, there are significant chemical and biological changes for nearby freshwater systems. The remaining land is in native vegetation (10%) and forestry (9%). In the 2006 Census, the Horowhenua district had a population of 29,868, and a total of 14,319 dwellings.

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[9] http://www.stats.govt.nz/browse_for_stats/industry_sectors/agriculture-horticulture-forestry/~/media/Statistics/browse-categories/industry-sectors/agriculture-horticulture-forestry/ag-prod-survey-tables-2003/hectares-used-farms-land-use-region.xls

5.2.1 Mangaore Stream

Mangaore Stream is located in hill country flowing north-west from the Tararua ranges through Shannon, to the confluence with the Manawatū River, which is known for poor water quality. According to Adkin (1948), the streams original course divided in two into the Makurerua Swamp. Species significant to this stream ecosystem are Shortjaw Kokopu, Redfin Bully and Koaro.

Figure 11: Mangaore Stream immediately below power station, February 2014

Mangaore Stream is used for hydroelectricity, Mangahao Power Station one of the first in New Zealand. Pasture dominates land use adjacent to the stream between the power station and Manawatū River. Immediately below the power station, the stream is accompanied by significant bush (see Figure 9). However immediately above the station, the stream is exposed to the sun and is surrounded by an invasion of pest plants, convolvulus and gorse (see Figure 10).

Figure 12: Mangaore Stream immediately above power station, February 2014

5.2.2 Hōkio Stream

Hōkio Stream was once the source of abundant sustenance to local Māori (Selby et al., 2010), the stream connecting Lake Waipunahau to the Tasman Sea. The lake once accommodated many pātaka kai (food stores), indicated by the early 1845 engraved sketch (Figure 11). The stream once teemed with whitebait (*galaxias* species), kākahi (freshwater mussel), koura (freshwater crayfish), and pātiki (flounder) (Selby et al., 2010). Surrounding land once teemed with karaka (*Corynocarpus laevigatus*) which was introduced as a food source for their fruits (Duguid, 1990).

Engraving from sketch by R. Taylor (see *Te Ika a Maui*, ed. 2, p.17).

Figure 13: Lake Waipunahau (Horowhenua) 1845 engraved sketch (Source: Adkin, 1942, p. 184)

Figure 14: Hōkio Stream at Hōkio Beach, January 2014

The course of Hōkio stream is largely unmodified, with some margins heavily infested with weeds, flowing through pastoral land (Boffa Miskell Ltd, 2012); the stream is 5km long from Lake Waipunahau (more commonly known as Lake Horowhenua) to the Tasman Sea.

The lake received sewage discharges from Levin for some decades since 1953. Today the stream and lake are unsafe sources of food for human consumption. Restoration of the lake and stream is an ongoing and often contentious between councils, tangata whenua (local Māori) and special interest groups, with many commitments to restore the lake system having been documented[10]. To date, such restoration initiatives have been unsuccessful, and the lake remains in very poor condition, thus negatively influencing the quality of the Hōkio stream.

5.2.3 Wairarawa Stream

The main course of Wairarawa stream, which flows from the Wairarawa Lagoons, is a mile in length with two head branches between which is an extensive swampy area (Adkin, 1948). The course of Wairarawa stream has been artificially straightened (Beadel, van Meeuwen-Dijkgraaf, & Todd, 2011), flowing through farmland, pine plantations and several culverts. The stream is now somewhat ephemeral and dry during the summer (see Figure 13). In Figure 13, there have been recent planting efforts at this site.

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[10] See Horizons Regional Council's *One Plan*, *Chapter 6*; and *He Hokioi Rerenga Tahi – Lake Horowhenua Accord.*

Figure 15: Wairarawa Stream immediately inland, February 2014

According to Beadel et al. (2011), the banks and outfall of Wairarawa stream are subject to an influx of exotic plant species, and indigenous vegetation is scarce. A thorough restoration plan for the Wairarawa Stream and Waitarere Sand Dunes was prepared for Horizons Regional Council by Wildlands Consultants Ltd (that are Beadel et al. (2011)), which has attracted significant local community participation.

5.2.4 Waiwiri Stream

Waiwiri Stream (see Figure 14) once accommodated at least 20 separate eel weirs (Adkin, 1948). The stream is an active passage between Lake Waiwiri and Tasman Sea. The stream flows through mainly grazed pasture, and is 6km in length from Lake Waiwiri (more commonly known as Lake Papaitonga). Much of the lake was established as a reserve in 1901, with remaining indigenous vegetation.

Figure 16: Waiwiri Stream June 2011 (Source: Dr. Huhana Smith personal communication, June 18 2014)

A wastewater treatment plant for Levin known as “the Pot” has been within the Waiwiri catchment since the 1970s. Management options to better manage the Pot are currently being examined by Horowhenua District Council (Wally Potts, personal communication, Septemper 9, 2013). Recent research for Waiwiri was produced by the Manaaki Taha Moana (MTM) project (Allen et al., 2012) - results from water quality testing differentiated between sources of *E.coli* from dairy, birds and the Pot. The study concluded that the main source of *E.coli* in the Waiwiri Stream is from cattle, both beef and dairy, demonstrating the effects of land use on nearby water bodies. The study made a number of recommendations, including “fencing and planting projects along the Waiwiri mainstem” (Allen et al., 2012).

5.2.5 Waikawa Stream

The Waikawa Stream is one of the larger watercourses in the region. Until the early 1870s, Waikawa did not flow directly to the sea (see Figure 15). Rather, it pursued a course nearly parallel to the coast north toward Ōhau River, joining to make a common exit to the sea (Adkin, 1948). The Waikawa Stream was briefly occupied by the infamous Māori Chief, Te Rauparaha, identified by a large bend about a mile from the coast. The stream and location was once rich in food from the two rivers, a lagoon, the sea and fertile soils of the district (Collins, 2010).

Figure 17: Waikawa Stream mouth, January 2014

5.2 Study Sites

This section describes the three study sites from which values data was taken to conduct the CBA in this project: Karapiro in South Waikato, Hurunui in Canterbury, and Canterbury streams and rivers.

5.2.1 Karapiro South Waikato

The study area of this research is the Karapiro catchment of the South Waikato. It extends from Lake Arapuni to the Karapiro dam including tributaries. The lakes are used by large numbers of recreational users and are popular for trout fishing, water skiing and aesthetics, as well as home to world champion rowers[11].

The Karapiro catchment is predominantly dairy (34%), pastoral (13%) and forestry (48%). Intensification and conversion of land from forestry to dairy is anticipated, potentially increasing the levels of nitrogen (N) and phosphorous (P) entering tributaries, hence a high priority for nutrient management (Marsh, 2012).

Marsh (2012) acknowledges that catchment level population data is unavailable, and he thus drew conclusions from the Waikato region as a whole. However, areas selected for sampling were Tokoroa, Putaruru, Tirau and remaining rural areas – these areas are of the South Waikato district, hence the use in this research of 2006 Census data for the area unit South Waikato district. The South Waikato District had a population of 22,644 and a total 9,225 dwellings (2006 Census).

Ecological Health for the Karapiro Catchment (Marsh 2012)

In this choice experiment of four alternative scenarios for the improved water quality of Lake Karapiro, WTP was estimated for a change in the value of freshwater ecological health. Indicators of ecological health for this choice experiment are those variables that Environment Waikato measure to assess water quality for plant and animal health. The variables used as indicators of ecological health are: dissolved oxygen, pH, turbidity (sediment), total ammonia, temperature, phosphorous and nitrogen. The preceding variables are vaguely described by Marsh (2012), who only suggested general effects on plant and animals. Ecological health status quo was described as "fewer than 40% excellent ecological health readings" (Marsh, 2012). Respondents had the choice of three

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[11] http://www.southwaikato.govt.nz/our-district/living-here/Pages/Tirau.aspx

alternatives based on an increasing percentage of excellent readings: 50%, 60% and more than 80%.

Other than the concern for increased agricultural intensification, the Karapiro study provided neither a description of the processes influencing a change in variable, nor any suggestions for mitigation. WTP (NZ$ per household for the next ten years) estimates for ecological health from this study are provided in table 7.

Table 7: Willingness to pay for ecological health ($), Karapiro New Zealand

	1st quartile	Median	Mean	3rd quartile
50% excellent readings	12	37	51	69
60% excellent readings	0	1	1	2
80% excellent readings	32	103	136	190

5.2.2 Hurunui Canterbury

The Hurunui River stretches 150 km with two main branches. The northern branch has its source from Lake Sumner and the southern from the Southern Alps[12]. The river is significant to local iwi Ngai Tahu and nationally important for fishing and kayaking (Marsh & Phillips, 2012), as well as sailing jet boating and swimming[13].

The Hurunui River is constrained by competing interests of water diversion for agriculture and preservation of natural resources. The catchment accommodates a diversity of land uses. The upper catchment is largely unspoilt beech forest and low intensity pastoral

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[12] http://landandwater.co.nz/councils-involved/environment-canterbury/hurunui-river/

[13] http://landandwater.co.nz/councils-involved/environment-canterbury/hurunui-river/

farming; the middle catchment is largely grazed pasture and native vegetation; the remainder is intensively farmed with sheep, beef, dairying and plantation forestry[14].

Hurunui district is most immediate to the catchment hence the use in this research of 2006 Census data for the area unit Hurunui district was used in this research**.** The Hurunui district covers an area of 864,640 ha[15], had a population of 10,476 and a total 5,658 dwellings (2006 Census).

Ecological Health for the Hurunui Catchment Canterbury (Marsh and Phillips 2012)

This choice experiment provided five alternative scenarios, including estimated utility by WTP as well as willingness to accept compensation (WTA) for a change in the freshwater value ecological health. Marsh and Phillips (2012) define ecological health as

> "…a measure of the life supporting capacity of the river. It covers aquatic ecosystems, associated significant habitats of indigenous fauna and areas of significant indigenous vegetation."

There are three levels of ecological health: status quo, good and not satisfactory. The status quo level was satisfactory, indicating that Environment Canterbury objectives are usually met; either side of 'status quo' are the levels 'good' (objectives always met), and 'not satisfactory' (objectives not met). This study estimated WTP "to improve ecology from not satisfactory to good" at $44, excluding respondents who select preferred environmental outcome despite the cost

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[14] http://landandwater.co.nz/councils-involved/environment-canterbury/hurunui-river/

[15] http://www.hurunui.govt.nz/our-district/about-hurunui/

In the published study, Marsh & Phillips (2012) provided an inadequate description for what was meant by ‘ecological health’ of Hurunui, or what Environment Canterbury’s objectives for freshwater health were. They did not allude to what they considered to be indicators of ecological health, consequently providing no account of the processes influencing ecological health. Subsequent examination of Environment Canterbury’s website identified a total of 13 variables that could be used as indicators of water quality[16]. In addition, despite Marsh and Phillips (2012) aspiring definition for ecological health suggesting the river provides important habitat for endangered fish and birds, there is no description of these species and their habitat needs.

