Cost Benefit Analysis of Riparian Planting of Waiwiri Stream, Horowhenua

Manaaki Taha Moana: Enhancing Coastal Ecosystems for Iwi, Report No. 15

Cost Benefit Analysis of Riparian Planting of Waiwiri Stream, Horowhenua

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Nga Mihi

Ki te tokerau ko te roto ko Waiwiri
Rere atu ngā wai ma te manga ko Waiwiri
Tae atu ki te one ko Hokio

Ki te tonga ko te awa ko Ohau
Rere atu ngā wai I Te Hakari
Tae atu ki te one ko Kuku

Kei waenganui, rere atu I te puna
ko te manga ko Waimarama
E tu tata ana ko Kikopiri te marae

To the north is the lake Waiwiri
Waters running by the stream Waiwiri
Reaching the beach Hokio

To the south is the river Ohau
Waters running past Te Hakari
Reaching the beach Kuku

In between, running from a spring
Is the stream Waimarama
Beside Kikopiri marae

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EXECUTIVE SUMMARY

Manaaki Taha Moana (MTM) is a research programme with a consortium of researchers from Massey University, Taiao Raukawa, Waka Digital, Cawthron Institute and Manaaki Te Awanui. Using both Western science and Mātauranga Māori (indigenous knowledge), the programme aims to restore and enhance coastal ecosystems and their services of importance through better understanding of these ecosystems and processes of degradation which affect them.

The purpose of this report is to establish, in relation to the Waiwiri catchment, the cost effectiveness of the riparian vegetation restoration method of restoring freshwater ecosystems to their ecological potential. For local iwi and hapū, the Waiwiri catchment is a system of high value, a place of ancestral landscape, and a significant site of Māori history. Like much of the Horowhenua coast in the 1880's, the Waiwiri catchment was once a dynamic environment adorned by native vegetation. It is now a static environment dominated by high-producing exotic grassland for dairy and beef farming. Current science around stream habitats and causes of poor water quality recommends that riparian restoration should take place at Waiwiri stream to maximise its ecological potential.

Freshwater and resource management in New Zealand are currently under reform. The "Freshwater reform 2013 and beyond" acknowledges the significance of fresh water for New Zealanders, a decline in water quality, and an emphasis for iwi/ Māori and community engagement. The freshwater reform identifies two imperative objectives to apply to all water bodies. The objectives are:

1. Ecosystem health and general protection for indigenous species; and
2. Human health secondary contact.

These objectives are defined by 12 freshwater attributes to be managed. The Resource Management Act 1991 (RMA) has also recently been under reform, requiring councils to use robust and thorough cost-benefit analysis (CBA) in planning decisions.

By drawing on the authority of recent policy reform, this report merges distinct disciplines, such as freshwater ecology and non-market valuation (NMV). Freshwater attributes to be managed as dictated by the freshwater reform, are elaborated on to better understand the processes which affect them. Given the increasing emphasis on CBA for policy appraisal, discussed are CBA, market failure for environmental resources, and NMV (particularly choice experimenting).

New Zealand choice experiments (surveys) for freshwater are then considered for data input towards the CBA. Provided for each survey are descriptions of study locale, population and dwelling data, and the attributes used in the surveys. In addition to providing a dollar value, the attributes of these surveys are an indication of community objectives, as well as a salient description of the freshwater attributes to be managed per the freshwater reform.

A framework for understanding the benefits of riparian vegetation is presented. The framework distinguishes between te marumaru (the canopy), ngā parapara (detrital inputs) and te papa (the floor) as conduits of exchange. The framework extends to better understanding how the freshwater attributes per the freshwater reform are affected by riparian vegetation through te marumaru, ngā parapara and te papa. With the potential to mitigate the effects of land use on freshwater, aspects of a riparian vegetation restoration project are then addressed; the efficiency of planting widths and project process from site analysis and preparation to maintenance.

The report proceeds by identifying costs, benefits and scenarios to be considered by the CBA. Costs include an opportunity cost of retiring the land area required for riparian restoration, and costs of fencing and labour, weed control, plants, and planting labour. Some benefits considered are the employment of kaitiaki (project custodians), soil retention, and willingness to pay (WTP) for a change in potential algal bloom, tributary water quality and management. 12 scenarios were considered. The first scenario considered is one in which no action takes place in the Waiwiri catchment, which imposes a cost on society of almost $11 million. Subsequent scenarios assume that both a width of 5m or 10m on both sides of the stream are retired, fenced and planted, and all drains and tributaries are fenced. At the most, 5m and 10m riparian restoration of the Waiwiri stream will cost $2.5 million and $3 million respectively; however the cost of either of these projects could be recovered within three years of project implementation. The dominant cost of doing nothing was a decline in tributary water quality. Furthermore, some costs can be seen as benefits, e.g. locally sourced plants and labour are an injection into the local economy.

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Te Reo Māori translations

hapū sub-tribe, extended family group

iwi tribe

kaitiaki Environmental guardian, protector

kaumātua elders

mahinga kai traditional food gathering places

mana authority, respect, prestige

pā fortified village

rohe boundary, tribal area

tangata whenua people of the land

taonga treasure

turangawaewae place where one has rights of residence and belonging through kinship and whakapapa.

urupā burial ground

wāhi tapu sacred place

whakapapa geneology, ancestry

whānau extended family, family group; whānau are part of hapū and iwi

1. INTRODUCTION

1.1 Background and context

This report is one in a series of reports and other outputs from the research programme "Enhancing Coastal Ecosystems for Iwi: Manaaki Taha Moana" (MAUX0907), funded by the Ministry for Business, Innovation and Employment. Manaaki Taha Moana (MTM) is a six-year programme, which ran run from October 2009 to September 2015, with research conducted primarily in two areas: Tauranga moana and the Horowhenua coast (from the Hokio Stream to Waitohu Stream). This programme built upon Massey University's previous research with Ngāti Raukawa in the lower north island: 'Ecosystem Services Benefits in Terrestrial Ecosystems for iwi' (MAUX0502). Subsequent research has also been funded by MBIE to continue the research with a case study in Tauranga moana – the Oranga Taiao Oranga Tangata (OTOT) research programme.

Professor Murray Patterson, of Massey's School of People, Environment and Planning was the Science Leader of MTM. A number of different organisations were contracted to deliver the research: Te Manaaki Awanui Trust in the Tauranga moana case study; Te Reo a Taiao Ngāti Raukawa Environmental Resource Unit (Taiao Raukawa) and Dr Huhana Smith in the Horowhenua coast case study; WakaDigital Ltd; Cawthron Institute; and Massey University. The research team engages extensively with local communities and end users through a variety of means. The MTM programme website is: http://www.mtm.ac.nz and readers are encouraged to visit our website to read more about this research programme.

The central research question of MTM was: "how can we best enhance and restore the value and resilience of coastal ecosystems and their services, so that this makes a positive contribution to iwi identity, survival and welfare in the case study regions?" Thus, our research aimed to restore and enhance coastal ecosystems and their services of importance to iwi/hapū, through a better knowledge of these ecosystems and the degradation processes that affect them. Mechanisms to facilitate uptake amongst other iwi throughout NZ were also employed. The key features of the research were that it was cross-cultural; interdisciplinary; applied/problem solving; technologically innovative; and integrates the ecological, environmental, cultural and social factors associated with coastal restoration.

The first phase of MTM was a 'Stocktake' of the published research and knowledge of coastal ecosystems and their services in the two case study regions. This phase resulted in a number of publications and coastal resource management tools.

Collectively, these components helped inform the research team and tangata whenua in the selection case studies for more in-depth study and tool development within the MTM research program me.

The second phase of MTM in the Tauranga case study included comprehensive ecological and cultural surveys of the harbour, with a focus on shellfish species for some projects. In the Horowhenua case study, the MTM team is involved in a number of action research projects to bring about restoration to coastal ecosystems along the coastal zone, including: Hokio Stream catchment; Waiwiri catchment; Ōhau River Loop; Kuku Estuary Frontage; Wetlands from Kuku/Ōhau to Waikawa; Lake Waiorongomai and stream to sea. A number of reports have been published detailing these initiatives (see: http://www.mtm.ac.nz/index.php/knowledge-centre/publications; http://www.mtm.ac.nz/index.php/toolkits).

The purpose of this report is to establish the cost effectiveness of the riparian vegetation restoration method of restoring freshwater ecosystems to their ecological potential. In doing so this report draws on multiple disciplines to address:

- recent policy reform relevant to freshwater management in New Zealand;
- freshwater attributes to be managed as dictated by policy;
- cost-benefit analysis as a decision tool and the need for data input;
- community objectives for freshwater and economic utility in the form of willingness to pay (WTP);
- riparian vegetation and freshwater attributes to be managed;
- riparian vegetation efficiency and planning;
- economic appraisal of riparian vegetation restoration by cost-benefit analysis;
- other benefits of riparian vegetation restoration.

1.2 Outline of this report

This report outlines a cost benefit analysis of riparian planting of Waiwiri Stream, that is, starting with the description of the Waiwiri Catchment (chapter 2) and the Freshwater Policy Reform (chapter 3), then the freshwater attributes to be managed (chapter 4). Chapter 5 represents the method of the cost benefit analysis, whereas chapter 6 reviews the community objectives identified by Choice Experiment through some case studies. We describe the benefits of riparian vegetation in Chapter 7 and how to restore riparian vegetation in chapter 8. The results of the cost benefit analysis are found in chapter 9 and chapter 10 outlines additional benefits of riparian planting. In chapters 11 and 12 we conclude and make some succinct recommendations.

2. WAIWIRI CATCHMENT

2.1 Location and Physical Environment

On the West coast of the North Island approximately 85 km north of Wellington, in the Horowhenua district near Levin, is Waiwiri Stream flowing westward to the sea from Lake Waiwiri (a shallow dune lake commonly known as Lake Papaitonga, after an island in it) (Allen, Sinner, Banks, & Doehring, 2012). In 1901 27.5ha of bush surrounding the lake was established as a reserve, now known as the Papaitonga Scenic Reserve. The lake itself was added to the reserve in 1991, bringing the total to 122ha of protected area.
The Papaitonga Scenic Reserve is reminiscent of the original ecology that once covered the Horowhenua sand country, with a once-common, intact succession of wetland to dry terrace native forest. The lake and stream are hydrologically and ecologically interdependent forming a single Outstanding Natural Feature and Landscape (ONFL) (Boffa Miskell Ltd, 2011).

2.2 Waiwiri Stream in its Prime

In the 1880's the coastal plain of the Horowhenua was grand, a green unbroken seam between sea and mountains, a mosaic of forests, lakes, lagoons and swamps (Geoff Park, 1995). Drier flats and sand dunes cloaked by matai, totara and rimu; swamp and lake margins adorned by kahikatea and pukatea; banks clothed with beautiful evergreens to the water's edge (Geoff Park, 1995). Noisy in bird song with pigeons in thousands (Geoff Park, 1995), and busy with the industrious activity of tuna and inanga migrating to the sea (Adkin, 1948). Once a dynamic environment of shifting dunes and river mouths, now a static one dominated by fixed channels, drainage and dune stabilisation (James & Joy, 2009).

2.3 Importance to Iwi and Hapu

Lake Waiwiri is described by local tohunga (experts), as a place of great mana and ancient mauri (Geoff Park, 1995). The lake is a place of ancestral landscape, sacred sites and ancient occupation, with well-known stories of Māori history. For iwi, the lake and stream are inextricably linked as components of one system (Geoff Park, 1995), a system of high value. Biodiversity that once inhabited the area was treasured and crucial to quality of life (Geoff Park, 1995), with the catchment once revered as an abundant food resource (Allen et al., 2012).

2.4 Waiwiri Catchment

A catchment is the land area that is drained by all tributary streams (Dodds & Whiles, 2010); a tributary a smaller branching stream channel that flows into a main stream channel[1] such as the Waiwiri Stream. While the main stream channel is greater in length than individual tributaries, the total length of tributaries is often greater, hence the relevance of processes that occur in tributaries which ultimately feed the main channel (Dodds & Whiles, 2010).

The Waiwiri catchment covers a land area of 1,500 ha. The Waiwiri Stream has a length of approximately 6km, the combined length of drains and tributaries' entering the stream is 20km. This catchment is dominated by dairy and beef farming with high-producing exotic grassland (74% or 1,110ha), the remaining 26% covered by a combination of pine forest, native vegetation, dune lakes and coastal sand (Allen et al., 2012).

Approximately 300 m from the stream is the 'Pot'. This is a 7.7ha unlined effluent treatment pond, built in 1986 with consent to receive both treated effluent and digested sludge from the Levin Wastewater Treatment Plant (Allen et al., 2012). Effluent soaks into shallow groundwater or is spray irrigated onto about 50ha of surrounding pine forest; furthermore, there are at least three drains flowing from the effluent disposal site into Waiwiri Stream (Allen et al., 2012).

2.5 Current Issues at Waiwiri Stream

A preliminary effort to enhance the population of some key fish species was made by the report prepared for Horizons by James and Joy (2009), *Prioritisation for restoration of out-flow stream habitat of coastal wetlands on the west coast of the Manawatu-Wanganui[2] region.* Local issues identified in this report are high temperatures and low dissolved oxygen, invasive aquatic weeds, and little habitat diversity.

More recently, and intended to assess the influence of pastoral land use and human effluent input, is the report prepared for Manaaki Taha Moana by Allen et al. (2012) *Waiwiri Stream: Sources of poor water quality and impacts on the coastal environment.* This report also makes reference to other water quality surveys for both the lake and stream, conducted as early as 1950. Water quality issues identified in the report include high nutrient concentrations, excessive *Escherichia Coli* counts, suspended sediment and elevated temperature.