The study did suggest vague mitigations such as, “some land use change and mitigations that aim to meet water quality…border dyke irrigation converted to spray irrigation” (Marsh & Phillips, 2012). As noted, much of the Hurunui catchment is intensively farmed with sheep, beef and dairy. As intensive farming has been associated with an increase of nitrates to freshwater bodies, a decrease in this land use, with dairying converted back to native vegetation, would certainly facilitate an improvement in water quality. Border dyke irrigation is a drain with multiple dams or ‘borders’ closed in order for water to spill onto adjacent land. This option is not favourable because it impinges on water quality because of “so much over-watering, and the entrainment of P [phosphorous], N [nitrate], and faecal bacteria” (Monaghan et al., 2009).

5.2.3 Canterbury Rivers and Streams

Canterbury is New Zealand’s largest region (Tait et al., 2011). As well as small spring-fed streams, Canterbury has 78,162 km of rivers broadly described as wide braided and narrow

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[16] http://ecan.govt.nz/advice/your-water/water-quality/Pages/measuring-water-quality.aspx

braided[17] of "international and national significance" (Goodwin, 2011). *Canterbury Water – The Regional Context* (Goodwin, 2011) emphasises the connectedness of economic, environmental, social and cultural activities of Canterbury's water resources.

Seventy five per cent of Canterbury region land is in some form of agriculture (Taylor, 2011) justifying the aim of the study to mitigate agricultural impacts on rivers and streams. Tait et al. (2011) made note of the agricultural history of the region, which had much conversion to water-intensive dairy farming and a rapid increase of dairy stock unit numbers.

The Canterbury region covers an area of 45,346 km² had a population of 521,832 and a total of 222,612 dwellings, according to the 2006 Census. It is relatively larger than Horowhenua, South Waikato and Hurunui. Canterbury districts that are closer to the size of Horowhenua are Selwyn, Ashburton and Waitaki. Of these three, the most similar to Horowhenua in terms of personal income, is to be used to compare personal income of Canterbury with the policy site Horowhenua.

Ecology for Canterbury Rivers and Streams (Tait, Baskaran, Cullen and Bicknell 2011)

The aim of this study was to estimate the benefits of mitigating agricultural impacts on rivers and streams in Canterbury which is experiencing an increase in water use for dairy farming. This experiment estimated WTP for two management scenarios fair and good with one of the commodities/ attributes being freshwater "ecology". The levels of ecology increased with quality to fair and then good, from a status quo of poor characterised by aquatic weeds covering most of the stream channel, thick green algae covering most of the stream bed, absence of fish and presence of only pollution tolerant insects.

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[17] http://ecan.govt.nz/about-us/your-region/pages/our-rivers.aspx

Tait et al. (2011) noted that people are most interested in a salient description of the values implicated by the presence of a pollutant, rather than scientific jargon. Like the two preceding studies there is a poor description of the processes which impinge on freshwater "ecology". The study suggests that nitrates are contributing to excess weed growth and other ecological effects, but does not elaborate on the other effects. The use of streams and rivers as habitat for plants and animals is judged as very important by participants. However, there is no indication of species or habitat needs. Table 8 provides ongoing WTP per household per year for two levels of change in ecology.

Table 8: Ongoing willingness to pay for a change in ecology ($) from poor to fair or good, Canterbury New Zealand

	Average	Lower quartile	Upper quartile
Ecology fair	64	50	80
Ecology good	84	62	105

5.3 Which Study Site Best Matches the Policy Site for Benefit Transfer?

WTP data to be considered for benefit transfer by this CBA of riparian vegetation restoration for Horowhenua was sourced from the three preceding study sites: South Waikato, Hurunui and Canterbury. As has been addressed in section 4.3.3, the benefit transfer method compromises research accuracy. To increase the accuracy of benefit transfer, personal income of Horowhenua is compared with study sites with the aim of identifying the study site with the 'least difference' or most like in personal income with Horowhenua. Personal income is the variable used because it is indicative of ability to pay.

5.3.1 Personal Income Data

Personal income data for all four sites (the three study sites and the policy site) was sourced from the New Zealand Census, 2006. The format that the data is provided in, is the number of values within an income brackets, as displayed in Table 9.

Table 9: Selected total personal income usually resident population Census 2006

Total Personal Incomefor the Census Usually Resident Population Count Aged 15 Years and Over (12 months ending 31 March 2006)

Census 2006

Territorial Authority	Loss	Zero Income	$1 - $5,000	$5,001 - $10,000	$10,001 - $15,000	$15,001 - $20,000	$20,001 - $25,000	$25,001 - $30,000	$30,001 - $35,000	$35,001 - $40,000	$40,001 - $50,000	$50,001 - $70,000	$70,001 - $100,000	$100,001 or More	Not Stated	Total
Horowhenua District	108	873	1,527	1,986	4,275	2,661	2,007	1,713	1,401	1,335	1,446	1,260	399	294	2,244	23,523
Hurunui District	75	252	561	609	1,041	825	702	675	579	597	633	648	198	180	654	8,238
South Waikato District	81	792	1,026	1,425	2,253	1,452	1,098	1,122	909	996	1,116	1,353	528	288	2,175	16,608
Canterbury Region	2,052	16,755	30,399	31,125	52,968	37,776	31,947	30,912	28,635	27,510	35,685	35,775	14,241	11,148	32,412	419,343

Source: Statistics New Zealand

This is not enough information to conduct a benefit transfer. Personal income data for each site had to be generated, achieved by using the statistical software system "R". For each site, a random sample for each income bracket between $1 and $100,000 was generated by the stated frequency of its occurrence, with the exception of the first two columns, loss and zero income. For example, for Horowhenua income bracket $70,001 - $100,000 which occurred 399 times, 399 elements between the values 70,001 and 100,000 were generated. Once data had been generated for each income bracket, the data was then put together to create one vector of personal income for each site. One assumption of this process is that a sample drawn from data for each site is comparable to a sample drawn from the actual population.

A Proxy for Canterbury

The preceding exercise to create one vector of personal income for each site was not possible for Canterbury as the number of elements exceeded the capacity of *R*. To consider WTP for ecology data produced by Tait et al. (2011), districts of Canterbury were considered as a potential proxy.

Table 10: Total personal income for the 2006 census usually resident population for selected Canterbury districts

Total Personal Incomefor the Census Usually Resident Population Count Aged 15 Years and Over (12 months ending 31 March 2006)

Census 2006

Territorial Authority	Loss	Zero Income	$1 - $5,000	$5,001 - $10,000	$10,001 - $15,000	$15,001 - $20,000	$20,001 - $25,000	$25,001 - $30,000	$30,001 - $35,000	$35,001 - $40,000	$40,001 - $50,000	$50,001 - $70,000	$70,001 - $100,000	$100,001 or More	Not Stated	Total
Kaikoura District	33	60	168	261	393	303	270	267	198	183	183	189	57	69	318	2,949
Waimakariri District	189	1,305	2,277	2,253	4,374	3,030	2,445	2,304	2,247	2,235	2,946	3,138	1,170	819	2,406	33,135
Selwyn District	210	1,164	1,947	1,650	2,430	1,821	1,713	1,953	1,944	1,848	2,577	2,907	1,191	909	1,668	25,926
Ashburton District	135	564	1,440	1,425	2,904	2,133	1,836	1,734	1,653	1,734	2,037	1,776	507	537	1,281	21,702
Timaru District	135	1,245	2,349	2,628	5,436	3,531	2,865	2,529	2,223	2,172	2,859	2,661	813	573	2,592	34,614
Mackenzie District	42	78	216	210	405	300	264	258	225	210	219	210	90	63	252	3,045
Waimate District	57	189	384	453	1,038	657	441	429	363	372	375	315	99	96	450	5,718
Waitaki District	111	435	1,017	1,368	2,904	1,800	1,323	1,194	1,125	1,026	1,182	972	351	261	1,341	16,401

Adapted from Statistics New Zealand

The first point of elimination was the total number of elements of each district. Kaikoura, Mackenzie and Waimate were eliminated because there are few elements; Waimakariri and Timaru were eliminated because there are more elements than Horowhenua. Districts that remain as a potential proxy of Canterbury are Selwyn, Ashburton and Waitaki. To identify the district most comparable to Canterbury, percentages of each income bracket were first calculated (a), followed by the difference between income brackets of Canterbury and the brackets of the remaining districts (b).

Table 11: Comparing the frequency of personal income for the 2006 census, districts of Canterbury New Zealand

Personal Incomefor the Census Usually Resident Population Count Aged 15 Years and Over (12 months ending 31 March 2006)																
Authority	Loss	Zero Income	$1 - $5,000	$5,001 - $10,000	$10,001 - $15,000	$15,001 - $20,000	$20,001 - $25,000	$25,001 - $30,000	$30,001 - $35,000	$35,001 - $40,000	$40,001 - $50,000	$50,001 - $70,000	$70,001 - $100,000	$100,001 or More	Not Stated	Total
Canterbury Region	2,052	16,755	30,399	31,125	52,968	37,776	31,947	30,912	28,635	27,510	35,685	35,775	14,241	11,148	32,412	419,343
a) percentage	0.00	0.04	0.07	0.07	0.13	0.09	0.08	0.07	0.07	0.07	0.09	0.09	0.03	0.03	0.08	
Selwyn District	210	1,164	1,947	1,650	2,430	1,821	1,713	1,953	1,944	1,848	2,577	2,907	1,191	909	1,668	25,926
a) percentage	0.01	0.04	0.08	0.06	0.09	0.07	0.07	0.08	0.07	0.07	0.10	0.11	0.05	0.04	0.06	
b) difference with Canterbury			0.00	0.01	0.03	0.02	0.01	0.00	-0.01	-0.01	-0.01	-0.03	-0.01	-0.01	0.01	
Ashburton District	135	564	1,440	1,425	2,904	2,133	1,836	1,734	1,653	1,734	2,037	1,776	507	537	1,281	21,702
a) percentage	0.01	0.03	0.07	0.07	0.13	0.10	0.08	0.08	0.08	0.08	0.09	0.08	0.02	0.02	0.06	
b) difference with Canterbury			0.01	0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	0.00	0.01	0.00	0.02	
Waitaki District	111	435	1,017	1,368	2,904	1,800	1,323	1,194	1,125	1,026	1,182	972	351	261	1,341	16,401
a) percentage	0.01	0.03	0.06	0.08	0.18	0.11	0.08	0.07	0.07	0.06	0.07	0.06	0.02	0.02	0.08	
b) difference with Canterbury			0.01	-0.01	-0.05	-0.02	0.00	0.00	0.00	0.00	0.01	0.03	0.01	0.01	0.00	

Adapted from Statistics New Zealand

Table 11 shows that Waitaki has zero difference with Canterbury in terms of the percentage of occurrence. Hence Waitaki district was used as a proxy for Canterbury, by generating a vector of personal income data for Waitaki district.