[1] http://www.physicalgeography.net/physgeoglos/t.html

[2] The Manuwatu-Wanganui region includes the Horowhenua district, where the Wairiri catchment is located.

The consensus between these two reports is that **Waiwiri Stream is in poor condition.** To assist the stream in reaching its ecological potential, both reports recommend riparian restoration i.e. fencing and planting of the riparian zone.

2.6 Ki te taha a te wai: The riparian

The riparian is an interface between the land and freshwater ecosystems (Gregory, Swanson, McKee, & Cummins, 1991). Alternately referred to as a riparian strip/ margin/ buffer/ zone, it is the land along the edges of natural watercourses streams, rivers, lakes and wetlands. Adjacent to the watercourse is the floodplain, and further up gradient the hill slope (S. Parkyn & Davies-Colley, 2003). Appropriate vegetation delays flood waters at the floodplain and inhibits surface flows at the hill slope (K.J. Collier et al., 1995). Riparian zones 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 et al., 1991).

3. POLICY REFORM

3.1 Freshwater reform 2013 and beyond

Freshwater management is a policy priority, central to the environment, identity and the economy (Ministry for the Environment, 2013). In 2013 the Ministry for the Environment (MfE) released the Freshwater reform 2013 and beyond (the freshwater reform) (2013). The reform acknowledges a decline in water quality in some areas and emphasises the significance of freshwater to the way of life and economy in New Zealand (NZ).

3.2 Resource Management Reform

Also in 2013, the Resource Management Reform Bill 2012 (the Bill), entered its second phase to further improve the Resource Management Act 1991 (RMA), and resource management generally[3]. One proposed improvement is requiring councils to use robust and thorough cost-benefit analysis in planning decisions[4]. Keywords of the proposed improvement are ‘objectives’ and ‘must’; a must for identifying alternative ways to achieve proposal objectives, and a must for justifying the potential of proposals to achieve the objectives. Furthermore is the requirement for identifying, assessing and quantifying anticipated benefits and costs which are environmental, economic, social and cultural, and opportunity costs.

3.3 Freshwater Objectives

Among the Government’s proposals presented in the freshwater reform is the implementation of a regulated National Objectives Framework (Ministry for the Environment, 2013). The purpose of the National Objectives Framework is to support the establishment of freshwater objectives and limits in regional plans, as required by the National Policy Statement for Freshwater Management 2011 (Ministry for the Environment, 2011). Freshwater objectives of regional plans must be a reflection of Iwi/Māori and community preferences for the environmental outcomes of a water body. The objectives are to be expressed in environmental terms which also provide for economic outcomes (Cabinet Economic Growth and Infrastructure Committee, 2012); taking into account local and national values and aspirations, and existing condition (Ministry for the Environment, 2013).

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[3] http://www.mfe.govt.nz/rma/rma-reforms-and-amendments/rma-reforms-programme-2013-and-beyond/resource-management-amendment

[4] http://www.mfe.govt.nz/more/cabinet-papers-and-related-material-search/regulatory-impact-statements/ris-package-improve-3

In addition to freshwater objectives for regional plans, the National Objectives Framework has two imperative objectives which will apply nationally to all water bodies. The imperative objectives are:

3. Ecosystem health and general protection for indigenous species; and
4. Human health secondary contact.

These two objectives are defined by attributes to be managed which will have four bands - A, B, C and D indicative of different environmental states one of which will be a minimum acceptable state. However, both attributes and bands have not yet been defined. The following table provides for the two imperative objectives as well as attributes to be managed. A brief account of each of these attributes relating to the Waiwiri Catchment will be provided by this report.

Table 1 Imperative freshwater objectives and attributes to be managed

Objective/ Value	**Attributes to be managed to improve water quality**
Ecosystem health and general protection for indigenous species	• Temperature • Periphyton • Sediment • Flows • Connectivity • Nitrate • Ammonia • Fish • Stream Invertebrate • Riparian margin
Human health for secondary contact	• *E. coli* • Cyanobacteria

3.4 Proposal and Alternative

The proposal of this scoping study is riparian vegetation restoration in pursuit of the preceding imperative freshwater objectives and attributes. The alternative considered here is the conversion of all land in the catchment back to native vegetation, once its former glory. It is assumed that the price of this alternative is one the community is not prepared to pay, however an alternative considered all the same.

4. FRESHWATER ATTRIBUTES TO BE MANAGED

4.1 Temperature

The water temperature of riverine systems is affected by the removal of overhanging vegetation (Dodds & Whiles, 2010. The shade provided by riparian vegetation reduces thermal loading on the stream, especially in summer. Stream and river temperatures exert an important influence on stream ecosystems (K.J. Collier et al., 1995) and aquatic life (Beschta, Bilby, Brown, Holtby, & Hofstra, 1987). Temperature tolerances vary among freshwater organisms, but all have an optimal range for survival (Dodds & Whiles, 2010). Aquatic organisms evolved in thermally buffered environments (Dodds & Whiles, 2010), and changes in temperature can influence rates of egg development, rearing success and species competition (Beschta et al., 1987).

The effects of water temperature on fish are well established; it affects distribution, abundance, and behaviour (Richardson, Boubée, & West, 1994), function and activity (K.J. Collier et al., 1995), and growth, reproduction and survival (Dodds & Whiles, 2010). Fish actively pursue water with near optimal temperature (Dodds & Whiles, 2010), abandoning areas of change. At low temperatures metabolism is depressed and more energy is required for activity (Dodds & Whiles, 2010); increases in temperature increases fish metabolism which must be satisfied before growth (K.J. Collier et al., 1995), consequently hindering fish growth. For reproduction (hence survival), temperature requirements may be more stringent (Dodds & Whiles, 2010); life phases affected by temperature are gonad development and spawning (Richardson et al., 1994), consequently affecting egg mortality and morphological characteristics during embryonic development (K.J. Collier et al., 1995).

Temperature is also a primary factor influencing the metabolism, growth and survival of stream invertebrates (J. M. Quinn, Steele, Hickey, & Vickers, 1994). At higher temperatures invertebrates feed more actively elevating growth (K.J. Collier et al., 1995), but the high metabolism consumes energy required for egg production (Dodds & Whiles, 2010). Many New Zealand stream invertebrate species have demonstrated a wide range of thermal tolerances consistent with observed invertebrate distributions in New Zealand thermal and warm spring waters (J. M. Quinn et al., 1994). Some New Zealand stream invertebrates however, are sensitive to water temperatures greater than 20˚C, which is commonly exceeded in open pasture streams (S. Parkyn, 2004).

Temperature can also have an indirect effect on aquatic organisms. Temperature affects the amount of dissolved oxygen (K.J. Collier et al., 1995), required for aquatic life to survive (Ministry for the Environment, 2008). As temperature increases, dissolved oxygen decreases while the oxygen needs of fish increase (Dodds & Whiles, 2010).

The temperature regime of a stream is influenced by tributaries joining or entering it, the stream temperature is the sum of the tributary temperatures weighted by their respective volume of discharge (Beschta et al., 1987). Deviation from the natural temperature in a habitat is known as thermal pollution (Dodds & Whiles, 2010). Human activities contribute to thermal pollution: discharges, industrial cooling, reduced stream flow, water withdrawals, hydroelectricity, and especially the removal of shade-providing riparian vegetation (Dodds & Whiles, 2010).

4.2 Periphyton

Commonly referred to as slime, periphyton are solar-powered freshwater algae and prokaryotes (e.g. cyanobacteria) found on the streambed (Larned, 2010). Periphyton are essential for the function of healthy ecosystems (J. Quinn & Raaphorst, 2009). Healthy streams are characterised by little obvious periphyton, as it is consumed by stream invertebrate (J. Quinn & Meleason, 2002).

Periphyton species vary in their resource requirements (Larned, 2010). Periphyton biomass accrual (proliferation or nuisance growth) is a result of excess resources, i.e. increased nutrients, light and temperature providing the energy for cell growth (Barry J F Biggs, 2000). The accumulation of excess resources in a water body is called eutrophication, which results in nuisance growth (McDowell, Larned, & Houlbrooke, 2009). The proliferation of a single species is known as a bloom.

Agriculture, and land conversion for agriculture, contribute greatly to eutrophication of streams, rivers, and lakes. Agricultural activities increase nutrient levels in lowland watercourses (K.J. Collier et al., 1995), and the removal of riparian vegetation exposes periphyton to increased light and heat (Mosich, Bunn, & Davies, 2001).

Nuisance growth and blooms are often observed during summer (Barry J. F. Biggs & Price, 1987) as thick slimy mats of long growths covering the streambed (J. Quinn & Meleason, 2002). Nuisance growths of periphyton are problematic for in-stream values, demonstrated by the following table.

Table 2: In-stream values affected by nuisance growths of periphyton

Instream Value	Problem
1. Aesthetics	Spoilt scenery and odour
2. Biodiversity	Habitat alteration, reduced invertebrate and benthic diversity
3. Contact recreation	Unsuitable for swimming and wading, odour
4. Industrial use	Distaste and odour, clogging of abstraction structures
5. Irrigation	Clogging of 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 and 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 of nets

4.3 Sediment

Sediment is a product of erosion (Roehl, 1962). Erosion occurs when soil particles from the ground's surface become detached, the detached particles then become sediment once it enters water (New Zealand Transport Agency, 2010). While erosion is a natural process, intense land use causes accelerated erosion generating higher levels of sediment (Ministry for the Environment, 2001). Addressed here are sheet and channel erosion, the effects of land use, and the effects of sediment on freshwater ecosystems.

Sheet erosion is the diffuse loss of soil (Ministry for the Environment, 2001). Processes contributing to sheet erosion are splash detachment, splash transport, run off detachment and run off transport (Walling, 1976). Sheet erosion occurs when the intensity of rainfall exceeds the ability of the soil to absorb the rain (New Zealand Transport Agency, 2010), and the force of rainfall impacting on bare soil dislodges soil particles[5] (i.e. sediment). These

[5] http://www.fao.org/docrep/t1765e/t1765e0d.htm

sediments are subsequently carried downslope by run off which continues to detach and transport additional soil particles.

Channel erosion also occurs in response to heavy rain (Ministry for the Environment, 2001). Heavy rain results in high volume channel flows with increased erosive power, consequently scouring the stream bank (New Zealand Transport Agency, 2010; Walling, 1976). Scouring of the bank dislodges soil which enters the water as sediment.

There is variation in the amount of suspended sediment in streams and rivers (K.J. Collier et al., 1995). Deforestation, conversion to agriculture and the direct effects of livestock have caused bank destabilisation(S. Parkyn, 2004), accelerated erosion, and increased sediment in waterways. Removing forest vegetation has rendered stream banks more vulnerable during flood flows, during which both forms of erosion, sediment transport, and deposition is greatest (K.J. Collier et al., 1995).

Almost all forms of agriculture result in increased erosion and the flow of sediment (Ministry for the Environment, 2001), and suspended sediment is higher in waterways draining pasture than native forests(K.J. Collier et al., 1995). Pasture land is characterised by soil compaction, or pugging, caused by stock damage as well as decreased groundcover(Ministry for the Environment, 2001). Soil compaction reduces the capacity of the soil to absorb rainfall increasing volume of runoff, exacerbated by inadequate groundcover to intercept and slow down the movement of sheet erosion.

Increased sediment degrades the freshwater ecosystem affecting stream habitat and water quality (S. Parkyn, 2004). Sediment can smother the beds of stony bottomed streams (River Ecosystems Group of Greater Wellington, 2003) filling spaces between stones reducing substrate quality, invertebrate habitat and consequently invertebrate community composition (I. G. Jowett, J. Richardson, & J. A. T. Boubee, 2009; S. Parkyn, 2004). Suspended sediment reduces optical clarity of water and visibility for animals (K.J. Collier et al., 1995; McKergrow, Tanner, Monaghan, & Anderson, 2007; Ministry for the Environment, 2001). Suspended sediment also reduces light penetration for plant growth (S. Parkyn, 2004).

4.4 Flow

Flow is a function of water volume and velocity (Dohner et al., 1997). There are several definitions for flow in pursuit of ecological integrity; Poff et al's (1997) natural flow regime, the Brisbane Declaration's (2007) environmental flow, and Beca Infrastructure Ltd's (2008) ecological flow. Flow has been described as a master variable orchestrating pattern and process in rivers and stream, with a critical role in sustaining native biodiversity (N. Leroy

Poff et al., 2010), providing ecological integrity for in-stream flora and fauna (Beca Infrastructure Limited, 2008; Ian G. Jowett & Duncan, 1990). The effect of flow on ecological integrity is addressed here per Poff et al's (1997) primary regulators; water quality, energy sources, and physical habitat.

To report on water quality, the Ministry for the Environment (MfE) measure bacteria, nutrients, visual clarity, water temperature, dissolved oxygen, and stream invertebrate. Low flow increases the concentration of bacteria and nutrients in-stream; nutrients which contribute to increased periphyton biomass reducing visual clarity. Decreased water volume also increases the water temperature, consequently decreasing dissolved oxygen.

Energy sources and energy flow are altered as a consequence of increased variation of the flow regime (N LeRoy Poff et al., 1997) such as flood and low flow. The food web is the system by which energy flows from energy sources to consumers (Snelder et al., 1998). During flood events, energy sources are reduced as periphyton and other organic matter are scoured and washed out. During low flow, periphyton has the potential to proliferate, changing a community structure dominated by grazing invertebrate (N LeRoy Poff et al., 1997).

Aquatic species have well defined preferences for habitat (Snelder et al., 1998). The flow regime affects physical habitat (Bunn & Arthington, 2002), characterised by water velocity, depth and substrate (I. Jowett & Richardson, 2008). Pools and riffles are ideal riverine habitat types (Aadland, 1993); pools are deep areas with low velocity and a fine sandy substrate, riffles are turbulent shallow areas with a substrate of gravel and small rocks (Dodds & Whiles, 2010). Flooding changes depth, increasing pool habitats with a loss of riffle habitats (N LeRoy Poff et al., 1997; Snelder et al., 1998). Decrease in velocity and volume characteristic of low flow results in a reduction and fragmentation of habitat space (Lake, 2000).

4.5 Connectivity

Long recognised as fundamental to species distribution, connectivity in general landscape ecology is the extent to which a landscape facilitates or inhibits movement of organisms among resource patches (Pringle, 2003). Consistent with this definition is the recent popularity of ecological corridors, a physical or biological strip connecting habitats and assisting the movement of organisms (Van Der Windt & Swart, 2008). Corridors are used by different species at different rates and to differing extents, and have the potential to enable many organisms to persist as climate changes (Krosby, Tewksbury, Haddad, & Hoekstra, 2010). As habitats decrease in area, connectivity between habitats becomes more important for the survival of species.

In freshwater corridors, water connects various landscapes (Amoros & Bornette, 2002), which interact through processes essential to some species and ecosystem functions (Beger et al., 2010). Hydrological connectivity is essential to the ecological integrity of the landscape (Pringle, 2003). Often cited are Ward's (1989) four-dimensions of hydrological connectivity (Amoros & Bornette, 2002; Jansson, Nilsson, & Malmqvist, 2007; Pringle, 2003): longitudinal, lateral, vertical and temporal.

The longitudinal dimension integrates upstream-downstream linkages (Ward, 1989). Considered here are fish migration, the colonisation cycle and Vannote et al's (1980) river continuum concept. Connectivity is vital for many of New Zealand's native fish which spend parts of their lifecycle in freshwater and at sea (Richardson, 1997), however in-stream barriers hinder the ability of migratory fish to colonise suitable habitats (James & Joy, 2009). Müller (1982) proposes the colonisation cycle of stream insects, demonstrating upstream-directed flight behaviour which can occur between different biotypes in pursuit of optimal conditions for eggs and nymph stages. The river continuum concept theorises that stream invertebrate communities minimise energy loss, with downstream communities consuming processed resources from upstream communities (Vannote, Minshall, Cummins, Sedell, & Cushing, 1980).

The lateral dimension occurs between the channel and the riparian zone and includes the movement of organisms and exchange of organic matter (Ward, 1989). Most aquatic insects spend only larval and nymph stages in water, leaving as winged adults to the riparian in preparation for reproduction (B. Smith & Collier, 2002). The riparian provides energy inputs such as leaf litter consumed by aquatic insects (Lecerf, Dobson, Dang, & Chauvet, 2005), and terrestrial insects to the channel consumed by fish (Hicks, 1997). Riparian vegetation also provides habitat diversity for both terrestrial and aquatic species (K.J. Collier et al., 1995).

The vertical dimension incorporates interactions through the hyporheic zone; the area where ground waters and aboveground waters meet (Ward, 1989), (Boulton, Findlay, Marmonier, Stanley, & Valett, 1998), i.e. the bed and banks of a water body. Important functions of organisms which inhabit this area are bioturbation, stream metabolism 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). Stream metabolism is indicative of the activity of the stream community (Riley & Dodds, 2013), the hyporheic zone has been observed to contribute at least 40% of total ecosystem activity (Fellows, Valett and Dahm, 2001). Aquatic hyphomycetes (fungi) disperse within the hyporheic zone (BÄRlocher, Seena, Wilson, & Dudley Williams, 2008), the significance is that hyphomycetes breakdown and enhance the quality of leaf litter entering the waterway which is subsequently consumed by stream invertebrates (Lecerf et al., 2005).

The appropriate temporal and spatial scale depends on the organism(s) of interest as well as the activities investigated (Ward, 1989). Amoros and Bornette (2002) differentiate between two temporal scales in connectivity dynamics, short term and long term.

4.6 Nitrate and Ammonia

Nitrate and ammonia are interdependent through the nitrogen cycle. Both are reactive nitrogen compounds received by freshwater ecosystems from associated catchments (GALLOWAY et al., 2003). Nitrate and ammonia are naturally received by water bodies as biological degradation products of organic matter (A. Alonso & Camargo, 2003). Prior to the agricultural and industrial revolutions, biological nitrogen fixation was the only process creating reactive nitrogen from nitrogen gas to support the transformation of carbon for plant growth (Marino & Howarth, 2010). Widespread fertiliser use now enhances this transformation. Compared to natural levels, concentrations of ammonia and nitrate to aquatic ecosystems have significantly increased because of animal waste, fertiliser, agricultural runoff, and sewage effluents (A. Alonso & Camargo, 2003; Arango et al., 2007; R. J. Wilcock et al., 1999), with implications for ecosystem health. The sources, processes and implications of nitrate and ammonia to freshwater ecosystems are differentiated.

Changes in concentrations of nitrate are associated with human disturbances and population densities in catchments (Vitousek et al., 1997). Disturbances include land conversion and the removal of native vegetation through to, and including, the riparian zone. The main cause of nitrate leaching in dairy farm catchments is considered to be stock effluent (Di & Cameron, 2002); with the concentration of nitrogen in the waste exceeding plant requirements and subject to leaching (de Klein, 2001). Nitrate leaches through soils to stream and groundwater (Vitousek et al., 1997). Nitrate accumulates in the topsoil during dry periods with little movement, as soil moisture increases particularly during winter nitrate is flushed from the soil to associated water bodies (R. J. Wilcock et al., 1999). At high nitrate levels microorganisms can convert nitrate to nitrite, which when absorbed in the bloodstream converts haemoglobin to methemoglobin (Vitousek et al., 1997); methemoglobin is ineffective in carrying oxygen to cells resulting in a depletion of oxygen and death (A. Alonso & Camargo, 2003).

Livestock waste stored, treated, applied to land and discharged to water, are all associated with ammonia losses (Á. Alonso & Camargo, 2009; Bussink & Oenema, 1998; C. W. Hickey & Vickers, 1994; R. J. Wilcock, McBride, Nagels, & Northcott, 1995). While nitrate is transported directly in water, ammonia is commonly absorbed onto clay and other particulate matter then carried by water as suspended sediment (K.J. Collier et al., 1995). Total ammonia is the sum of two compounds, un-ionised (NH_3) and ionised (NH_4^+) (Emerson, Russo, Lund, & Thurston, 1975). For aquatic animals, NH_4^+ is only toxic at high concentrations and low pH (Á. Alonso & Camargo, 2009). Considerably more toxic is NH_3, which increases with increases in pH and temperature (Emerson et al., 1975); further complicated by in-stream plant growth changing the daily pattern of pH, increasing during the day and decreasing at night (Crumpton & Isenhart, 1988). For fish, NH_3 causes an increase in gill ventilation, hyperexcitability, convulsions and finally death (A. Alonso & Camargo, 2003). For stream insects behavioural endpoints are considered of more interest, indicative of physiological and ecological processes preceding mortality (Á. Alonso & Camargo, 2009).

4.7 Fish

In a study for prioritising restoration of out-flow stream habitat on the west coast of New Zealand, James and Joy (2009) identify key fish species: eels (*Anguilla* genus), and inanga and giant kokopu (both of the *Galaxias* genus). These are native to New Zealand and somewhat common, with positive associations for co-occurrence (Minns, 1990).

4.7.1 Eel

Found at almost all habitats with access to the sea (Jellyman, 1989); eels live long and have catadromous lifecycles, spawning and hatching at sea and returning as juveniles to freshwater, developing to adults and returning to the sea to spawn and die (Davey & Jellyman, 2005). Eel species in New Zealand are shortfinned (*Anguilla australis)* and longfinned *(Anguilla dieffenbachia*) (E. Graynoth & Taylor, 2000). These species differ in habitat preference (Glova, Jellyman, & Bonnett, 1998), diet (Hicks, 1997; Jellyman, 1989), and growth (Chisnall & Kalish, 1993). The longfinned eel is endemic (Eric Graynoth, Jellyman, & Bonnett, 2008) found only in New Zealand, and is the species considered here.

Habitat for small longfinned eels (<30cm) is, dependent on water velocity and substrate, greatest in riffles (Glova et al., 1998). Larger eels known to prefer low velocity habitat such as pools (Baillie, Hicks, den Heuvel, Kimberley, & Hogg, 2013), associated with a variety of cover (macrophytes, banks, in stream debris and shade (Glova et al., 1998).

Eels are opportunistic and feed intermittently on a wide range of food items (Jellyman, 1989). In an analysis of gut contents, Hicks (1997) observed that longfinned eel consumed both aquatic and terrestrial insects. Jellyman (1989) observed a change in diet with size: at <30cm the longfinned ate both land and stream invertebrate, and crustacea; at larger sizes diet was dominated by the consumption of fish perch, eels and bullies.

4.7.2 Inanga and Giant Kokopu

Inanga (*Galaxias* maculatus) and giant kokopu (*Galaxias argenteus)* are two of five species in the New Zealand whitebait fishery (I. G. Jowett, 2002). Both inanga and giant kokopu have an amphidromous life cycle (R. M. McDowall & Kelly, 1999); spawning in rivers or estuaries, moving to the sea as hatched larvae and returning as juveniles to freshwater to complete their lifecycle.

For both species, preferred habitat is characterised by pools deep gently flowing water with shelter from overhanging riparian vegetation (Bonnett & Lambert, 2002; I. Jowett & Richardson, 2008; Richardson, 2002). Both these species feed on land and stream organisms (I. G. Jowett, 2002; R. McDowall, 1980). Inanga are typical of the genus feeding on insect drift, remaining stationary in the current while taking food from the drift and surface, and at locations where the current concentrates food (I. G. Jowett, 2002). Giant kokopu are described as generalist feeders, observed to feed on predominantly land and stream insects but also fish (Bonnett & Lambert, 2002).

4.8 Stream Invertebrates

Invertebrates play important roles in processes of the freshwater ecosystem; processing in-stream and terrestrial organic carbon which influences periphyton growth, nutrients, and food available for higher order consumers fish and birds (J. Quinn & Hickey, 1990). Abundance and distribution of macro invertebrates are influenced by a number of biophysical and physical parameters (Death & Joy, 2004).

Organic pollution enters water bodies from sources non-point (e.g. run off) and point (e.g. drains), and is a significant contributor to changes in invertebrate diversity and consequently stream communities (Thompson & Parkinson, 2011). Different species have different tolerance to pollution, but where there are healthy stream invertebrate communities it is almost certain that other ecosystem components are in good health too (Stark & Maxted, 2007). Organic waste is used or converted by micro-organisms, mainly bacteria, fungi and protozoa, which consequently compete with invertebrates for oxygen (Fergusson, Dakers, & Gunn, 2003).

Invertebrate communities are used as biotic indices of water quality and ecosystem health (J. Quinn & Hickey, 1990), two common biotic indices measuring communities are MCI and %EPT. The Macro Invertebrate Community Index (MCI) considers all species present in a sample collected; %EPT measures the abundance and diversity of pollution sensitive stream invertebrate Ephemeroptera (mayfly), Plecoptera (stonefly) and Trichoptera (caddisfly), hence the acronym.

Wadeable, hard bottomed or stony streams support communities dominated by EPT (Stark & Maxted, 2007). The EPT community has demonstrated significant correlation with native vegetation in the riparian zone (Kevin J. Collier, 1995). Considered here are a mayfly *Acanthophlebia cruentata*, a stonefly *Auestroperla cyrene*, and a caddisfly *Aoteapsyche raruraru.*

4.8.1 Acanthophlebia cruentata, a mayfly

Mayflies have demonstrated sensitivity to high water temperatures, low dissolved oxygen and increased sediment (Kevin J. Collier, Wright-Stow, & Smith, 2004). *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 organic matter (FPOM) (Kevin J. Collier et al., 2004).

4.8.2 Auestroperla cyrene, a stonefly

Auestroperla cyrene colonises 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 and not eaten by predatory insects or fish (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 (McLellan, 1995).

4.8.3 Aoteapsyche raruraru, a caddisfly

Caddisflies are most common at lake outlets, declining in abundance with increasing distance from the lake (Harding, 1997). Decreasing abundance associated with food quality, temperature change, flow variability, substrate instability, competition and predation (Harding, 1997). *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 animal matter and FPOM (Harding, 1997)

4.9 E. coli: Pathways of faecal contamination

Waterborne pathogens (and associated faecal indicator organisms) derived from faeces are a significant water quality concern (Dufour, Bartram, Bos, & Gannon, 2012). Compared to other developed countries, there are concerns for the risk from pathogens of faecal origin in New Zealand's freshwaters with **implications** for public health, drinking water treatment costs, recreational water use and aquaculture, as well as cattle productivity (Allen et al., 2012; Rob Collins et al., 2007; Donnison, Ross, & Thorrold, 2004). *Escherichia coli* is the most commonly used indicator of faecal coliforms, strains such as *E. coli* O157:H7 pose a serious health risk to humans (Jamieson, Gordon, Joy, & Lee, 2004).

Manaaki Taha Moana Report No. 9 for Waiwiri Stream (Allen et al., 2012) indicates that the dominant source of faecal contamination to the stream is cow faeces. This faecal contamination enters the waterways via two general pathways, direct and indirect deposition (Rob Collins et al., 2007).

4.9.1 Direct deposition

Direct deposition includes faecal matter deposited directly into waterways by grazing or crossing cattle. The waterway includes the channel and the riparian zone, as the incidence of faecal microbes is imminent due to wash-in by surface runoff and entrainment by rising water (Rob Collins et al., 2007). Direct deposition eliminates opportunity for die-off of microbes in the faecal matter increasing the opportunity for them to enter the water (Rob Collins et al., 2007).