5.3.2 Boxplots, a Visual of Personal Income Data

Boxplots are presented for personal income of all sites[18]. Boxplots demonstrate the minimum, the first and third quartiles, the median or middle value in contrast to the mean, and upper outliers, which are significantly distant from other observations. According to the boxplots, Waitaki as a proxy for the Canterbury region has the least difference in personal income to the Horowhenua district. This was considered sufficient reason to use the WTP for ecosystem health data estimates for the Canterbury region.

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[18] boxplot(horo.income, sth.waikato.income, hurunui.income, waitaki.income, main="Personal Income Census 2006", names=c("Horowhenua", "South Waikato", "Hurunui", "Waitaki"))

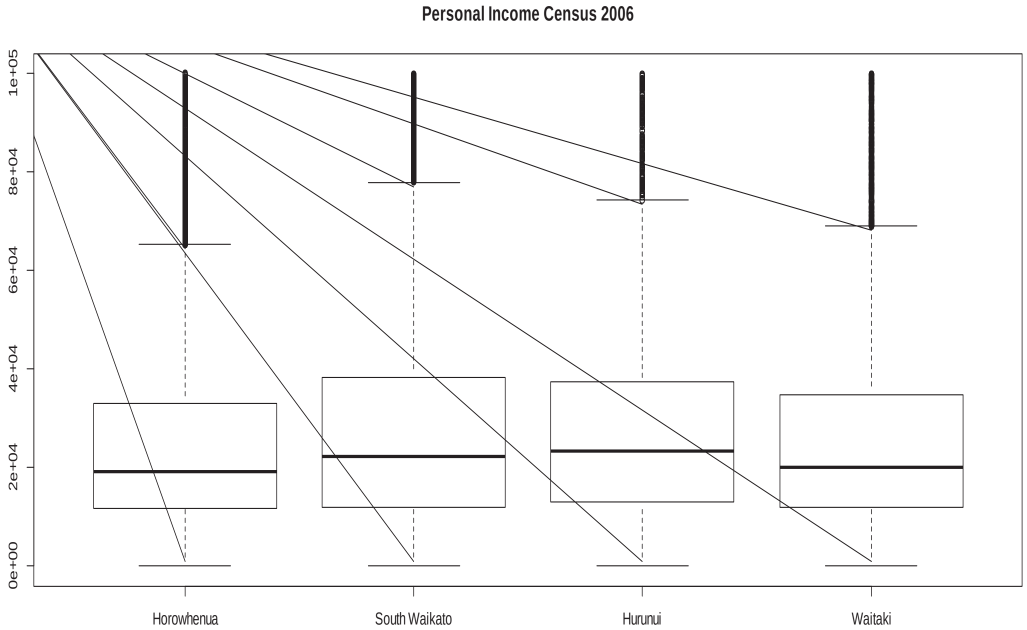

Figure 18: Boxplots of personal income of Horowhenua, South Waikato, Hurunui and Waitaki, New Zealand

Further analysis data analysis was conducted, as is displayed in Tables 12, 13 and 14, for populations, and random samples of 250 and 1,000. Data provided in the tables are parameters (Table 12) and statistics (Tables 13 and 14) for personal income, and output of the Welch T Test and the Wilcoxon rank sum test, which will be discussed below. The Kruskall Wallis test was also used it provided the same output for all sites, however it did not provide further differentiation and therefore is not considered further. The first set of data for personal income is consistent with the boxplots – for median mean and third quartile, Waitaki has the least difference with Horowhenua.

Table 12: Parameters generated for personal income Horowhenua, South Waikato, Hurunui, Waitaki New Zealand

Parameter		Horowhenua	South Waikato	Hurunui	Waitaki
Personal Income ($)	Standard deviation	17540	20604	19179	18158
	minimum	1	3	8	3
	1st quartile	11,730	11,910	12,960	12,050
	Median	19,200	22,180	23,440	20,130
	Mean	24,060	27,520	27,380	25,190
	3rd quartile	33,140	38,290	37,510	34,850
	Maximum	99,970	99,880	99,920	99,820
Welch T Test	T		-15.8856	-12.7785	-5.7432
	p value		2.2e-16	2.2e-16	9.382e-09
	95% confidence interval (CI)		-3883.101 -3030.107	-3826.914 -2808.995	-1511.3155 -742.2208
	CI range		853	1018	769
Mann-Whitney Test	W		122,448,009	63,307,263	137,703,276
	p value		2.2e-16	2.2e-16	3.295e-08

Table 13: Statistics generated for personal income n=250 Horowhenua, South Waikato, Hurunui, Waitaki New Zealand

Statistic		**Horowhenua**	**South Waikato**	**Hurunui**	**Waitaki**
Personal Income ($)	Standard deviation	16,189	20,939	17,228	16,186
	minimum	27	33	91	57
	1st quartile	12,810	12,180	13,510	12,910
	Median	19,540	23,120	21,970	22,060
	Mean	24,170	27,680	26,370	24,860
	3rd quartile	33,690	38,040	35,300	34,270
	Maximum	97,050	99,880	98,850	90,760
Welch T Test	T		-2.1021	-1.4779	-0.4808
	p value		0.03608	0.1401	0.6309
	95% confidence		-6808.2068	-5147.3284	-3540.782
	interval (CI)		-229.3692	727.9844	2148.582
	CI range		6579	5875	5690
Wilcoxon rank sum test	W		29,517	28,803	30,362
	p value		0.2835	0.1299	0.5827

Table 14: Statistics generated for personal income n=1000 Horowhenua, South Waikato, Hurunui, Waitaki New Zealand

Statistic		Horowhenua	South Waikato	Hurunui	Waitaki
Personal Income ($)	Standard deviation	17181	20444	19293	18842
	minimum	6	46	66	3
	1st quartile	11,470	11,450	13,000	12,370
	Median	19,060	23,050	23,520	20,720
	Mean	23,730	28,070	27,420	25,810
	3rd quartile	33,900	40,180	37,800	35,430
	Maximum	97,210	99,290	98,950	99,520
Welch T Test	T		-5.1463	-4.5239	-2.5832
	p value		2.925e-07	6.432e-06	0.009861
	95% confidence interval (CI)		-6002.197 -2689.797	-5297.915 -2093.607	-3664.3627 -501.5493
	CI range		3313	3204	3162
Wilcoxon rank sum test	W		447,338	442,264	470,885.5
	p value		4.54e-05	7.783e-06	0.02416

5.3.3 Welch T Test

The Welch T-test examines the difference in the means of two groups. The null hypothesis is that the means are the same but the two population variances might differ[19]. The outputs generated by *R* for the Welch t-test are the t-statistic, the p-value and a 95% confidence interval. Whether the t-statistic is negative or positive is ignored. A larger value of the t-statistic indicates a smaller probability that the means are the same[20]. When the p-value is large, the null hypothesis is accepted[21]. The confidence interval (CI) contains

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[19] http://graphpad.com/support/faqid/1568/

[20] http://www.sahs.utmb.edu/pellinore/intro_to_research/wad/differences.htm

[21] http://graphpad.com/support/faqid/1568/

the true difference between the means[22]. In addition is the CI range which indicates the number of potential values for the true difference between the means, the more potential values the less accuracy.

5.3.4 Wilcoxon Rank Sum Test

The Wilcoxon rank sum test examines whether two independent samples could derive from the same population[23], alternatively whether independent population distributions are identical (Yau, 2013). The null hypothesis is that the two populations, from which the samples are drawn, are identical populations. Outputs generated by R are "W" and the p-value; "W" is significant if it is less than or equal to *U critical* (= $\mu - z * \delta - 0.5$) (Hole, 2009), and a large p-value is indicative of less evidence that the two populations differ[24].

5.4 So which study site best matches the policy site for benefit transfer?

A comparison of personal income of Horowhenua with the study sites South Waikato, Hurunui and Waitaki (as a proxy for Canterbury), indicates that Waitaki has the least difference in personal income with Horowhenua. First the boxplots demonstrated that there was least difference in personal income between Horowhenua and Waitaki at the median, the 3rd quartile and maximum excluding outliers. In addition to the mean for population data generated, Horowhenua and Waitaki means of personal income were the same as indicated by the output of the Welch T test, with a lower value for the t statistic and higher p value compared with the other study sites. The p value of the Wilcoxon rank

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[22] http://www.graphpad.com/guides/prism/6/statistics/index.htm?how_the_unpaired_t_test_works2.htm

[23] http://sphweb.bumc.bu.edu/otlt/MPH-Modules/BS/BS704_Nonparametric/BS704_Nonparametric4.html

[24] http://graphpad.com/guides/prism/6/statistics/index.htm?how_the_mann-whitney_test_works.htm

sum test however, indicates less evidence for difference between personal income of Horowhenua and Waitaki with a larger p value compared to other study sites.

Identifying the site most like Horowhenua from which to take data for benefit transfer was undertaken as described in this chapter. The next chapter uses willingness to pay data from the Waitaki study to conduct a CBA for riparian planting in the Horowhenua streams in this research.

Chapter 6: Cost Benefit Data Analysis

The purpose of this chapter is to outline the steps that were undertaken in the cost benefit analysis (CBA) calculations for riparian planting of Horowhenua District Council's (HDC) Group 2 Priority Water Bodies. Riparian planting is often considered by width, which is the land retired either side of water bodies. Two riparian planting projects are considered by this cost benefit analysis: riparian planting of either 5 or 10 metres. To undertake this CBA, a time horizon, a discount rate and data for costs and benefits of riparian planting were required. Time horizon and discount rate are the first topic of this chapter, followed by willingness to pay (WTP) for fair or good stream ecology health, as outlined by Tait et al. (2011).

The chapter then identifies costs for riparian planting of HDC's Group 2 Priority Water Bodies. The costs addressed here are the opportunity cost of retiring land, fencing, plants and planting labour, and employing Kaitiaki (carers) for maintenance.

6.1 Time Horizon and Discount Rate

New Zealand Treasury (2005) recommends a time horizon of 20 years because impacts beyond 20 years become insignificant. The time horizons used for riparian planting retiring a 5m width are 10 years and 18 years. One time horizon is used for riparian planting retiring a 10m, that is 20 years. The range of discount rates to be used is from 7% to 11%.