4.9.2 Indirect pathways

Indirect pathways of faecal microbes occur via subsurface drainage or seepage, and surface runoff (Rob Collins et al., 2007). Microbial contamination of watercourses depends on the transport of organisms either independent or attached to particles of soil or faeces via hydrological pathways (Dufour et al., 2012).

Microbial transport in ground waters can be significant (Jamieson et al., 2004), with high levels of faecal contamination by vertical movement of pollutants down through the soil horizons (National Institute of Water and Atmospheric Research, 2006). The microbes will generally wash into the ground with rainfall and are immobilised or modified by various processes (K.J. Collier et al., 1995), dependent on the degree of fine pores of the soil matrix and contact with reactive internal surfaces (Rob Collins et al., 2007); soils of fine pores minimise the generation of surface runoff (National Institute of Water and Atmospheric Research, 2006). Water that bypasses fine pores and instead flows through macro pores such as cracks and worm holes reduces the opportunity for microbial attenuation (Rob Collins et al., 2007).

There is a general consensus that overland flow is the primary microbial transport process associated with non-point source pollution of surface waters (Jamieson, 2004: 7). Surface runoff generated upon dairy pasture is contaminated by faecal microbes with concentrations of both *E. coli* and *Campylobacter* (National Institute of Water and Atmospheric Research, 2006). Bacteria lack the propensity to settle or deposit and are highly mobile in overland flow, hence high concentrations of bacteria in overland flow from agricultural land (Muirhead, Collins, & Bremer, 2006).

4.10 Cyanobacteria

Cyanobacteria is a member of the periphyton community (Barry J F Biggs, 2000); commonly known as blue-green algae. Cyanobacteria are some of the pioneer organisms of early earth (Mur, Skulerg, & Utkilen, 1999), among the most primitive forms of life (Bay of Plenty District Health Board, 2009). Considered here are the properties of cyanobacteria, disturbance, resource requirements, and public concern.
Cyanobacteria are an essential component of the earth's biota (Whitman, Coleman, & Wiebe, 1998; Whitton & Potts, 2012). They are the most widely distributed group of photosynthetic prokaryotes (Stanier & Cohen-Bazire, 1977) exhibiting a combination of properties found in both algae and bacteria (Bartram et al., 1999). Like algae, cyanobacteria are capable of autotrophy by photosynthesis (Barry J F Biggs, 2000), harvesting light for growth. Cyanobacteria share the only unifying character of bacteria, a prokaryotic cell structure (Stanier & Cohen-Bazire, 1977), with cells that have no nucleus (Mur et al., 1999).

A disturbance is defined as a loss from the community (Barry J F Biggs, 2000); disturbances affecting cyanobacteria biomass are current velocity, wave action and periodic drying (Scott & Marcarelli, 2012). Velocity and wave action during high flows can move the substrate, sands and gravels; consequently cyanobacteria (periphyton generally) is abraded, scoured or dislodged (Barry J F Biggs, 2000; Scott & Marcarelli, 2012). Nuisance growth is most prominent during low flows (Barry J F Biggs, 2000), and proliferates as the period of low flow increases (Scott & Marcarelli, 2012).

As periphyton cyanobacteria use both light and nutrients for growth, cyanobacteria are found in most illuminated environments (Whitton & Potts, 2012), and are able to use long-wavelength light (Scott & Marcarelli, 2012). Some species however, are known to survive long periods of darkness existing where no other microalgae can (Mur et al., 1999). Its use of nutrients helps to explain its dominance in low light conditions, growing below algae mats (Scott & Marcarelli, 2012) and waters with high turbidity (Mur et al., 1999). Cyanobacteria are able to out-compete other organisms for the nutrients phosphorous and nitrogen (B. Biggs, 1990; Mur et al., 1999); with the ability to store enough phosphorous for a 4-32 fold increase in biomass (Mur et al., 1999). Where waters are rich in nutrients nuisance growths can occur (Bartram et al., 1999).

Public concern for cyanobacteria is based on the ability of some species to produce cyanotoxins (Bartram et al., 1999), with wide ranging implications. Human health effects include but not limited to, diarrhoea, vomiting, headaches, fever, muscle aches, fatigue, sore throats, conjunctivitis, blistering around the mouth, itchy skin rashes, and the worsening of conditions hay fever, eczema and dermatitis (Bay of Plenty District Health Board, 2009).
Stock and domestic animal health are also at risk from toxic blooms of cyanobacteria (Barry J

F Biggs, 2000), the death of dogs associated with consumption of the cyanobacteria or water where a bloom is observed (Hamill, 2001). Where cyanobacteria mats have been observed there has also been a decrease in pollution sensitive invertebrate (EPT, previously discussed) (Barry J F Biggs, 2000).

5. METHOD OF ANALYSIS

5.1 Cost benefit analysis (CBA)

CBA originates from investment appraisal now increasingly used in policy appraisal (D. Pearce, 1998), analysing the effects of changes to an existing regime. With an intention for public sector policy and resource allocation, the New Zealand Treasury (2005) describes CBA as an economic assessment tool, quantifying costs and benefits in monetary terms, and applying discounting.

Once alternatives have been identified as suggested by the bill, the first step of the CBA is identifying the marginal or incremental costs and benefits of alternatives (Campbell & Brown, 2003), for each year of the period of analysis (in this scoping study 10 years). Once this data is collected, net gain or loss for each year for each alternative is calculated, i.e. subtracting costs from benefits.

The second step of CBA discounting estimates in today's dollars the value of those net gains or losses expected in the future by taking into consideration the time value of money at a cost determined by prevailing interest rates. Discounting considers the weighting of the present over the future, as the later the cost or benefit the less it matters today (D. W. Pearce, Barbier, & Markandya, 1990), and the less it is worth today too.

Finally, for each alternative, the discounted values for each year are totalled to provide a total value in today's dollars (otherwise known as net present value, NPV). A positive value indicating that benefits exceed the costs, a negative value indicating costs exceed benefits. Net present values of alternative policies competing for resource allocation can be compared and ranked, providing decision-makers with a consistent basis for assessing proposals (The Treasury Business Analysis Team, 2005).

5.2 Market Failure and Nonmarket Valuation

As a method of investment appraisal, data for the CBA is normally observed in a tradable market, simplifying data collection (Farber, Costanza, & Wilson, 2002). Market failure occurs however (Campbell & Brown, 2003), where there is no market or market prices, particularly for wider social and environmental costs and benefits (The Treasury Business Analysis Team, 2005).

As scarcity of environmental resources increases, so too do demands to measure their values for consideration in decisions (Smith: 1993: 56). It is necessary for the analyst to elicit the values society places on these costs and benefits (Campbell & Brown, 2003), to make a fair comparison of alternatives and avoid making inferior decisions potentially reducing overall benefits to society (Boyer & Polasky, 2004). Hence nonmarket valuation placing monetary values on project inputs and/ or outputs which affect the level of economic (material) welfare but do not have market prices (Campbell & Brown, 2003).

There are two broad categories for nonmarket valuation methods, stated preference (relies on answers to carefully worded survey questions) and revealed preference (analyses choices made by individuals) (Champ et al, 2003: 21). Farber et al. (2002) identify six major economic valuation techniques in the absence of market valuations. Nonmarket methods of valuation considered in this scoping study are choice experimenting a stated preference method; and the revealed preference methods: hedonic pricing, replacement cost, avoided cost and opportunity costs.

5.3 Stated Preference by Choice Experiment

Stated preference methods provide hypothetical scenarios and survey people to identify their preference for trading off costs and benefits (The Treasury Business Analysis Team, 2015). Different approaches of the method include conjoint analysis, the contingent valuation method and choice experiments (Alpizar, Carlsson, & Martinsson, 2003). While debate exists for the validity and reliability of results from survey based method, for some situations there is no alternative for determining values for environmental amenities (Boyer & Polasky, 2004).

Where policy alternatives have multiple impacts and the value of the impacts must be estimated, choice experimenting (CE) is a suitable tool (Marsh & Phillips, 2012). CE has been becoming increasingly established in non-market valuation to estimate the economic value of environmental changes where ecosystem services are not priced by an active market (Baskaran, Cullen, & Colombo, 2010; Bell et al., 2012; Marsh & Phillips, 2012; Scarpa & Rose, 2008; Tait, Baskaran, Cullen, & Bicknell, 2011).

Generally, respondents are presented with alternative choice sets from which they are asked to identify their preference (Scarpa & Rose, 2008). Choice sets provide the outcomes of alternative hypothetical policy scenarios (Tait et al., 2011). Policy scenarios vary in their effects and are described by a number of attributes defined by a qualitative or numerical level (Scarpa & Rose, 2008). When an alternative is chosen it is assumed that respondents are making a trade-off between the different attributes and levels (Tait et al., 2011), and that the chosen alternative has higher utility or satisfaction for the respondent than any of the other alternatives provided (Kerr & Sharp, 2003). By including a monetary attribute in each alternative, the respondent’s household willingness to pay (WTP) or willingness to accept compensation (WTA) can be estimated (Baskaran, Cullen, & Colombo, 2009; Tait et al., 2011).

5.4 Revealed preference methods

Sometimes purchases in related markets can be used to provide information on non-market values. The value of a non-market good is revealed by studying actual behaviour of a closely related market (Alpizar et al., 2003). Revealed preference methods infer people's willingness to pay from observations of prices in such related markets (The Treasury Business Analysis Team, 2015). Revealed preference methods considered here are hedonic pricing, replacement cost, avoided cost and opportunity costs.

Hedonic pricing methods use values of market goods with many characteristics that contribute to its value to estimate the value of each characteristic (Boyer & Polasky, 2004). The values of the characteristics are estimated from market transactions (Champ, Boyle, & Brown, 2003), observing the differences in the market price of goods sharing the characteristics (Morancho, 2003).

Replacement costs are those which would occur if the services provided by the environment could be replaced with man-made systems (Farber et al., 2002), should the natural function no longer function properly or no longer exist (Boyer & Polasky, 2004). This method is only a good indicator if a replacement would be necessary (Heal, 2000) and if replacement is possible.

Avoided costs are those services that allow society to avoid costs that would have been incurred in the absence of those services (Farber et al., 2002). Opportunity cost is the cost of the next best option that would be forfeited if the proposal under consideration is pursued (The Treasury Business Analysis Team, 2005); alternatively the opportunity cost can be obtained by estimating the cost of preventing or limiting environmental damage by not pursuing, or by modifying the proposal (Campbell & Brown, 2003).

5.5 Benefit Transfer

Nonmarket values have two primary sources, primary research and benefit transfer (Rosenberger & Stanley, 2006). Primary research is the ideal, however designing and implementing an original study is both time consuming and expensive (Patterson & Glavovic, 2008). Benefit transfer is the method of using estimates of an original study to construct values for resources that may be different in type or location (Smith, 1993); it can form the basis of policy analysis generating important information in many scientific and management contexts (Patterson & Glavovic, 2008). Benefit transfer has been the subject of criticism questioning accuracy; Loomis and Rosenberger (2006) suggest that errors can be minimised and accuracy increased when sites and affected populations share common experiences and attitudes. If the objective of the study is to gain more knowledge about a particular benefit at a policy site, or provide an initial assessment of the value of policy options, then it may be that a relatively low level of accuracy is acceptable (Baskaran et al., 2010).

6. COMMUNITY OBJECTIVES IDENTIFIED BY CHOICE EXPERIMENT

Values provided by New Zealand choice experiments for freshwater are considered by this scoping study. Demonstrated by the following table, the attributes valued by the choice experiments are significantly consistent with the aforementioned freshwater attributes to be managed in pursuit of the imperative freshwater objectives. Attributes valued by the choice experiments are a salient description of the freshwater attributes to be managed.

	Freshwater attributes to be managed										
Attributes considered by this cost benefit analysis of riparian planting	Temperature	Periphyton	Sediment	Flow	Connectivity	Nitrate and ammonia	Fish	Stream invertebrate	Riparian margin	E.coli	Cyanobacteria
Suitability for swimming and recreation (Marsh, 2012)		●				●			●		●
Suitability for swimming and recreation (Marsh and Phillips, 2012)		●	●						●	●	●
Ecological health (Marsh and Phillips, 2012)	●	●	●	●	●	●	●	●	●		
Tributary water quality (Marsh and Phillips, 2012)	●	●	●	●	●	●	●	●	●	●	●
Freshwater management (Tait, Baskaran, Cullen and Bicknell, 2011)	●	●	●	●	●	●	●	●	●	●	
Natural character (Bell, Sinner, Phillips, Yap, Scarpa, Batstone and Marsh, 2012)									●		
Soil retention (Forgie, van den Belt and Schiele, 2012)			●								
Stock loss/ health (Forgie, van den Belt and Schiele, 2012)									●	●	●

Figure 1 Freshwater attributes to be managed and attributes considered by this cost benefit analysis of riparian planting

6.1 Karapiro Catchment (Marsh, 2012)

The study area of this research is the Karapiro catchment of the South Waikato, from Lake Arapuni to the Karapiro dam including tributaries. The lakes are used by large numbers of recreational users not resident, popular for trout fishing, water skiing and aesthetics, as well as home to world champion rowers[6].

The study acknowledges that catchment level population data is unavailable drawing conclusions from 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 region henceforth the use of data for this area.

The South Waikato District Council (SWDC) covers an area of 179,117 ha, with a population of 22,644 and a total 9,225 dwellings (2006 Census). The catchment is indicative of the region, with land use in dairy and pastoral farming (47%) and forestry (48%) (Marsh, 2012). 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).

6.1.1 Suitability for swimming and recreation

There were a total of six attributes selected for the choice experiment, however only suitability for swimming and recreation is considered in this scoping study. This attribute is defined as the probability of health warnings as a result of algal blooms. The study suggests that algal blooms could result due to increased levels of N and P (Marsh, 2012). This attribute, suitability for swimming and recreation, is indicative of raised levels of periphyton, nitrates and cyanobacteria as previously addressed.

There are two levels of the suitability for swimming and recreation attribute used in this scoping study: a 10% or a 2% chance of algal bloom and consequently health warnings. Willingness to pay (WTP) for this attribute for the next ten years (Marsh, 2012) are provided in the following table (NZ$/ household/ year).

Table 3 WTP for suitability for swimming and recreation (Marsh, 2012)

Chance of algal bloom	1st quartile ($)	Median ($)	Mean ($)	3rd quartile ($)
10%	44	141	190	260
2%	32	102	141	191

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

6.2 Hurunui River and Catchment (Marsh & Phillips, 2012)

The study area of this research is the Hurunui River which stretches 150 km with two main branches; the north sourced by Lake Sumner, and the south from the Southern Alps[7]. 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.

The Hurunui River encompasses a catchment area of 267,100 ha[7]; Hurunui District is most immediate to the catchment hence the use of data for this region throughout this scoping study**.** The Hurunui District covers an area of 864,640 ha[8], with a population of 10,476 and a total 5,658 dwellings (2006 Census). The catchment accommodates a diversity of land uses: the upper catchment unspoilt beech forest and low intensity pastoral farming; the middle catchment largely grazed pasture and native vegetation; the remainder intensively farmed with sheep, beef, dairying and plantation forestry[9].

6.2.1 Suitability for swimming and recreation, Ecological health, Tributary water quality

A set of six attributes were selected for the choice experiment of the Hurunui. Of these six, applicable to this scoping study are: suitability for swimming and recreation, ecological health, and tributary water quality. These attributes are measured on a common scale of levels, 'satisfactory' indicative of minimum standard, 'good' exceeds minimum standard, 'unsatisfactory' does not meet minimum standard and 'poor' a decline from unsatisfactory (Marsh & Phillips, 2012).

The attribute 'suitability for swimming and recreation' is defined as a measure of water clarity and levels of *E. coli* bacteria and algae (Marsh & Phillips, 2012). This attribute is indicative of sediment, *E. coli,* periphyton, nitrates and cyanobacteria previously addressed. At the time of the experiment suitability for swimming and recreation was satisfactory meeting minimum standards with water usually clear, safe and free of algae (Marsh & Phillips, 2012).

Ecological health is defined as a measure of the life-supporting capacity of the river, covering aquatic ecosystems and habitats of indigenous fauna and vegetation (Marsh & Phillips, 2012). This attribute is indicative of the imperative freshwater objective 'ecosystem health and general protection for indigenous species', and relative freshwater attributes to be managed. At the time of the experiment, ecological health was satisfactory meeting minimum standards.

[7] https://www.lawa.org.nz/explore-data/canterbury-region/river-quality/hurunui-river-catchment/
[8] http://www.hurunui.govt.nz/our-district/about-hurunui/
[9] http://landandwater.co.nz/councils-involved/environment-canterbury/hurunui-river/

Tributary water quality measures the health of Hurunui tributaries: water clarity, sedimentation, algal growth, suitability for contact recreation, ecosystem health and habitat values (Marsh & Phillips, 2012). This attribute is indicative of both imperative freshwater objectives 'ecosystem health and general protection for indigenous species' and 'human health for secondary contact'. At the time of the experiment tributary water quality was unsatisfactory, not meeting minimum standards.

The following table is a summary of the attributes of the Hurunui experiment considered by this scoping study. Provided for the attributes are the status quo, a change from status quo, and for the change in attribute willingness to accept compensation (WTA), or willingness to pay (WTP) for the next ten years (Marsh & Phillips, 2012).

Table 4 WTP/WTA for change in attributes (Marsh & Phillips, 2012)

Attribute (status quo)	Change from status quo	WTA (-$)/ WTP ($)
Suitability for swimming and recreation (satisfactory)	-1 (unsatisfactory)	-$315
Ecological health (satisfactory)	-1 (unsatisfactory)	-$254
Tributary water quality (unsatisfactory)	-1 (poor)	-$224
	+1 (satisfactory)	$87
	+2 (good)	$147

6.3 Canterbury Rivers and streams (Tait, Baskaran, Cullen and Bicknell, 2011)

This study attempts to cover all rivers and streams of Canterbury, 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 braided of international and national significance (Goodwin, 2011). *Canterbury Water – The Regional Context* (Goodwin, 2011) emphasises connectedness of economic, environmental, social and cultural activities of Canterbury's water resources.

The Canterbury region covers an area of 45,346 km^2 (Tait et al., 2011), has a population of 521,832 and a total of 222,612 dwellings (2006 Census). 75% of the region is in some form of agriculture (Taylor, 2011), justifying the aim of the study to mitigate agricultural impacts on rivers and streams. The study places an emphasis on agricultural history, conversion to water-intensive dairy farming, and a rapid increase of dairy stock unit numbers (Tait et al., 2011).

6.3.1 Health risk, Ecology, Flow conditions

The choice experiment used three river and stream quality attributes to be valued in the choice experiment: 'health risk', 'ecology' and 'flow conditions'. These attributes were combined to estimate the value of WTP for two improvement scenarios: management 'fair' and 'good'.

Health risk was defined as the risk of becoming ill as a result of recreational contact with water that had received animal waste. This attribute was measured as the number of people per 1,000 that would become sick each year. Two levels were considered by the experiment, 10 and 30 people per 1,000 per year sick from contact recreation. This attribute is indicative of *E. coli* previously addressed.

The ecology attribute levels used in this experiment are 'fair' and 'good' with 'poor' as a base level. This attribute is indicative of the imperative freshwater objective 'ecosystem health and general protection for indigenous species'. Reproduced here are the definitions for the three levels of the ecology attribute.

Table 5 Ecology attribute level definitions (Tait et al., 2011)

Ecology Attribute Level	Definition
Poor	Weeds are the only aquatic plants covering most of stream channel Stream-bed covered mostly by green algae Only pollution-tolerant insects are present No fish species present
Fair	Approximately 50% of stream channel covered by plants Algae covers 20% of stream bed Few types of aquatic plants, insects or fish Population densities reduced
Good	Less than 50% of stream channel covered by plants Algae covers less than 20% of stream-bed Diverse and abundant range of aquatic plants, fish and insects Pollution-sensitive taxa dominate insect communities

Improvement levels for flow conditions are 1 and 3 months of low-flow conditions per year, the base or status quo of flow was 5 months of low-flow conditions per year (Tait et al., 2011).

6.3.2 *Improvement scenarios*

The improvement scenarios considered by the choice experiment for Canterbury Rivers and Streams were 'management fair' and 'management good'. These scenarios are a combination of the attributes 'health risk', 'ecology' and 'flow conditions'. Reproduced below are definitions and WTP estimates; noted is the endorsement by focus groups and interviews that payments be on-going (Tait et al., 2011).

Table 6 WTP for improved management of streams and rivers (Tait et al., 2011)

Scenario	Definition	Average ($)	Lower quartile ($)	Upper quartile ($)
Management fair	• 30 people per 1,000 become sick from recreational contact each year • Ecological quality fair • 3 months low flow per year	154	125	187
Management good	• 10 people per 1,000 become sick from recreational contact each year • Ecological quality good • 1 month low flow per year	213	169	260

6.4 Tasman District Rivers (Bell et al., 2012)

The interests of this study are the three rivers Takaka, Matakitaki and Lew-Wairoa-Waimea extending both the Tasman and Nelson Regions (Bell et al., 2012). These rivers are valued for recreation, biodiversity, food, traditional culture and drinking water as well as productivity for hydroelectricity and irrigation for horticulture and agriculture[10].

The Tasman and Nelson regions cover land areas of 42,240 ha and 973,395 ha respectively[11]. The Tasman region had a population of 44,625 and a total of 20,169 dwellings, and Nelson a population of 42,888 and 18,654 dwellings (2006 Census). In 1996, 53% of these combined land areas were in indigenous forest, 15% in primary pastoral, 11% in plantation, and 16% shrub and tussock (Nagashima, Sands, Whyte, Bilek, & Nakagoshi, 2001).

[10] http://www.tasman.govt.nz/environment/water/rivers/
[11] http://www.nelsoncitycouncil.co.nz/about-nelson/facts-and-figures/#rent

6.4.1 *Natural character*

The rivers were described using four attributes (Bell et al., 2012), however only one is used in this scoping study, 'natural character'. The different levels of this attribute are for vegetation: 'highly modified', 'mixed', 'mostly natural' or 'all native species'. Similar to Waiwiri stream is the Lower Takaka with highly modified vegetation. This attribute is indicative of the riparian margin which is to be addressed. Provided in the following table are estimates of WTP for a change in vegetation from 'highly modified'; to be considered in this scoping study is a change from 'highly modified' to 'all native species'.

Table 7 WTP for change in vegetation. Source: Bell et al., 2012

Change of highly modified vegetation to:	Mean ($)	5% ($)	95% ($)
Mixed	57	28	85
Mostly Natural	100	80	129
All Native Species	189	96	296

6.5 Manawatü River Catchment (Forgie, van den Belt, & Schiele, 2012)

The Manawatü River is the focus of this study, which by cost benefit analysis (CBA) considers five alternative actions to improve water quality, drawing largely on the Waikato River Independent Scoping Study (National Institute of Water and Atmospheric Research, 2010) for data. The Manawatü River is 180 km[12] long covering a catchment area of 500,898 ha with a combined tributary length of 9,648 km. The catchment is divided into nine sub-catchments, from the headwaters in the Ruahine Ranges, winding its way to the Tasman Sea at Foxton Beach. The main land use in the catchment is farming, with grassland used for sheep, beef and deer 62% 365,747 ha, and dairy 13% 77022 ha (Forgie et al., 2012).

6.5.1 *Soil retention, Flood Protection, Stock health and loss*

Forgie et al. (2012) CBA considers both farm and community benefits. Drawing from Forgie et al.'s (2012) CBA, three attributes are considered in this scoping study: 'soil retention', 'stock loss' and 'stock health'. Increased soil retention reduces the incidence of sediment entering the water, thus this attribute is indicative of sediment. 'Stock loss' and 'stock health' occur when stock enter the waterway or consume bad quality water[13], these two attributes are indicative of *E. coli* and cyanobacteria.

[12] https://en.wikipedia.org/wiki/Manawatu_River
[13] http://www.trc.govt.nz/riparian-case-studies/

7. NGA RAWA A TE MAHEUHEU: BENEFITS OF RIPARIAN VEGETATION

The riparian zone is the interface between terrestrial and aquatic ecosystems (Gregory et al., 1991), the land adjacent to a water body such as a stream. Once upon a time, the riparian zone 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 and secondary human contact. The purpose here is to demonstrate how riparian vegetation mitigates freshwater attributes to be managed in pursuit of the imperative freshwater objectives. This is considered by dividing riparian vegetation into three parts: te marumaru (the canopy), nga parapara (detrital inputs), and te papa (the riparian floor).

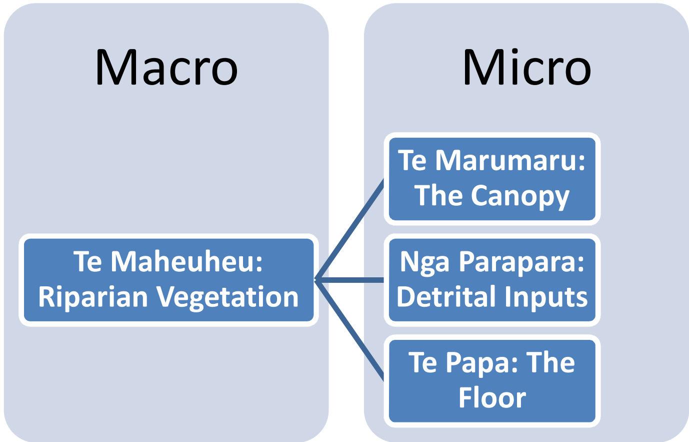

Figure 2 Riparian vegetation as conduits of exchange

The preceding framework identifies riparian vegetation at the macro level, and at the micro level are tangible characteristics of the vegetation functioning as channels of exchange: te marumaru, ngā parapara and te papa (Figure 2). Similar to the preceding framework is the Pusey and Arthington (2003) conceptual model depicting how the riparian zone impacts on riverine fish. Rather than riparian vegetation, the macro level of the Pusey and Arthington (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.

8.1 Te Marumaru: The Canopy

Most of New Zealand was originally forested, with small native streams characterised by dense shade (Stephanie M Parkyn, Davies-Colley, Halliday, Costley, & Croker, 2003); a canopy, under which animal and plant communities had evolved (K.J. Collier et al., 1995). Lowland stream habitats dominated by indigenous vegetation providing heavy shade are now uncommon in New Zealand (Champion & Tanner, 2000), as is the case for Waiwiri stream. When solar radiation levels increase particularly during summer, the effects of shading by a forest canopy are significant, intercepting light and reducing the energy exchange at the stream surface (Beschta et al., 1987). K.J. Collier et al. (1995) define total solar radiation as photosynthetically available radiation (PAR) and near infrared radiation (NIR), the effects of which are addressed here.

7.1.1 Te rama tawhiti: Photosynthetically available radiation

Photosynthetically available radiation (PAR), is light available for primary production (Kelble, Ortner, Hitchcock, & Boyer, 2005), such as Biggs' (2000) periphyton biomass accrual, and light harvesting by cyanobacteria. In a local study mimicking the effects of shading from PAR, where periphyton blooms are common during summer in unshaded channels, periphyton growth decreased with increasing shade (J. M. Quinn, Cooper, Stroud, & Burrell, 1997). As previously mentioned, higher production of periphyton has the potential to cause a change in invertebrate species composition.