6.2 Willingness to Pay for Ecosystem Health for Coastal Freshwater Streams

It was concluded in the previous chapter that Waitaki be a proxy for the Canterbury region because it has the least difference in personal income with the Horowhenua. It is thus most likely to reflect the WTP preferences of the Horowhenua population. Therefore, data for WTP for ecology (fair and good) collected for Canterbury Rivers and streams is the most appropriate data to use for this CBA. For the preliminary analysis, with reference to WTP data for Canterbury, WTP data used for 5m and 10m riparian widths are listed in by Table 15.

Table 15: Willingness to pay for fair or good ecology ($): average, lower quartile and upper quartile

	WTP for Ecology fair by 5m Riparian Width ($.household.year)	WTP for Ecology good by 10m Riparian Width ($.household.year)
Average	64	84
Lower Quartile	50	62
Upper Quartile	80	105

Dwellings and Annual Benefit WTP for Ecosystem Health

As previously mentioned there are a total of 14,319 dwellings in Horowhenua. The number of dwellings or households is multiplied by WTP data to generate the total annual benefit; this is depicted in Table 16.

Table 16: Willingness to pay for fair or good ecology multiplied by the number of dwellings Horowhenua New Zealand

	WTP for Ecology fair by 5m Riparian Width ($.year)	WTP for Ecology good by 10m Riparian Width ($.year)
Average	916,416	1,202,796
Lower Quartile	715,950	887,778
Upper Quartile	1,145,520	1,503,495

6.3 Riparian Planting Costs

A successful riparian planting project requires retiring land, fencing, plants and planting labour, and ongoing maintenance. The costs associated with these activities are addressed below.

6.3.1 Opportunity Cost of Retiring Land

As previously mentioned, opportunity costs measure forgone benefits from alternative land uses, dominated by land acquisition costs observed in an active market. For a riparian planting project, land is retired or taken out of productive use. To calculate the opportunity cost of retiring land for riparian planting, data on total land area to be retired is required. Then, for increased accuracy, land use and relative price per hectare is required.

Riparian planting is often considered by width, which is the land retired either side of water bodies. Widths considered by this study are 5m and 10m. In order to calculate the total land area to be retired, the width is multiplied by two indicative of two sides of the streams. The preceding value is then multiplied by the length of the streams. For this analysis of riparian planting for widths of either 5m or 10m, respectively 30.7ha and 61.4 ha total land area would have to be retired.

Land use in the Horowhenua is approximated using Statistics New Zealand's Agricultural Production Statistics (2003)[25] (see Appendix 2). Land use (ha) for the Manawatu-Wanganui region are provided in column two of table 17, percentages for land use are then calculated and provided in column three. Columns five and seven provide an approximation of land area in the relevant land use given land to be retired for widths 5m and 10m respectively.

With land area of each land use calculated, land acquisition costs for these land uses was taken from the source, interest.co.nz[26] (see Appendix 3). For each land use, Table X below shows the median prices for the preceding three months, rather than average price which

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[25] *http://www.stats.govt.nz/browse_for_stats/industry_sectors/agriculture-horticulture-forestry/~/media/Statistics/browse-categories/industry-sectors/agriculture-horticulture-forestry/ag-prod-survey-tables-2003/hectares-used-farms-land-use-region.xls, *retrieved December 2013*

[26] **http://www.interest.co.nz/rural-news/67841/176-farms-were-sold-november-prices-hectare-rise-dairy-fall-all-other-types, *last retrieved March 2014*

are exceptionally volatile. The data is drawn from the Real Estate Institute monthly reports for November 2013. Prices per hectare per land use are provided in column four of table 17.

Table 17: Land use and opportunity cost of retiring land for riparian planting, Horowhenua New Zealand

Land use*	ha*	%	$/ha**	5m width		10m width	
				ha	$	ha	$
Grassland	1186044	0.7714	14826	23.6836	351133.1	47.3672	702266.2
Cropland	17848	0.0116	21452	0.3563	7645.47	0.7127	15290.94
Horticulture	6290	0.0040	16629	0.1256	2088.64	0.2512	4177.28
Forestry	142357	0.0925	2399	2.8426	6819.55	5.6853	13639.11
Native	160422	0.1043	0	3.2033	0	6.4067	0
Other	24455	0.0159	80712	0.4883	39414.2	0.9766	78828.41
Total	1537416	1		30.7	407101	61.4	814202

6.3.2 Fencing

Fencing both sides of the streams is assumed by this analysis. To maximise the longevity of fences in flowing waterways, it is recommended that photos be taken at times of peak water levels as a reference for setting out fences[27]. Otherwise, fencing can occur well before planting and as soon as possible for animal control or stock inclusion.

Schedule 2 of the Fencing Act 1978 suggests that a 7 or 8 wire fence is adequate for rural settings, which are the assumed setting of riparian sites. Waikato Regional Council provides a planting and fencing waterways calculation sheet[28] (see Appendix 4). The interactive calculation sheet suggests alternative fencing costs including materials and labour (exclusive of GST) for flat and hill country. With the exception of Mangaore stream,

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[27] http://www.lifestyleblock.co.nz/lifestyle-file/running-the-farm/fencing/item/1010-fencing-waterways.html

[28] http://www.waikatoregion.govt.nz/Environment/Natural-resources/Land-and-soil/Managing-Land-and-Soil/Managing-farm-runoff/Planting-and-fencing-waterways-calculation-sheet/

the remaining streams are on flat country, hence the differentiation of fencing costs per Table 18, calculated assuming the fence is an 8 wire fence.

Table 18: Fencing costs for flat and hill country, Horowhenua New Zealand

	$ per metre	**$ per Kilometre**	**Hill fencing 27.4km ($)**	**Flat fencing 34km ($)**
8 wire flat country	3.75	3,750		127,500
8 wire hill country	16.00	16,000	438,400	

6.3.3 Planting

Plants and planting labour costs have been calculated based on a narration provided from a local nursery by email (see Appendix 5). The nursery indicated an average plant price of $4.025 in 2013, an ideal plant spacing of 1m, and the number of plants that one person might plant per hour. With this data, it was possible to calculate number of plants required for riparian planting of both widths 5m and 10m, and the number of labour hours required for planting given the number of plants required; this data is provided in table 19. The site careersnz[29] estimate that gardeners earn between $13 and $25 per hour. Thus, the cost of labour for planting is assumed at $18.

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[29] http://www.careers.govt.nz/jobs/agriculture-horticulture/gardener/

Table 19: Plant units, plant cost and planting labour for ripairan restoration Horowhenua New Zealand

Variables relevant to estimating costs	5m riparian width either side of streams	10m riparian width either side of streams
Total length of streams (km)	30.7	30.7
Both sides of length	61.4	61.4
Number of plants required	307,000	614,000
Total cost of plants ($4.025 p/plant) ($)	1,235,675	2,471,350
Labour hours required for planting (25 plants p/ hour)	12,280	24,560
Cost of labour for planting @ $18/hour ($)	221,040	442,080

6.3.4 Kaitiaki for Maintenance of Riparian Planting

Success of riparian vegetation restoration requires on-going regular maintenance and care, essential to ensure the survival of planting. A schedule should be prepared for mulching, silviculture, weed and animal control, and fence maintenance.

Kaitiaki are guardians who maintain care of a rohe (area) over which they typically have whakapapa (genealogical) connections. Kaitiaki are essential to the success of riparian vegetation restoration, as they are key to executing on-going regular maintenance and care of the stream plantings. Employing Kaitiaki to maintain riparian vegetation restoration is assumed a cost for this CBA of riparian vegetation restoration. The cost of Kaitiaki is initially calculated as two Kaitiaki for 20 hours each per 5m riparian width, therefore for a 10m riparian width four Kaitiaki would be employed for 20 hours each. Relative to planting, which was estimated to cost $18/hr, the Kaitiaki role is assumed to be more technical and was therefore calculated based on $20/hour. Initially the annual cost of Kaitiaki is $41,600 for a 5m riparian width, and $83,200 for a 10m riparian width. In the final year of the cost benefit analysis, this cost is calculated as an annuity in perpetuity, the value of an on-going annual payment.

6.4 5m Width Riparian Planting

6.2.1 Preliminary Analysis

Table 20 provides net present value for a 5m width of riparian planting given the riparian planting costs as stated. Additional assumptions are variability in WTP, two time horizons (10 and 18 years), and a range of alternative discount rates.

Table 20: Preliminary net present value of riparian planting by WTP ($); width 5m, stream length 30.7km, time horizons 10 and 18 years, discount rate 7-11%

	Discount rate (%)									
	7	8	9	10	11	7	8	9	10	11
	10 year time horizon					**18 year time horizon**				
	Net present value ($millions)									
WTP ($) for ecology per Tait et al. (2011)										
Average (64)	10.01	8.54	7.40	6.50	5.77	10.57	9.06	7.90	6.98	6.23
Lower quarlite (50)	7.25	6.12	5.26	4.57	4.02	7.77	6.61	5.72	5.01	4.44
Upper quartile (80)	13.17	11.30	9.85	8.70	7.77	13.78	11.87	10.40	9.23	8.28

6.2.2 Sensitivity Analysis, an Increase in Costs

Table 21 provides net present value for a project of a 5m width of riparian restoration using the capital charge rate 2011/12 of 8% as the discount rate, and time horizons 10 and 18 years. Additional assumptions are:

- First quartile of WTP data generated by Marsh 2012 for the Karapiro catchment because the lower quartiles for personal income were nearest between Horowhenua and South Waikato.
- Assuming a WTP value of $0.5 per week per dwelling for two reasons: a) $0.5 per week is an insignificant cost to pay for ecosystem health, and b) demonstrate some middle ground between higher WTP values estimated by Tait et al (2011) for

Canterbury, and the first quartile for WTP estimated by Marsh (2012) for the Karapiro catchment.

- A change in Kaitiaki required; alternatively two, four and six.

Table 21: Net present value sensitivity analysis; width 5m, stream length 30.7km, time horizons 10 and 18 years, Kaitiaki required (2, 4, 6) each 20 hours/ week

	Number of Kaitiaki each 20 hours/ week					
	2	4	6	2	4	6
	10 year time horizon			**18 year time horizon**		
	Net present value ($millions)					
$0.5/ week/ dwelling	1.99	1.45	0.90	2.28	1.73	1.18
WTP ($)						
per Tait et al. (2011)						
Average (64)	8.54	8.00	7.45	8.94	8.39	7.84
Lower quarlite (50)	6.12	5.58	5.04	6.49	5.94	5.39
Upper quartile (80)	11.30	10.75	10.21	11.75	11.20	10.65
per Marsh (2012)						
First quartile (12)	- 0.42	- 0.97	- 1.51	- 0.18	- 0.73	- 1.28

6.5 10m Width Riparian Vegetation Restoration

6.5.1 Preliminary Analysis

Table 22 provides net present value for a project of a 10m width of riparian planting over a 20 year time horizon given costs previously addressed. Additional assumptions are variability in WTP and discount rate.