It has also been observed that increased exposure to light is significantly correlated with the growth of macrophytes (James & Joy, 2009; S. M. Parkyn et al., 2003; Sand-Jlnsen et al., 1989), larger plants which prefer fine substrates where roots can establish (K.J. Collier et al., 1995). Macrophytes obscure some of the reaches of Waiwiri stream, rendering minimal visible water movement (James & Joy, 2009). Some macrophytes are noxious plants because of their potential to block water bodies, characterised by daily variations in dissolved oxygen, temperature and pH (R. Wilcock, Champion, Nagels, & Croker, 1999).

7.1.2 Te rama tata: Near-infrared radiation

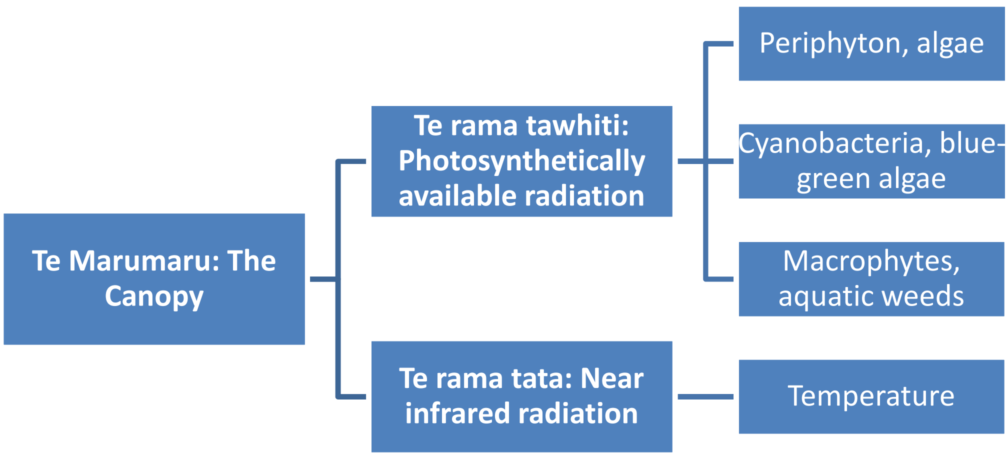

Figure 3 Te marumaru (riparian vegetation canopy) and freshwater attributes to be managed

Near-infrared radiation (NIR) is not used by plants but influences the stream temperature regime (K.J. Collier et al., 1995). Light transmitted to the water is absorbed by water, suspended particles or dissolved materials, and converted to heat (Dodds & Whiles, 2010).

The resulting increase in temperature is inversely proportional to mean depth, as 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, increases ammonia concentrations and the metabolism, reproduction and survival of stream insects and fish. In addition, it has been observed that large changes in diurnal temperature during the summer are significant in reducing afternoon stream flows (Constantz, Thomas, & Zellweger, 1994).

The relationship between the canopy and PAR and NIR is shown in Figure 3 above.

7.2 Nga Parapara: Detrital Inputs

Leaf litter and woody debris make up the detrital inputs to a stream system. The exchange of detrital inputs from riparian vegetation to a receiving water body is a dimension of lateral connectivity. These detrital inputs are considered here, as well as their contribution to healthy ecosystem functioning.

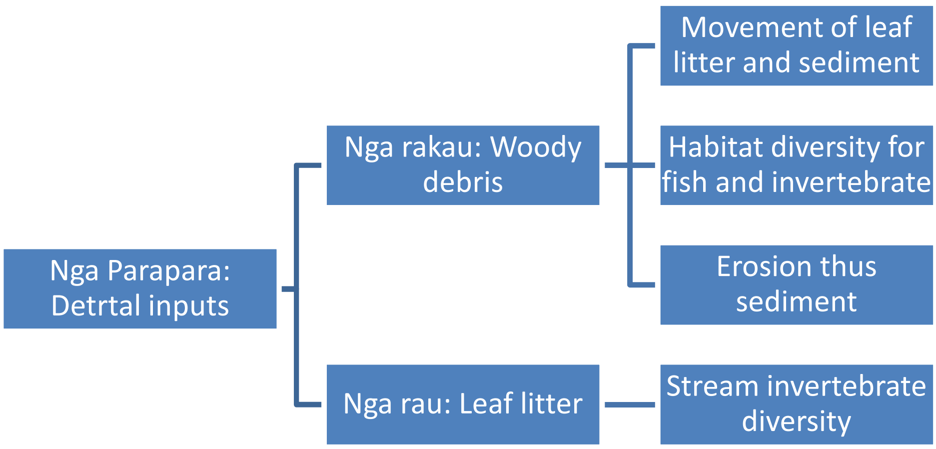

Figure 4 Nga parapara (detrital inputs of riparian vegetation) and freshwater attributes to be managed

7.2.1 Nga Rakau: Wood

The loss of riparian forests has resulted in the reduction of natural wood loadings in streams (Baillie et al., 2013). Woody debris entered streams in different forms: whole trees, logs, chunks of wood, roots and branches (Evans, Townsend, & Crowl, 1993). Wood entering streams have a significant structural and functional role integral to stream ecosystems (M. Meleason, Quinn, & Davies-Colley, 2002; Tank & Winterbourn, 1996). In-stream process affected by wood are material movement, habitat and geomorphic effects (Baillie et al., 2013; Naiman & Decamps, 1997).

When large wood enters a stream and lodges, it forms a dam retaining additional organic matter such as smaller wood and leaves (Bilby & Likens, 1980). Woody debris increases the time available for biological processing of organic matter (Evans et al., 1993), significant for leaf litter processing (Bilby & Likens, 1980). Wood dams can also create backwater pools with low water velocity, accumulating and controlling the movement of sediment (M. Meleason et al., 2002), mitigating the consequences of sediment in stream systems (Baillie et al., 2013).

Woody debris affects the flow, diverting and obstructing stream flow influencing depth, current and substrate, creating a diverse range of wooded pools (Evans et al., 1993). In addition to overhead cover, wooded pools provide habitat diversity and complexity for fish (Baillie et al., 2013). Although providing only a small proportion of habitat, wooded pools are important habitat for fish assemblages dominated by freshwater eels and *Galaxias* species (Baillie et al., 2013). Woody debris also provides habitat stability for both terrestrial and aquatic invertebrate communities (Naiman & Decamps, 1997).

Wood influences the structure and complexity of stream channels and geomorphic processes (Evans et al., 1993). Geomorphic effects of a log have been described as effects on stream bed (erosion or deposition) or stream bank (armouring or inducing erosion) (M. A. Meleason, Davies-Colley, Wright-Stow, Horrox, & Costley, 2005).

7.2.2 Nga rau: Leaves

Detritus is a major carbon source sustaining most ecosystems, the stream is no exception (Anderson & Sedell, 1979; Kenneth W Cummins, 1973; Wallace, Eggert, Meyer, & Webster, 1997). Leaf litter is a primary energy supply for all freshwater food webs (Kenneth W Cummins, 1973; Lecerf et al., 2005; Power, Sun, Parker, Dietrich, & Wootton, 1995), and an important food material for NZ stream insects (Hicks, 1997; Winterbourn, 1982). Stream consumers rely directly or indirectly on leaf litter, with the potential to increase biodiversity through 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 demonstrated by feeding groups of mainly insect larvae, detrital processing, and the river continuum concept. The Vannote et al. (1980) river continuum concept was considered in the address for the longitudinal dimension of connectivity, with downstream communities consuming processed resources from upstream communities.

Feeding groups considered in leaf litter processing are aquatic microbes (fungi and bacteria), shredders, collector-gatherers and filter feeders. When leaf litter enters the stream it is colonised by aquatic microbes such as fungal hyphae who breakdown and condition the litter enhancing the quality for subsequent consumption (Kenneth W. Cummins & Klug, 1979; Gessner, Chauvet, & Dobson, 1999; Lecerf et al., 2005). The resulting product is conditioned leaf litter (CLL) (Anderson & Sedell, 1979). The remaining groups all feed on CLL, and have a nutritional dependence on the associated microbes (Dodds & Whiles, 2010; J. M. Quinn, Smith, Burrell, & Parkyn, 2000; Vannote et al., 1980).

The shredder group are not limited to insect larvae, decapod consumers such as crayfish and shrimps are also known to act as shredders (Anderson & Sedell, 1979; Usio, 2000); the pre-mentioned stonefly *Austroperla cyrene* is a known shredder (Winterbourn, 1982). Shredders consume CLL in the form of coarse particulate organic matter (CPOM >1mm) (Vannote et al., 1980). Shredders have a significant role for stream food webs extended to processing (S. M. Parkyn & Winterbourn, 1997; J. M. Quinn et al., 2000), by engulfing or tearing CLL, reducing particle size (Anderson & Sedell, 1979), resulting in a continuous contribution to other pools of organic matter (Kenneth W. Cummins & Klug, 1979): fine 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, settled out, trapped by vegetation, or entrained into the streambed (Anderson & Sedell, 1979). The pre-mentioned *Acanthophlebia cruentata* is a potential collector gatherer with terrestrial FPOM being a main source of nutrition (Kevin J. Collier et al., 2004).

To capture FPOM-UPOM, filter feeders use morphological structures such as specialised head fans or behavioural activities such as net building, that obtain suspended materials from water drift (Anderson & Sedell, 1979). The pre-mentioned *Aoteapsyche raruraru* is a filter feeder who uses different methods for constructing nets depending on the velocity of the current (Harding, 1997).

Shredders are most abundant at the headwaters where the riparian is most vegetated, collectors moderately present at both the headwaters and middle reaches, and abundance of filter feeders increases from low at headwaters to moderate at middle reaches (Dodds & Whiles, 2010).

7.3 Te Papa: The Riparian Floor

Riparian vegetation acts as a physical barrier to sediments and nutrients being carried into streams (M. B. C. Hickey & Doran, 2004; Schmitt, Dosskey, & Hoagland, 1999). The spatial distribution of plant shoots, plant litter and plant roots on the floor of the riparian zone influences stream water chemistry through diverse processes (Dosskey et al., 2010). These processes will be considered by addressing ngä pihinga (the shoots), paraumu (humus) and ngä paiaka (the roots).

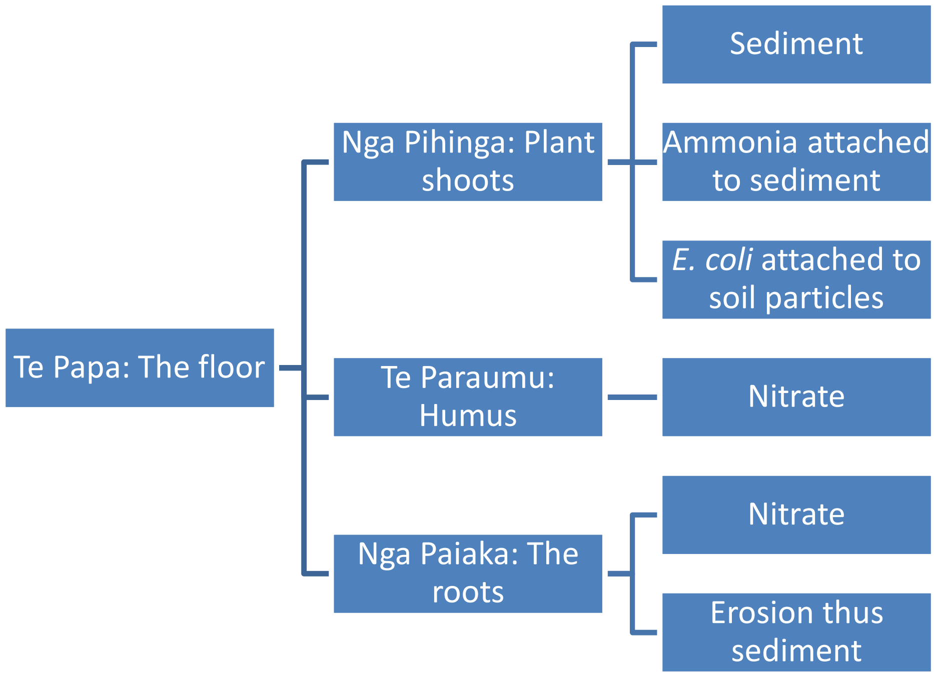

Figure 5 Te papa (the riparian floor) and freshwater attributes to be managed

7.3.1 Ngä Pihinga: Plant Shoots

Riparian planting is a proven method to reduce sediment loads in surface runoff (Daniels & Gilliam, 1996; Pinay, Roques, & Fabre, 1993). Particulate settling removes sediment and sediment-bound contaminants from runoff flow (Schmitt et al., 1999), such as ammonia bound to trapped runoff sediment (Ettema, Lowrance, & Coleman, 1999), and *e. coli* attached to soil particles (National Institute of Water and Atmospheric Research, 2006). Proliferate stems, thatch and grasses slow the flow of runoff, promoting the settling of suspended sediment entrained in the runoff (Schmitt et al., 1999).

7.3.2 Te Paraumu: Humus

Soil in the riparian zone can provide ideal conditions for nitrogen conversions and be important sites of nitrate removal (M. B. C. Hickey & Doran, 2004). 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 (Dosskey et al., 2010). These micro-organisms also perform denitrification, converting nitrate to nitrogen gases (M. B. C. Hickey & Doran, 2004); the release of dinitrogen gas as an end product is a permanent loss of nitrogen from the system, rather than a transferring a pollutant from one media to another (Fennessy & Cronk, 1997).