Table 22: Preliminary net present value of riparian planting by WTP ($); width 10m, stream length 30.7km, time horizons 20 years, discount rate 7-11%

	Discount rate (%)				
	7	8	9	10	11
	Net present value ($millions)				
WTP ($) for ecology per Tait et al. (2011)					
Average (84)	8.57	7.89	7.28	6.72	6.21
Lower quartile (62)	5.23	4.80	4.40	4.04	3.70
Upper quartile (105)	11.75	10.85	10.02	9.28	8.60

6.5.2 Sensitivity Analysis, an Increase in Costs

Table 23 provides net present value for a project of a 10m width of riparian vegetation restoration using the capital charge rate 2011/12 of 8% as the discount rate, with a time horizon of 20 years. Additional assumptions are:

- First quartile of WTP data generated for the Karapiro catchment because the lower quartiles for personal income were nearest between Horowhenua and South Waikato.
- Assuming a WTP value of $1 per week per household fortwo reasons: a) $1 per week is an insignificant cost to pay for ecosystem health; b) to demonstrate some middle ground between higher WTP values in Canterbury and the first quartile for WTP in the Karapiro catchment.
- Kaitiaki are employed at 40 hours per week, an increase in Kaitiaki are required the alternatives are 2, 4 and 6.

Table 23: Net present value sensitivity analysis; width 10m, stream length 30.7km, time horizon 20 years, Kaitiaki required (2, 4, 6) each 40 hours/ week

	Number of Kaitiaki each 40 hours/ week		
	2	4	6
	Net present value ($millions)		
$1/ week/ dwelling	3.39	2.29	1.18
WTP ($)			
per Tait et al. (2011)			
Average (84)	7.89	6.79	5.68
Lower quartile (62)	4.80	3.70	2.59
Upper quartile (105)	10.85	9.74	8.64
per Marsh (2012)			
First quartile (32)	0.58	- 0.52	- 1.63

6.6 Injection into Local Economy

The investment in locally sourced plants and labour (both planting and Kaitiaki) is also a benefit to the local economy as the investment remains and circulates locally. These costs could be recorded in both the costs and benefits of the analysis consequently cancelling each other out to zero. Of these costs however, taxes will leave the local economy and are thus a cost; these taxes are goods and services tax (GST) and income tax. In New Zealand, GST is added to the price of most goods and services at a rate of 15%; provided certain criteria are met it can be claimed back, this is assumed true for this scenario and therefore the cost and benefit of locally sourced plants is excluded from the proceeding analysis. Income tax in New Zealand is calculated by marginal tax rates, rates relevant here are 12.2% for taxable income up to $14,000 and 19.2% from $14,001 to $48,000. Assuming a time horizon of ten years, the costs of income taxes per year, for two planting labourers per 5m riparian width and each Kaitiaki are provided in table 24.

Table 24: Income taxes for planting labour and Kaitiaki (ongoing maintenance) for riparian restoration, Horowhenua New Zealand

	5m Riparian Width ($)	10m Riparian Width ($)
Income tax for planting labour	2,697	5,394
Income tax per Katiaki employed	3,014	3,014

5m Width Riparian Restoration, an Injection into Local Economy

Fundamental assumptions of this analysis are a time horizon of ten years and a discount rate of 8% for a 5m riparian width. The costs are the opportunity cost of retiring land, fencing and income tax for both planting labourers and Kaitiaki. Additional assumptions of the cost of income tax for Kaitiaki are 20 hours/ week and 40 hours/ week, and employing increasing numbers of Kaitiaki 2, 4, 6 and 20. The benefit of these analyses is alternative values for WTP as per the preceding analysis; for each household per year alternative WTP values of $64, $50, $12 and $26.

Table 25: Net present value of an injection into local economy; width 5m, stream length 30.7km, time horizon 10 years, Kaitiaki required (2, 4, 6, 20) each 20 hours/ week

	Number of Kaitiaki each 20 hours/ week			
	2	4	6	20
	Net present value ($millions)			
$0.5/ week/ dwelling	3.41	3.33	3.25	2.70
WTP ($)				
per Tait et al. (2011)				
Average (64)	9.96	9.88	9.80	9.25
Lower quartile (50)	7.55	7.47	7.39	6.84
per Marsh (2012)				
First quartile (12)	1.00	0.92	0.84	0.29

Table 26: Net present value of an injection into local economy; width 5m, stream length 30.7km, time horizon 10 years, Kaitiaki required (2, 4, 6, 20) each 40 hours/ week

	Number of Kaitiaki each 40 hours/ week			
	2	4	6	20
	Net present value ($millions)			
$0.5/ week/ dwelling	3.31	3.12	2.94	1.66
WTP ($)				
per Tait et al. (2011)				
Average (64)	9.86	9.67	9.49	8.21
Lower quartile (50)	7.44	7.26	7.08	5.80
Per Marsh (2012)				
First quartile (12)	0.89	0.71	0.53	- 0.75

10m Width Riparian Restoration, an Injection into Local Economy

Fundamental assumptions of this analysis are a time horizon of 20 years and a discount rate of 8% for a 10m riparian width. The costs are the opportunity cost of retiring land, fencing and income tax for both planting labourers and Kaitiaki. Additional assumption of the cost of income tax for Kaitiaki is employing increasing numbers of Kaitiaki, 2 per preliminary analysis, increased to 4, 6 and 20. The benefit of this analysis is some of the values for WTP as per the preceding analysis; for each household per year alternative WTP values of $84, $62, $32 and $52.

Table 27: Net present value of an injection into local economy; width 10m, stream length 30.7km, time horizon 20 years, Kaitiaki required (2, 4, 6, 20) each 40 hours/ week

	Number of Kaitiaki each 40 hours/ week			
	2	4	6	20
	Net present value ($millions)			
$1/ week/ dwelling	5.75	5.60	5.45	4.39
WTP ($)				
per Tait et al. (2011)				
Average (84)	10.25	10.10	9.95	8.89
Lower quartile (62)	7.16	7.01	6.85	5.79
Per Marsh (2012)				
First quartile (32)	2.94	2.79	2.64	1.57

6.7 Results of cost benefit data analysis

Net present value of riparian planting either 5 or 10 metre widths of the Horowhenua streams in this study ranges from $-1.6 million (with increased costs) to $10.3 million (assuming an injection into the local economy). This finding is explored more in section 7.4.

Chapter 7: Discussion and Conclusions

Freshwater ecosystem health is a policy priority in New Zealand, as addressed by the Freshwater Reform 2013 and Beyond (hereafter the Freshwater Reform). Of further relevance to this thesis is the Resource Management Reform Bill 2012 which emphasises robust and thorough cost benefit analysis (CBA). In this context, the overall aim of this thesis was to therefore develop and apply a CBA methodology to evaluate the costs and benefits of two riparian planting options of either 5 or 10 metre widths, for restoring freshwater coastal streams of Horowhenua New Zealand.

In regard to this overall aim, Chapter 7 reviews the outcomes of this thesis by discussing the main conceptual and methodological contributions of this thesis, the most important empirical results, the practical implications of the empirical results, the limitations of the research and the avenues for future research.

7.1 Conceptual and Methodological Contributions

This thesis has made a number of conceptual and methodological contributions during development and application of a CBA methodology to evaluate riparian planting options. Some of these conceptual and methodological contributions will also apply in other areas of environmental CBA.

7.1.1 Desired policy outcome an innovation for the CBA methodology

In this thesis it is argued that the first step in CBA should be an explicit evaluation of the desired policy outcome/s of the policy or project that is being evaluated. Furthermore, it is contended that this first step in CBA should not only apply to environmental policy and program analysis, but also to other areas of policy such as security, education and health. This important step seems to be omitted from CBA; consequently without an explicit reference point information may be less organised rendering the CBA ambiguous. This argument for including the desired policy outcome as the first steps draws on the important work of Sen (2000). Sen (2000) argues that the first general condition of CBA is an explicit evaluation “which demands full explication of the reasons for taking a decision, rather than relying on an unreasoned conviction or on an implicitly derived conclusion”. To conduct explicit evaluation, clarity of the desired policy outcome/s serves as a reference point for analysis.

In the context of this study the desired policy outcome that is freshwater ecosystem health for coastal streams, needed to be rigorously defined and elaborated upon; to not do so risk the subsequent CBA to be misleading. Serving as foundations for defining the desired policy outcome, the Freshwater Reform identifies 10 attributes to be managed for ‘ecosystem health and general protection for indigenous species’. However, the Freshwater Reform only identified the 10 attributes, did not provide any description or basis upon the occurrence of those attributes, or how they could be managed and/or measured.

This thesis provides comprehensive descriptions of the attributes to be managed for ‘ecosystem health and general protection for indigenous species’. Explicit evaluation of each of these attributes clarifies what causes the occurrence of an attribute in freshwater coastal streams and the effects of its occurrence. For example sediment occurs as a result of erosion (both sheet and channel) consequently reducing habitat quality and diversity, with reduced visual clarity for sighted freshwater organisms and human recreation. Another example is thermal pollution results in a change of in-stream temperature; consequently threatening the survival of fish and stream invertebrates. Collectively the descriptions for attributes in this thesis provide a more comprehensive interpretation for freshwater ecosystem health of coastal streams in New Zealand.

The interpretation in this thesis for freshwater ecosystem health, exceeds the limited interpretations provided by choice experiments addressed in this thesis. Marsh (2012) to interpreted ecological health vaguely, referring to the variables Environment Waikato use to measure water quality and a sentence of how each variable effects aquatic life. Similarly, Marsh and Phillips (2012) defined ecological health as "…a measure of life supporting capacity…" with no suggestion of indicators. Tait et al. (2011) identify three levels of ecology (poor, fair and good), each level differing in the abundance of aquatic weeds, algae, invertebrates and fish. Tait et al. (2011) also noted that people are most interested in a salient description rather than scientific jargon, emphasising the importance of designing choice experiments with useful information for potential participants.

7.1.2 A new comprehensive framework of the ecology of riparian vegetation

The riparian margin is the area between land and water. It is generally accepted that riparian vegetation improves freshwater quality (Gregory, Swanson, McKee, & Cummins, 1991; Naiman & Decamps, 1997; Thompson & Parkinson, 2011). This thesis presents a new comprehensive framework of the ecosystem functions of riparian vegetation for freshwater coastal streams. The framework differentiates three conduits of riparian vegetation - the canopy, detrital inputs and the riparian floor. These three conduits enhance the provision of ecosystem functions which lead to an improvement of freshwater ecosystem health. The canopy shades the water from sun light, which without canopy heats the water, and provides energy for undesirable growth of aquatic weeds and algae. Detrital inputs contribute to biodiversity, woody debris increase habitat diversity and leaf litter serves as food for consumers throughout a costal stream ecosystem. At the riparian floor are sedges and/or thatch, humus and root systems. Sedges and/ or thatch entrap sediment and attached contaminants, hindering transport to freshwater coastal streams. Humus is a by-product of decomposing plant litter such as leaves and roots on the riparian floor, humus provides habitat for denitrifying organisms which reduce the incidence of nitrate to the water. The root system binds the soil reducing erosion and uptakes nutrients in the soil.

At the early stages of this research it became apparent, that in order to fully comprehend and articulate the inherent complex nature of riparian vegetation, scattered information had to be organised. Other iterations of organising the information occurred prior to the current framework of the ecology of riparian vegetation. During this thesis, this framework was presented several times to stakeholders and it always captures attention and interest. As such the framework has proven effective at imparting knowledge. A key strength of this framework is that it collates very scattered literature about the ecosystem functions of riparian vegetation, and then organises it into a comprehensive and systematic format. A further strength of this new framework is also the use of both Māori and English words/ concepts which enhanced communication and resonates exceptionally well when presented to Iwi and Hapū. Another strength of the framework is the *hierarchal order* (see Figure 8) which identifies three conduits (canopy, detrital inputs, and riparian floor), it then divides each of these three conduits into sub-conduits. It is only at the sub-conduit level it becomes apparent how riparian vegetation delivers ecosystem functions that ultimately improve freshwater ecosystem health.

The framework developed in this thesis, is consistent with the first elements of the TEEB ecosystem services framework (De Groot, Fisher, & Christie, 2010). The TEEB framework follows a linear sequence of:

(a) Biophysical structure and process → (b) Ecosystem function → (c) Ecosystem service → (d) Benefit(s) → (e) Economic value

This new framework effectively expands on and links (a) biophysical structures – refer to Figure 8 and associated figures. It then focuses on how ‘biophysical structure and process’ provide (b) ecosystem functions – for example the canopy as a biophysical structure of riparian vegetation intercepts light reaching water bodies thus mitigating in-stream temperature and eutrophication. The thesis also focuses on (e) economic values of riparian planting. Given these commonalities with the TEEB ecosystem services framework, a valuable future research project would take the existing new framework developed in this study, and extend it to include all of the elements and linkages implicit in the TEEB framework. The TEEB framework is important in public policy debate. The proposed extension of the framework presented in this thesis, amongst other matters, would facilitate its exposure to public policy personnel and the rapidly growing field of ecosystem services research.

Subsequent to developing the new Riparian Framework, a somewhat similar study surfaced (Pusey and Arthington, 2003). Though Pusey and Arthington's (2003) framework only focused on the impact of the riparian on "riverine fish communities". In contrast the framework developed in this thesis covers the 10 attributes to be managed for freshwater coastal streams.

7.1.3 A methodology for identifying most suitable study site for benefit transfer of data

Benefit transfer (BT) is a method for transferring existing economic valuation information or data to new contexts (Rosenberger & Phipps, 2007). Although Atkinson and Mourato (2008) criticise BT as "the preserve of the highly trained specialist rather than a tool that can be routinely used", relatively effective straightforward tests can be used to test the validity of BT. In this thesis a relatively straightforward testing procedure was developed to identify which of the study sites (Karapiro South Waikato, Hurunui Canterbury and Canterbury) is most suitable for BT of valuation data to the policy site (Horowhenua), by comparing personal income.

There were two parts to the BT testing procedure developed and applied in this thesis. The first part was required because data immediately available for personal income was ordinal rather than continuous. For study sites and policy site, continuous data was randomly generated based on ordinal data (see Section 5.3.1). The second part used continuous data generated for each site to compare study sites with policy site by producing boxplots, quartiles and averages, as well statistics for the Welch T test and the Wilcoxon rank sum test.

The BT testing procedure developed and applied has both weaknesses and strengths. Two weaknesses and counteracting strengths are considered here. The first weakness considered is that demographics other than personal income could have been used for comparing study sites with policy site. However, personal income is assumed to be indicative of preference in water quality. Tait et al. (2011) in a New Zealand choice experiment identifies income as a significant influencing factor of respondents when choosing between alternative changes in water quality. Another weakness is the use of randomly generated continuous data based on ordinal data for personal income. However, a counter argument is that there is significant potential of wider use of this method. Ordinal personal income data provided by Statistics New Zealand is immediately available for other regions and districts for comparing study sites with other imminent policy sites. Converting ordinal data to estimated continuous data can be carried out by using random number generators available in most statistics programmes, and furthermore this procedure can potentially be undertaken in an Excel spreadsheet.

7.2 Empirical results

7.2.1 Most preferred option

Cost benefit data analysis in this thesis produced positive net present values (NPV) for riparian planting options of either 5 or 10 metre widths. A positive NPV indicates that riparian planting of Mangaore, Hōkio, Waiwarara, Waiwiri and Waikawa Streams is in the best interest of public benefit. More specifically, the NPV of riparian planting options either 5 or 10 metre widths of the Horowhenua streams in this study ranges from $-1.6 million (with increased costs) to $10.3 million (assuming an injection into the local economy). It must be noted however, that a negative NPV was a relatively rare occurrence, a negative value occurred nine times of over 100 analyses. Based on the CBA criterion for a positive NPV, it would be acceptable to proceed with riparian planting of either 5 or 10 metre widths. If the criterion is to proceed with the highest positive NPV ($10.3 million per table 27) then a 10 metre width is preferred; if the criterion is to proceed with the lowest positive NPV ($0.3 million per table 25), then a 5 metre width is preferred. Higher NPV is also indicative of higher willingness to pay ($) endorsed in this thesis as an allocation of current rate payments rather than an increase in rate payments (see Section 4.3.3).

Also considered by cost benefit data analysis, is that riparian planting of freshwater coastal streams will inject money into the local Horowhenua economy (see Section 6.6). The example applied in this thesis assumed that locally sourced plants and labour (both planting and Kaitiaki) will benefit the local economy as the investment remains and circulates locally. The only ‘leakages’ from the local economy are income taxes. The preceding example reasonably demonstrates an injection into the local economy if labour is a consumer in the local economy. Multiplier effects were almost completely ignored by the analysis of an injection into the local economy other than more Kaitiaki required (80, 160, 240 and 800 hours p/ week). Increasing Kaitiaki hours had an insignificant effect on

NPV, based on the assumption that Kaitiaki are consumers in the local economy and the only leakage is relative income taxes. An additional multiplier effect of an injection into local economy raised here is geographic. On a geographic scale it is almost certain that riparian planting for freshwater ecosystem health required in Horowhenua let alone all of New Zealand far exceeds the 30.7 kilometres of streams addressed by this thesis. By expanding a greater geographical scale than Horowhenua, the assumption that the only costs that leave a local economy are income taxes, there is potential for a productive industry of riparian planting.

An alternative decision criterion may even rely on the proposed time horizons, the most efficient use of time for freshwater ecosystem health. For the policy site in this thesis, a time horizon of 10 years was considered for riparian planting of a 5 metre width, less than the time horizon for riparian planting of a 10 metre width. Riparian planting of a 5 metre width would occur at all five streams of the analysis over a time horizon of 10 years. For a 10 metre width there is a risk that during the first 10 years riparian planting would not reach all of the streams, instead some streams first. Thus one solution is to proceed with riparian planting of a 5 metre width over ten years, and then riparian planting of an additional 5 metre width.

7.2.2 Implications of the Empirical results

According to the empirical results, riparian planting of Horowhenua District Council’s (HDC) Group 2 Priority Water Bodies is in the best interest of public benefit. However, proceeding with riparian planting has practical implications one of which is funding. This thesis assumed that riparian planting would be funded by willingness to pay (WTP), by an allocation of current rate payments rather than an increase in rate payments (see Section 4.3.3). In New Zealand rate payments or public funds are collected by both regional and district councils, those relevant to Horowhenua are Horizons Regional Council (HRC) and

HDC. This presents an implication that HRC and HDC (in the best interest of public benefit) might share in allocating public funds to riparian planting of HDC's Group 2 Priority Water Bodies. Although riparian planting is in the best interest of public benefit, it is one alternative of others competing for an allocation of scarce council funding. CBA provides a useful methodology for prioritising scarce funding, consistent with the Resource Management Reform Bill (2012) which emphasises robust and thorough CBA.

Another implication is property rights which were not directly addressed in this thesis, rather implied by the opportunity cost. Riparian planting is in the best interest of public benefit but could occur on privately owned property, so it is important to delineate between public and private benefits. By selling or leasing all or part of privately owned property, private owners "can capture the benefits produced by long term investments" (Schlager & Ostrom, 1992): 256), such as an investment in riparian planting. The opportunity cost considered in this thesis, assumes the value of land retired for riparian planting can be estimated by recent sale values for similar land use in the region. This opportunity cost to the public, is a private benefit. Other examples of private benefits of riparian planting are – Conservation Stewardship Program Payments for conservation performance in the United States, cost-share programmes such as the Maryland Agricultural Cost Share Programme, the Natural Values Trading scheme in Finland compensating land owners for committing to a voluntary fixed term contract for the maintenance or enhancing biodiversity, and more locally grants for riparian management where naturally occurring erosion is identified in the Bay of Plenty region. Selling and leasing are only two examples of managing property rights for riparian planting, and riparian planting is imminent to the world-wide restoration of freshwater ecosystem health; the administration of property rights of riparian margins, is certain to be a subject of future research.

7.3 Limitations and Future Research

Table 28 outlines the most important limitations of this research, and how these limitations can be overcome by future research endeavours. It should also be noted that, in addition to these 'most important' limitations and associated avenues for future research. Although not elaborated any further, two other limitations specifically addressed in this thesis which require further examination include economic multiplier effects to a local economy of riparian planting, as well as property rights.