7.3.3 Nga paiaka: The Roots

Root systems interact with soil water and groundwater, with the potential to remove nitrate through plant uptake for growth (M. B. C. Hickey & Doran, 2004).The rate of uptake from the root zone is greatest when vegetation is undergoing intense growth with leaf, stem and tissues rapidly adding biomass (Dosskey et al., 2010). Riparian vegetation has demonstrated large removals of nitrate from shallow groundwater(Daniels & Gilliam, 1996), plant uptake as a nitrate depletion mechanism is significant in New Zealand compared to other countries (Cooper, 1990).

The roots of riparian vegetation bind the soils and reduce vulnerability to erosion (K.J. Collier et al., 1995), root reinforcement resists flow, reducing erosion (Abernethy & Rutherfurd, 1998) and is best achieved by large wood. Improved bank stabilisation reduces sediment inputs to the stream (I. Jowett, J. Richardson, & J. Boubee, 2009).

8. RIPARIAN VEGETATION RESTORATION

8.1 Width of Riparian Zone

It is generally accepted that an increase in the width of vegetation in the riparian zone increases the benefits to water quality (Daniels & Gilliam, 1996). However, it is assumed that landowners would prefer retiring a smaller strip of land than a larger. Temperature, periphyton and cyanobacteria, sediment, nitrate, ammonia, and *E. coli* are the attributes, discussed below, considered relative to the width of riparian planting; these attributes directly affect fish, invertebrate communities, and human health.

8.1.1 Temperature

Influencing stream temperature are shade and exposure to near infrared radiation. The shading of streams depends on the ratio of canopy height to stream width as the single most important factor (Davies-Colley, Meleason, Hall, & Rutherford, 2009). A New Zealand study of streams observed that small streams which have undergone riparian restoration demonstrated more rapid shade recovery as the canopy closes above the stream, as well as a correlated decline in temperature (Davies-Colley et al., 2009). Matarawa stream (2-3m wide[14]), with a mean buffer width of 3.5m and mean canopy height of 1.7m demonstrated a low temperature range relative to nine other streams in a study conducted to measure the efficiency of riparian restoration (S. Parkyn & Davies-Colley, 2003).

8.1.2 Periphyton and Cyanobacteria

Periphyton and cyanobacteria (as a member of the periphyton community), proliferate as a consequence of exposure to an excess of light, heat and nutrients. Assuming that closure of a canopy reduces exposure to light and heat, the riparian zone width must also be managed for nutrient control. Stimulating periphyton growth is the nutrient phosphorus, which attaches to sediment. In a simulated vegetated riparian zone, Daniels and Gilliam (1996) observed the most significant decrease in phosphorus of 40 to 60% in the first 3m of riparian width, and at 6m width total phosphorus decreased by 70%.

8.1.3 Sediment

Sediment generated by sheet erosion is transported by run off; riparian vegetation promotes the settling of sediment, reducing the amount reaching the stream. Mendez, Dillaha, and Mostaghimi (1999) observed the deposition of sediment primarily in the first meter of the

[14] http://www.southwaikato.govt.nz/our-council/strategies-plans-policies-bylaws/plans/reserve-management-plans/Pages/Matarawa-Park-Reserve-Management-Plan.aspx

vegetated riparian zone, with a small difference in the effectiveness between widths of 4.3 and 8.5m, decreasing sediment by 83 and 87% respectively. In Daniels and Gilliam (1996) simulated vegetated riparian in widths of 5 and 10m, sediment reduced by 70 and 80% respectively.

8.1.4 Nitrate

The removal of a significant portion of nitrate occurs in riparian zones both by denitrification and plant uptake. In a New Zealand study where the riparian width was estimated to be between 3 and 4m (S. Parkyn, 2004), Cooper (1990) observed a 56 – 100% reduction of nitrate in the riparian zone. In a study of four plots differing in vegetation type, reductions in nitrate ranged from 50 to 90%, with grass filters being most effective, demonstrating removal of 90% of nitrate at a simulated width of 3m (Daniels & Gilliam, 1996).

8.1.5 Ammonia NH_3 and NH_4

Simulating riparian restoration with a width of 35m, a decrease of 25% un-ionised ammonia (NH_3) was observed (Clausen, Guillard, Sigmund, & Dors, 2000). S. Parkyn (2004) references the work of Madison, Blevins, Frye, and Barfield (1992), indicating that increasing the width of riparian vegetation has little effect on a reduction in ammonia (NH_4), observing a 90% reduction in a width of 4.6m, and almost 100% in a width of 9.1m. Two grass plots observed by Daniels and Gilliam (1996), demonstrated a reduction in ammonia (NH_4) of between 20 and 50% at a width of 3m, at a width of 6m both plots demonstrated a reduction in ammonia (NH_4) of 50%.

8.1.6 E. coli

The efficiency of the riparian zone to mitigate *e. coli* to freshwater is dependent on slope, soil drainage and bacterial attachment, as well as width of vegetation (National Institute of Water and Atmospheric Research, 2006). On flat country such as the Waiwiri catchment, assuming poorly drained soil and medium bacterial attachment, a width of 5m has an efficiency of 90% (National Institute of Water and Atmospheric Research, 2006). Studies in New Zealand have mimicked surface runoff anticipated during heavy and prolonged rainfall representing a worst case scenario (RP Collins, Ross, & Donnison, 2002). At a simulated riparian zone width of 5m, and under slower rates of water application, entrapment of *E.coli* exceeded 95% (R. Collins, Donnison, Ross, & McLeod, 2004). S. Parkyn and Davies-Colley (2003) observed a reduction in *e. coli* of at least 10% in riparian zones with widths of 3.5, 10.6 and 11.4m.

8.1.7 Width Efficiency

A number of literature sources have been reviewed with regards to width efficiency, as depicted below.

Attribute	Study	Width (m)	Efficiency
Temperature	Davies-Colley et al. (2009)	3.5	Ratio of canopy height to stream width
Periphyton and Cyanobacteria	Daniels and Gilliam (1996), decrease of phosphorous	3	40 to 60%
		6	70%
Sediment	Mendez et al. (1999)	4.3	83%
		8.5	87%
	Daniels and Gilliam (1996)	5	70%
		10	80%
Nitrate	Cooper (1990)	3-4	56-100%
	Daniels and Gilliam (1996)	3	90%
Ammonia	Clausen et al. (2000)	35	25%
	S. Parkyn (2004)	4.6	90%
		9.1	c. 100%
	Daniels and Gilliam (1996)	3	20%
		6	50%
E. coli	National Institute of Water and Atmospheric Research (2006)	5	90%
	R. Collins et al. (2004)	5	90%
	S. Parkyn and Davies-Colley (2003)	3.5, 10.6, 11.4	10%

8.2 Approach to riparian planting

The approach to riparian planting taken here has been based on the following six resources relating to riparian restoration and management:

- Project Twin Streams, Waitakere City
- Sherry River, Motueka Catchment
- Dairy NZ farm facts for riparian management
- Lynwood Nurseries, Ohau
- Taranaki Regional Council, Sustainable land management
- NIWA, Sustainable riparian plantings

8.2.1 Site analysis and preparation

To be considered first is the purpose of planting which will depend first on adjacent land use to determine which attributes must be managed, as well as the objectives of the land owner for private land, or community objectives for public land. This first step will determine the width of the riparian margin required, and selection of appropriate plant varieties for the site. Adjacent land characteristics and use will determine the width of land to be retired and the ideal location for fencing. Riparian width increases where land is steeper and banks are unstable.

8.2.2 Riparian zoning

Land retired for riparian management is commonly divided into three zones;

- Zone A - the pasture zone (generally left in pasture),
- Zone B - tree and shrub zone, and
- Zone C - the wet zone.

Establishing small lengths well rather than longer lengths is recommended, there are two benefits to this. First, taking on a large area may exceed labour and materials available. Second, observations can be made on the area restored, identifying successes and areas for improvement.

8.2.3 Fencing

Fencing can occur well before planting, as soon as possible is recommended for animal control. Permanent fencing is recommended (Ledgard & Henley, 2009), emphasising that freshwater objectives will not be achieved by temporary measures. Fencing is best on flat terrace above water channel, 1m of pasture between fence and zone B. Fencing straight lines requires less materials and labour compared to fencing following the water course.

8.2.4 Plant selection

Plant species should be zone specific; dry/wet, sun/shade; with a demonstrated high survival rate. Species preference for moisture must be considered; deep rooting species seeking water at depth rather than surface, and not species requiring water for long term survival. Locally sourced natives are best as they are adapted to local soils and climate. Plants must be ordered in advance of planting, and should be hardened off in the open for 1 month prior to planting. Planting time varies, some say spring, others recommend planting seedlings best in June establishing over winter and spring prior to summer drought; species vulnerable to frost planted as late as October.

Zone B is ideally 2-5m between zones A and C, with at least 3 rows of planting for canopy closure and erosion control. Many species are recommended for zone B, coprosmas (taupata and karamu), mahoe and cabbage trees (Ti Kouka) mahoe known to be consumed by stream insects (S. M. Parkyn & Winterbourn, 1997). In addition to mahoe are kahikatea and houhere, species observed in Horowhenua early 20th century (Cowan, 1932); kahikatea however requires extra shelter. At the interface of zone A to zone B, densely leaved shrubs (e.g. manuka, lemonwood and kohuhu) are recommended to reduce the penetration of light stimulating the growth of nuisance weeds in zone B.

Zone C consists of low growing water tolerant species with long flexible leaves that bend with the flow of water rather than impeding floodwater. Ideally 1-2m wide and further divided into two areas, a good cover of grasses on bank edge will increase stability. Closest to the stream are toetoe, harakeke and purei, species which tolerate flood inundation. At the interface with zone B recommended are bushy species with good early site dominance, such as koromiko, kohuhu and totara; like kahikatea totara requires additional shelter.

8.2.5 Pest control

Animal control is required prior to planting to increase the success and survival of planting. Blackberry and buckthorn are problematic and must be poisoned well in advance of planting; grass and weeds should be sprayed or removed 3-4 weeks prior to planting. Weed control is common over 2 years, selecting chemical herbicides according to weeds to be controlled. Caution recommended when planting, avoiding contact of roots with sprayed soil.

8.2.6 Initial planting

Bank stabilisation and canopy closure are generally the aim of initial planting, with spaces no more than 1m between plants. Canopy closure will ensure shading of water, dominance of native species for seedling establishment, and maintain weed control. Species should be kept simple, additional species can be planted at later stages, but a majority of planting can still occur at initial planting. Once canopy closure has established, planting for complexity and structure can commence; such as species mentioned with a preference for shelter kahikatea and totara.

Table 8: Riparian zones, purpose and species for initial planting

Zone	Purpose	Species
Interface of A and B	Weed control	• Manuka • Lemonwood
B	Native seedling establishment	• Mahoe • Ti kouka
Interface of B and C	Stability and shade water	• Koromiko • Karamu
C	Shade water	• Toetoe • Harakeke • Purei

8.2.7 Kaitiakitanga: Guardianship and Maintenance

The success of riparian vegetation restoration depends on continuing 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.

9. COST BENEFIT ANALYSIS FOR RIPARIAN VEGETATION RESTORATION OF WAIWIRI CATCHMENT

In pursuit of the imperative freshwater objectives, established so far are;

- Freshwater attributes to be managed;
- community values indicative of freshwater attributes to be managed;
- riparian vegetation and freshwater attributes to be managed;
- the process of riparian vegetation restoration.

What remains is the actual cost benefit analysis, by description of calculating relevant costs and benefits, scenarios to be considered, and comparison of scenarios.

9.1 Calculation of costs and benefits

Where necessary, values have been adjusted for inflation using the Reserve Bank of New Zealand's inflation calculator[15].

Annualised cost of planted riparian is based on the value provided by the Waikato River Independent Scoping Study (WRISS) (National Institute of Water and Atmospheric Research, 2010). The WRISS estimates an annual cost of $80/ha/year for a 5m riparian buffer; this value has been multiplied by the land area of proposed riparian widths, and then adjusted for inflation to better reflect the potential cost in today's dollars. 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

Table 9 Annualised cost of planted riparian

Riparian Width (m)	Riparian land area (ha)	Annual cost ($, 2010)	Annual cost ($, 2013)
5	6	480	495.62
10	12	960	991.24

Opportunity cost of retiring the stream riparian width is based on the median price per hectare as reported by interest.co.nz drawn from the Real Estate Institute monthly reports for May 2013. The median price for dairy farms sold in the Wanganui/ Manawatu was $25,622/ha; this value was then multiplied by the land area of proposed stream riparian widths.

[15] http://www.rbnz.govt.nz/monetary_policy/inflation_calculator/

Table 10 Opportunity cost of retiring land for riparian planting

Riparian Width (m)	Riparian land area (ha)	Opportunity cost ($)
5	6	25,622 X 6 = 153,732
10	12	25,622 X 12 = 307,464

Fencing and weed control per Greater Wellington's Riparian Management Strategy (2003), are used to estimate the cost of permanent fencing, fencing labour and weed control. The strategy estimates costs per kilometre, which have been adjusted for inflation to better reflect the potential cost in today's dollars. The length of the stream, drains and tributaries, are multiplied by two, with the assumption that both sides of the water course are in pasture; the lengths are then multiplied by the relevant costs.

Table 11 Cost of fencing stream, and drains and tributaries

Fencing	Stream	Drains and Tributaries
Length (km)	6	20.3
Length both sides (km)	12	40.564
Permanent fencing/ km 2013 $18,064.69	12 X 18,064.69 = $216,776	40.564 X 18,064.69 = $732,776
Fencing labour/ km 2013 $13,256.59	12 X 13,256.59 = $159,079	40.564 X 13,256.59 = $537,740

Table 12 Cost of weed control of stream riparian

Weed control	5m riparian width	10m riparian width
2003 $/ km	4166	8333
2013 $/ km	5329.85	10661
Total cost	12 km X 5329.85 = $63,958	12 km X 10661 = $127,932

Plants and planting labour costs have been calculated based on estimates provided by a local nursery. The estimates provided indicate an average plant price in 2013, how many plants would be typical of a 5m or 10m riparian width, and the number of plants that one person might plant per hour. Estimates provided by the nursery were used to calculate additional information needed; the number of plants required to plant the drains and tributaries, number of labour hours required for planting, and the cost of labour for planting.