The most important limitations and suggested future research endeavours are self-evident from Table 28 and require no further explanation. However, it is appropriate to elaborate on future research to include other benefits of riparian planting. Comparable to this study for freshwater ecosystem health, other benefits of investigation could include Indigenous values, recreational values, aesthetics, and economic such as the economic multiplier previously mentioned. An investigation of either indigenous values or recreational values could use contingent valuation with an alternative payment vehicle rather than willingness to pay through rates. An alternative payment vehicle considered during this thesis and proposed here is work days per year prepared to sacrifice for an indigenous or recreational experience. Also used to estimate a monetary value for recreational values is the travel cost method which theorises that the cost of travel can reflect a monetary value for the recreational experience. The travel cost method could potentially also be used to investigate indigenous values. By including these additional benefits in CBA calculations for riparian planting, it is likely that NPV will increase providing an even stronger justification for riparian planting of freshwater coastal streams.

Table 28: Limitations of this research and future research endeavours

	Limitations	Future Research
1.	The ecology of riparian vegetation and its benefits were sourced from literature rather than a first-hand observation subsequent to riparian planting. A first-hand observation requires many years of research.	Use the Riparian Framework presented in this thesis as a reference point for monitoring and reporting an observation subsequent to riparian planting. A first-hand observation is expected to provide higher quality evidence in support of riparian planting.
2.	The Riparian Framework demonstrates the linkages between biophysical structures of riparian vegetation and ecosystem functions; but is incomplete as an ecosystem assessment as it does not include ecosystem services, benefits and economic values.	Extend the Riparian Framework to include ecosystem services, benefits and values of riparian vegetation according to ecosystem services frameworks for example the TEEB (De Groot et al., 2010).
3.	In addition to freshwater ecosystem health for coastal streams as addressed by this thesis, there are many other benefits of riparian vegetation. Examples include Indigenous values, recreation, and aesthetics. These benefits were not addressed for good reason; in order to interpret other benefits in the same way that freshwater ecosystem health was described is beyond the scope of this study.	Identify other benefits of riparian vegetation using the 'desired policy outcome' theory. For example for aesthetics identify a general reference point for desired outcome of aesthetics from which an explicit evaluation of aesthetics can build.
4.	This cost benefit analysis used willingness to pay values that were generated for other locale in New Zealand, rather than conducting a primary contingent valuation or choice experiment in the Horowhenua region.	For subsequent cost benefit analysis using willingness to pay, conduct a contingent valuation or choice experiment for the relative study locale.

7.4 Concluding comments

This research thesis successfully achieved the stated aim to “develop and apply a cost benefit analysis (CBA) methodology to evaluate the costs and benefits of riparian planting options for restoring freshwater coastal streams”. Application of the CBA methodology for riparian planting of Horowhenua District Council’s Group 2 Priority Water Bodies in most cases produced positive NPV; indicating that riparian planting is in the best interest of public benefit.

The most significant conceptual outcome developed is the comprehensive Riparian Framework, identifying biophysical structures of riparian vegetation which serve ecosystem functions. However, compared with ecosystem assessment the Riparian Framework is incomplete requiring research aiming to extend the Riparian Framework to include ecosystem services and benefits. Subsequent versions of the Riparian Framework will include ecosystem services and benefits, and so should become more compatible with ecosystem services frameworks, and inherent economic valuation on which CBA relies.

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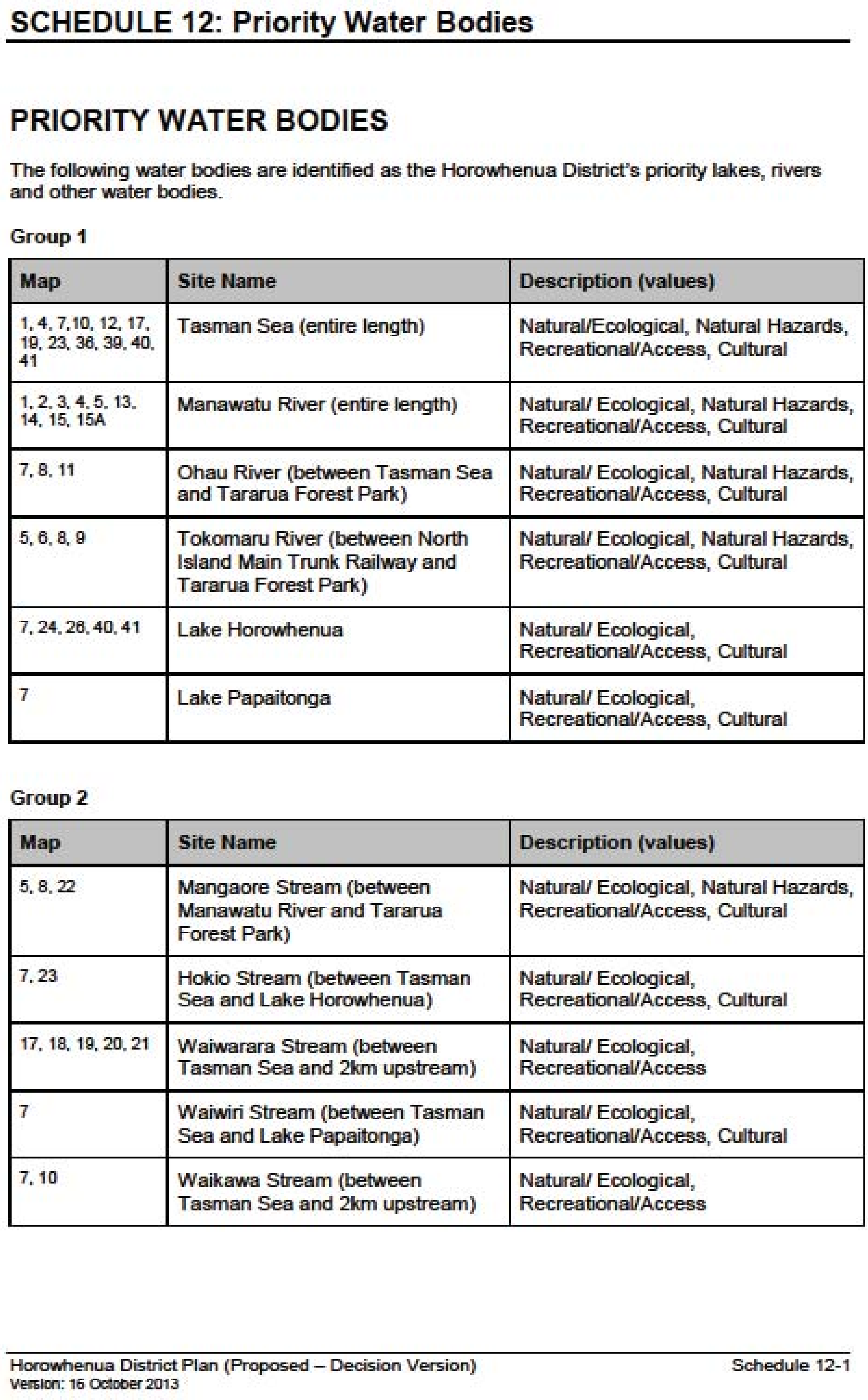
Appendix 1: Horowhenua District Plan (Proposed – Decision Version), Schedule 12: Priority Water Bodies



SCHEDULE 12: Priority Water Bodies

PRIORITY WATER BODIES

The following water bodies are identified as the Horowhenua District's priority lakes, rivers and other water bodies.

Group 1

Map	Site Name	Description (values)
1, 4, 7,10, 12, 17, 19, 23, 36, 39, 40, 41	Tasman Sea (entire length)	Natural/Ecological, Natural Hazards, Recreational/Access, Cultural
1, 2, 3, 4, 5, 13, 14, 15, 15A	Manawatu River (entire length)	Natural/ Ecological, Natural Hazards, Recreational/Access, Cultural
7, 8, 11	Ohau River (between Tasman Sea and Tararua Forest Park)	Natural/ Ecological, Natural Hazards, Recreational/Access, Cultural
5, 6, 8, 9	Tokomaru River (between North Island Main Trunk Railway and Tararua Forest Park)	Natural/ Ecological, Natural Hazards, Recreational/Access, Cultural
7, 24, 26, 40, 41	Lake Horowhenua	Natural/ Ecological, Recreational/Access, Cultural
7	Lake Papaitonga	Natural/ Ecological, Recreational/Access, Cultural

Group 2

Map	Site Name	Description (values)
5, 8, 22	Mangaore Stream (between Manawatu River and Tararua Forest Park)	Natural/ Ecological, Natural Hazards, Recreational/Access, Cultural
7, 23	Hokio Stream (between Tasman Sea and Lake Horowhenua)	Natural/ Ecological, Recreational/Access, Cultural
17, 18, 19, 20, 21	Waiwarara Stream (between Tasman Sea and 2km upstream)	Natural/ Ecological, Recreational/Access
7	Waiwiri Stream (between Tasman Sea and Lake Papaitonga)	Natural/ Ecological, Recreational/Access, Cultural
7, 10	Waikawa Stream (between Tasman Sea and 2km upstream)	Natural/ Ecological, Recreational/Access

Horowhenua District Plan (Proposed – Decision Version) Schedule 12-1
Version: 16 October 2013

Appendix 2: Hectares Used and Farms by Land Use, June 2003

Agricultural Production Statistics (Final Results): June 2003

Hectares Used and Farms by Land Use by Region[1]

At 30 June 2003

Region	Tussock and danthonia used for grazing		Grassland		Grain, seed and fodder crop land		Land in horticulture		Planted production forest		Mature native bush		Native scrub and regenerating native bush		Other land		Total land	
	Number of farms	Area in hectares	Number of farms	Area in hectares	Number of farms	Area in hectares	Number of farms	Area in hectares	Number of farms	Area in hectares	Number of farms	Area in hectares	Number of farms	Area in hectares	Number of farms	Area in hectares	Number of farms	Area in hectares
Northland	..S	..S	4,452	484,387	123	2,030	924	4,559	1,512	173,646	1,584	31,428	1,605	55,666	2,955	38,479	5,430	794,296
Auckland	..S	..S	3,639	188,253	..S	..S	1,422	9,083	1,005	56,249	984	13,578	771	14,331	2,790	12,060	4,983	297,956
Waikato	..S	..S	9,795	1,133,506 R	759	15,300	951	9,950	2,202	309,987 R	..S	..S	1,569	73,669 R	5,523	63,746	10,989	1,684,342 R
Bay of Plenty	..S	..S	3,009	216,819	..S	..S	2,838	15,262 R	903	283,321	..S	..S	741	21,672	2,649	36,400 R	5,463	622,608
Gisborne	..S	..S	918	399,382 R	117	4,972	387	7,989	420	138,900	240	40,912 R	375	60,436	669	13,850	1,296	672,516
Hawke's Bay	129	39,686	2,454	669,060	354	10,100	1,218	20,428	957	122,995	..S	..S	552	45,207	1,950	35,845	3,651	958,912 R
Taranaki	..S	..S	3,237	340,824 R	..S	..S	162	750	762	24,097 R	606	27,858 R	672	44,064 R	2,004	9,193	3,564	451,075 R
Manawatu-Wanganui	..S	..S	5,280	1,186,044 R	738	17,848	600	6,290	1,794	142,357	1,026	59,605	1,188	100,817	3,198	24,455	6,141	1,545,368
Wellington	..S	..S	1,737	327,603	264	6,548	..S	..S	798	70,210	..S	..S	639	63,843	1,188	13,458	2,322	511,570
TOTAL North Island	**..S**	**..S**	**34,524**	**4,945,879 R**	**2,853**	**66,974**	**8,904**	**77,843 R**	**10,350**	**1,321,762 R**	**..S**	**..S**	**8,109**	**479,704 R**	**22,923**	**247,487 R**	**43,836**	**7,538,664 R**
Tasman	..S	..S	1,215	104,567	..S	..S	690	7,143	642	91,682	357	17,459	516	24,075	..S	..S	1,791	266,652
Nelson	..S	..S	..S	..S	..S	..S	..S	..C	..S	..C	..S	..S	..S	..S	..S	..C	..S	..C
Marlborough	204	289,138 R	948	199,422	174	5,600	750	12,372	468	58,300	..S	..S	..S	..S	858	6,798 R	1,683	651,203
West Coast	72	7,710	666	105,396	36	1,027	..S	..S	171	..C	243	17,975	..S	..S	345	13,273	756	..C
Canterbury	1,056	1,459,235 R	7,875	1,125,073 R	2,685	174,725 R	1,743	15,764	2,178	118,060 R	..S	..S	..S	..S	5,596	61,874 R	9,765	3,123,254 R
Otago	717	1,123,944 R	3,063	878,409 R	1,233	52,435	582	4,943	1,140	111,810	336	33,972 R	537	62,194 R	..S	..S	3,849	2,334,638 R
Southland	657	272,942	3,849	715,731	1,662	47,934	162	1,830	870	83,996	507	24,149	561	22,405	2,250	17,774	4,137	1,186,760
Chatham Islands	..S	..S	..S	..S	..S	..S	..S	..C	..S	..C	..S	..S	..S	..S	..S	..C	..S	..S
TOTAL South Island	**2,808**	**3,183,406 R**	**17,814**	**3,169,501 R**	**5,895**	**283,296 R**	**3,987**	**42,245**	**5,553**	**507,373 R**	**2,103**	**163,907 R**	**2,928**	**364,306 R**	**12,117**	**182,819 R**	**22,218**	**7,896,853 R**
TOTAL New Zealand	**3,687**	**3,272,688 R**	**52,338**	**8,115,379 R**	**8,751**	**350,270 R**	**12,888**	**120,088 R**	**15,903**	**1,829,136 R**	**9,240**	**473,640 R**	**11,040**	**844,010 R**	**35,040**	**430,306 R**	**66,054**	**15,435,517 R**

(1) Figures may not add to the totals due to rounding.

Symbols:

C	confidential
S	suppressed
R	revised
..	data not available

Published by Statistics New Zealand

Appendix 3: Land acquisition costs according to land use in New Zealand, November 2013

Table 29: Land acquisition costs according to land use in New Zealand, November 2013

$/ha - November 2013	*Arable*	*Dairy*	*Finishing*	*Forestry*	*Grazing*	*Hort*	*Special*
New Zealand	**24,727**	**40,023**	**19,696**	**5,000**	**17,364**	**142,341**	**16,735**
Northland		15,139	11,633	4,439	7,317	17,304	3,503
Auckland		32,386	42,147	236,661	21,133	204,460	711,881
Waikato	348,182	45,480	20,193		36,818	82,500	9,471
Bay of Plenty		28,040			20,850	217,987	
Gisborne			13,047		5,296	104,305	1,261
Hawkes Bay	16,398		9,930		14169	107,143	
Taranaki	74,122	45,096	151,757		26,937		
Manawatu/Wanganui	21,452	14,826	21,935	2,399	5,650	16,629	80,712
Wellington	24,118		7,905	14,798	19,651		69,716
West Coast					15,756		
Canterbury	42,149	51,199	24,651		20,984	41,269	44,444
Otago	19,199	32,295	9,631	5,000	10,848	37,989	35,737
Southland		40,052	24,356		23,225	457,746	15,170

Source: http://www.interest.co.nz/rural-news/67841/176-farms-were-sold-november-prices-hectare-rise-dairy-fall-all-other-types *last retrieved June 30, 2014*

Appendix 4: Fencing costs according to Waikato Regional Council

Table 30: Fencing costs according to Waikato Regional Council

Cost of fences

		Metres of fencing	
Dairy and beef / flat			
1-wire electric	$1.65 per metre*	x	=
(2.5 mm wire, No. 2 ¼ round posts, 7.5 metre spacing)			
each additional wire - electric	$0.30 per metre*	x	=
each additional wire - non-electric	$0.30 per metre*	x	=
Sheep and beef / hill country			
8-wire post and batten	$16 per metre*	x	=
(2.5 mm wire, No. 1 ½ round posts, 4.5 metre spacing)			
8-wire	$10 per metre*	x	=
(2.5 mm wire, 1 wire electric, No.1 ¼ round posts, 4 metre spacing)			
5-wire	$6.20 per metre*	x	=
(2.5 mm wire, 2 wire electric, No. 2 ¼ round posts, 4 metre spacing)			

* These prices include materials and contractor labour. Contractor labour is about half of the total cost.

Source: http://www.waikatoregion.govt.nz/Environment/Natural-resources/Land-and-soil/Managing-Land-and-Soil/Managing-farm-runoff/Planting-and-fencing-waterways-calculation-sheet/ *last retrieved June 30, 2014*

Appendix 5: A narration from which plants and planting labour costs have been calculated

Thank you for visiting our nursery, great to catch up and go over your project outline.

My understanding from our meeting is that you would like some assistance with the planning and costing for the practical installation components of this project.

Detailed plant scheduling can only occur after the width of the buffer zones has been determined and inspections of the entire site has been made.

If you could review the information below and let me know if it is of assistance and is there anything I have missed.

This information is a draft only and I will need to double check my calculations before becoming final.

Site Preparation and protection

A plan for the control of pest animals will be required. DOC and Horizons may be able to assist with this. If control of the pest animals cannot be achieved, susceptible plants will need to be physically protected for 2 years (+/- 1 year depending on species). The most cost effective method for this will be achieved by using nova coil or similar product.

A plan for the control of specific plant pest species prior to planting will be required. Blackberry and Buckthorn will be problematic and will need to be poisoned well in advance of any planned planting. A second application of herbicide may be required in some cases. I recommend you do not attempt to physically remove these weed species except for access ways and individual planting spots, These poisoned plants can act as shelter for the new plants.

Proposed plant hole preparation will consist of spot spraying with herbicide 0.3 – 0.5 metre diameter areas 2-3 months prior to planting. In some cases a second application of herbicide may be required.

Post Planting Protection

A plan to monitor and manage pest problems after planting will be required and will consist of on-going control of unwanted competing plants species, animal pests and removal of protective sleeves. Huhana Smith and Richard Anderson may be able to give you a good idea of the amount of time required to achieve this on a per hectare/annum basis.

Plant Schedule

At this point, it is not possible to provide a detailed plant schedule without a thorough site inspection. Also, the width of buffer zone needs to be known which will have an effect on the range of species that can be included in each of the general planting zones. Basic plant schedule considerations will include the plants species are known to be endemic to the Foxton ecological district, the plant species seedling or cutting grown plant are available for growing onto a suitable size for planting and can be easily grown and is known to have a high survival rate once planted.

These points may seem fundamental but it is surprising how many projects have performed poorly because these basic points were overlooked.

I suggest the species list be kept simple and focus on those plants which will provide the greatest cost/benefit.

Expansion of the species range can be increased in the later stages of the project after the initial plantings have become established.

The planned duration of the project will need to be determined. This will influence which species will be planted in the various stages of the project. I suggest planning the installation of the project be in 3 year blocks which should fit well with funding agencies. For this project, I suspect a 3 year programme could work but would consider a 6 year programme if the required plant quantity exceeded 100,000 units. The majority of plants would be installed in the earlier stages.

2

The plant schedule will also be guided not only by the amount of money available but also by the amount of labour required to install and maintain the plants. My understanding is that the installation of the plants will rely on volunteer labour. If this is the case then I suggest a contingency allowance be made available for the hire of contractors to install the plants if volunteer labour falls short of the requirement.

Plant Quantities

At this stage I think it is reasonable to assume the project will require average plant spacing to be at 1 metre intervals. The number of rows each side of the stream will be determined by the location of the fences.

I recommend not planting within 0.75 metres from the fence. If the buffer was 5 metres either side of the stream edges, then 5 rows can be accommodated (rows located at 0 metres – stream edge, 1,2,3 and 4 metres from the stream edge)

If the stream is 6 kilometres long then 6,000 plants per row will be required. For a 5 metre buffer either side of the stream then 60,000 plants will be required. If the stream edge was not planted then the quantity will reduce to 48,000 plants.

I would allow a contingency for 10% plant losses which would amount to an additional 5000 – 6000 plants. If losses are smaller than anticipated, the schedule could be easily changed to accommodate this. If a 10 metre buffer is required the plant quantities described above will double.

Labour Requirement – Calculations based on all planting made in year 1

Based on commercial planting rates and assuming a mixture of site conditions including situations where vehicles can't drive all the way to the planting site, uneven planting sites, rain, high stream water level, frosts and other unforeseen problems, a conservative planting rate of 25 plants per hour/person should be achievable. Based on this rate, for 48,000 plants, 1,920 hours work will be required. If planting occurred over a 4 month period with 15 workable days per month and 6 workable hours per day (360 hours), then 5 – 6 will be required. This labour requirement includes time spent collecting the plants and travelling to site.

If voluntary labour was used then the number of people required for the project for the same number of hours could easily double to 12 people plus 1 or 2 project controllers. For 60,000 plants, at least 7 people would be required or 14 volunteers.

If planting was undertaken over a number of years, the annual labour requirements would reduce accordingly.

Costing

The following costing information is provided as a guide only and does not represent a formal quotation or estimate from Lynwood Nursery Limited. Prices exclude GST

If the average plant price in 2013 value terms is around $3.50 then the cost of plants for a 5 metre buffer will be between $170,000 – $210,000 plus a contingency of 10% for losses.

Additional costs will be site preparation, pest control, plant protection, post planting maintenance and a contingency sum for contract labour if volunteer labour is insufficient.

Cheers