Table 13 Cost of plants and planting labour

	5m riparian width either side of stream	**10m riparian width either side of stream**	**2m either side of drains and tributaries**	**Drains and tributaries to a maximum of 2.5km**
Length of stream, drains and tributaries (km)	6	6	20.282	15.467
Both sides of length	12	12	40.564	30.934
Number of plants required	60,000	120,000	81,128	61,868
Total cost of plants ($)	241,500	483,000	326,540	249,018
Labour hours required for planting	2,400	4,800	3,245	2,474
Cost of labour for planting @ $18/hour ($)	43,200	86,400	58,412	44,545

Kaitiaki[16] are essential to the success of riparian vegetation restoration, key to executing on-going regular maintenance and care of the stream plantings. The annual benefit of Kaitiaki is calculated assuming that a minimum of two Kaitiaki are employed to work together maintaining and caring for stream plantings; a combined total of 40hours per week for a 5m riparian width, and a combined total of 80 hours per week for a 10m riparian width. Careersnz (careers.govt.nz), estimate that gardeners earn per hour between $13 and $25. The benefit of Kaitiaki is calculated based on $20/hour. In the final year of the cost benefit analysis, this benefit is calculated as an annuity in perpetuity the value of an on-going annual payment.

[16] Kaitiaki – Guardians, caretakers.

Table 14 Benefit of Kaitiaki ($)

	5m riparian width	10m riparian width
Combined total of labour hours per week	40	80
Monetary benefit of kaitiaki per week @ $20/hour ($)	800	1,600
Annual benefit of kaitiaki per year @ 52 Weeks ($)	41,600	83,200

Soil retention is estimated as the avoided loss of 9 ton/ ha/ year (*calculation a*), 25 % of which is assumed topsoil (Forgie et al., 2012) (*calculation b*). The cost of topsoil in New Zealand is quoted at $55/ m³ [17], however topsoil loss is estimated in tons hence *calculation c* to convert $55/ m³ to $/ ton [18]. Multiplying avoided top soil loss by cost of top soil produces the soil retention benefit ($). In the final year of the cost benefit analysis, this benefit is calculated as an annuity in perpetuity.

Table 15 Benefit/ cost of soil retention ($)

Variable	Calculation
Waiwiri catchment area (ha)	1,500
a. Total avoided soil loss (ton)	= 9 X 1,500 = 13,500
b. Avoided top soil loss (ton)	= 25% of 13,500 = 3,375
c. Cost of top soil ($/ ton)	= 55/1.44 = 38.19
d. Soil retention @ $38.19/ ton ($)	= 3,375 X 38.19 = 128,891

Stock loss and stock health are distinct benefits both based on the same assumptions of 0.005 cattle/ ha/ year, in July 2013 2 year old heifers sold for up to $860[19] generating a value of $4.3/ ha/ year. Recalling that 1,110 ha of the Waiwiri catchment is in exotic grassland associated with dairy and beef, this value is multiplied by $4.3. In the final year of the cost benefit analysis, these benefits are calculated as an on-going annual payment.

[17] http://www.gardenmakers.co.nz/catalogue.html?sid=5
[18] http://www.myersgroup.co.uk/nm/technicalpage.asp?pageID=15
[19] http://www.dannevirke.net.nz/dannevirke-farming.html

Table 16 Benefit/ cost of stock loss and stock health ($)

	Stock loss	Stock health
$/ ha/ year	4.3	4.3
Exotic grassland associated with dairy and beef (ha)	1,110	1,110
Annual benefit ($)	= 4.3 X 1,110 = 4,773	= 4.3 X 1,110 = 4,773

Willingness to pay (WTP) is based on the lowest value per household provided by the choice experiments previously discussed. To calculate annual WTP, WTP/ household is multiplied by the number of households in Levin 2001, which is 7293. In the final year of the cost benefit analysis, WTP for a change in management is calculated as an on-going annual payment.

Table 17 Willingness to pay estimated by choice experiments

	5m riparian width		10m riparian width	
	$/ household	**Annual WTP ($)**	**$/ household**	**Annual WTP ($)**
10% chance of algal bloom (for ten years)	44	320,892		
2 % chance of algal bloom (for ten years)			32	233,376
Change in tributary water quality (for ten years)	87	634,491	87	634,491
Change in management fair/ good (on-going)	125	911,625	169	1,232,517
Change of vegetation to native species (for five years)	96	700,128	96	700,128

Change in tributary water quality includes drains and tributaries in the catchment, subject to change depending on lengths planted. Where all tributaries/ drains are assumed planted (scenarios A and F), the benefit of change in tributary water quality is considered. Where there is no planting (scenarios B and G), it is assumed that there is no benefit for tributary water quality. Drains planted for a maximum of 2.5km (15.47km), the percentage of the length of all drains is calculated, this percentage is then used to calculate the portion of the benefit of change in tributary water quality that is applicable.

Table 18 Willingness to pay for change in tributary water quality

	All drains	Maximum of 2.5km of each drain
Length (km)	20.282	15.467
Percentage	100%	= 15.467/20.282 = 76.26%
Change in tributary water quality ($)	634,491	= 76.26% X 634,491 = 483,861

9.2 Alternative Scenarios

12 scenarios are considered. The first is the status quo, for this scenario both a narration and table of costs is presented here. **All remaining scenarios are based on two assumptions: riparian vegetation restoration of a width of either 5m or 10m, and all drains and tributaries are fenced**. The preceding assumptions incur the opportunity cost of retiring land, fencing of stream, drains and tributaries, and planting of the stream riparian; an initial cost of $2.15 million and $2.65 million, for a stream riparian width of 5m and 10m respectively. Cost benefit analysis tables for these scenarios are provided in the appendix.

9.2.1 Status Quo

This scenario assumes no riparian vegetation restoration, nor fencing. Costs are still anticipated despite avoiding the opportunity cost of retired land, and costs of fencing and planting. The benefits 'soil retention', 'stock loss' and 'stock health' become costs expected in the absence of riparian vegetation restoration.

In addition Marsh and Phillips (2012) estimated willingness to accept compensation for a decline in attributes: suitability for swimming and recreation; ecological health; and tributary water quality. 'Tributary water quality' is the only attribute considered in this scenario. At the time of Marsh and Phillip's (2012) study, water quality of tributaries of the study locale Hurunui catchment were unsatisfactory which is characteristic of the Waiwiri catchment. For an additional decline in tributary water quality to poor, Marsh and Phillips (2012) study suggested that residents would require compensation of $224 per household per year by decreasing local taxes for 10 years; that is a decrease in local tax revenue collected by either district or regional councils.

The cost benefit analysis (CBA) for no riparian vegetation restoration is provided below. It is **assumed that there are no benefits of doing nothing** and letting tributary water quality of the Waiwiri catchment to decline further from unsatisfactory to poor. The cost of doing nothing in today's dollars (NPV) is almost $11 million.

Table 19 CBA of no riparian vegetation or fencing

The Status Quo										
No riparian vegetation restoration. Costs expected are the loss of top soil, stock loss and stock health. In addition a decrease in local tax revenue is anticipated for an additional decline in tributary water quality.										
COSTS	1	2	3	4	5	6	7	8	9	10
Loss of top soil	128891	128891	128891	128891	128891	128891	128891	128891	128891	128891
Stock loss	4251	4251	4251	4251	4251	4251	4251	4251	4251	4251
Stock health	4251	4251	4251	4251	4251	4251	4251	4251	4251	4251
Decline in tributary water quality (WTA)	1633632	1633632	1633632	1633632	1633632	1633632	1633632	1633632	1633632	1633632
Total costs	1771025	1771025	1771025	1771025	1771025	1771025	1771025	1771025	1771025	1771025
PV (total costs)	1610023	1463657	1330597	1209634	1099667	999697	908816	826196	751087	682807
Net present value (NPV)	$ 10,882,182									

9.2.2 The Rolls-Royce

In addition to stream planting, and drain and tributary fencing, this scenario assumes that all drains are planted. Benefits expected of this scenario are

- Kaitiaki (on-going)
- Soil retention (on-going)
- Stock loss (on-going)
- Stock health (on-going)
- 10% or 2% chance of algal bloom (WTP for ten years)
- Change in tributary water quality (WTP for ten years)
- Management fair or good (WTP on-going)
- Vegetation to native species (WTP for five years)

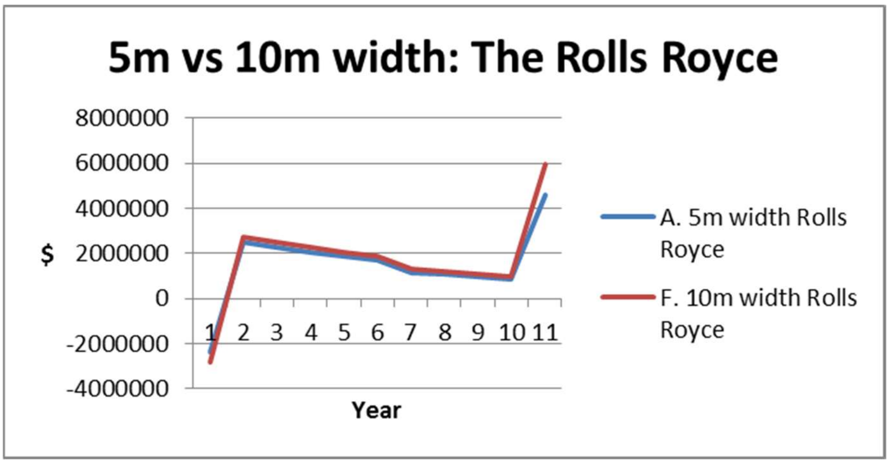

Figure 6: 5m vs 10m riparian restoration of Waiwiri stream with all drains and tributaries fenced and planted

9.2.3 Drains and tributaries not planted

This scenario assumes minimal stream planting, and drain and tributary fencing. The above-mentioned benefits are expected of this scenario with the exception of a change in tributary water quality which has been excluded as a benefit.

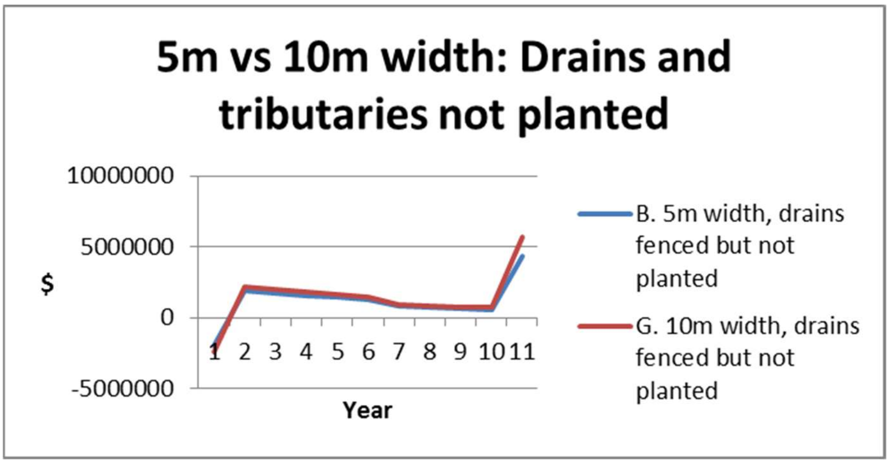

Figure 7: 5m vs 10m riparian restoration of Waiwiri stream with all drains and tributaries fenced only

9.2.4 Planting of some drains and tributaries

This scenario assumes that from the stream 2.5 km of all drains and tributaries will be planted, that is 15.467km of a total of 20.282km, or 76.26%. All benefits expected of the Rolls-Royce are expected for this scenario but assumes only 76.26% of change in tributary water quality benefit.

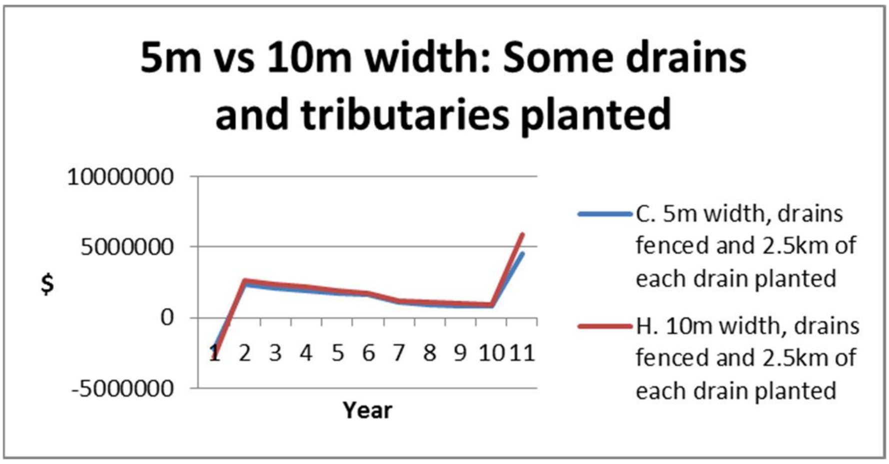

Figure 8: 5m vs 10m riparian restoration of Waiwiri stream; all drains and tributaries fenced, and a maximum of 2.5km of drains or tributaries planted

9.2.5 Willingness to pay (WTP) only for change in management

This scenario assumes all costs of the Rolls-Royce scenario however with a change in management the only benefit. The purpose is to demonstrate a realistic value of benefits without potential exaggeration.

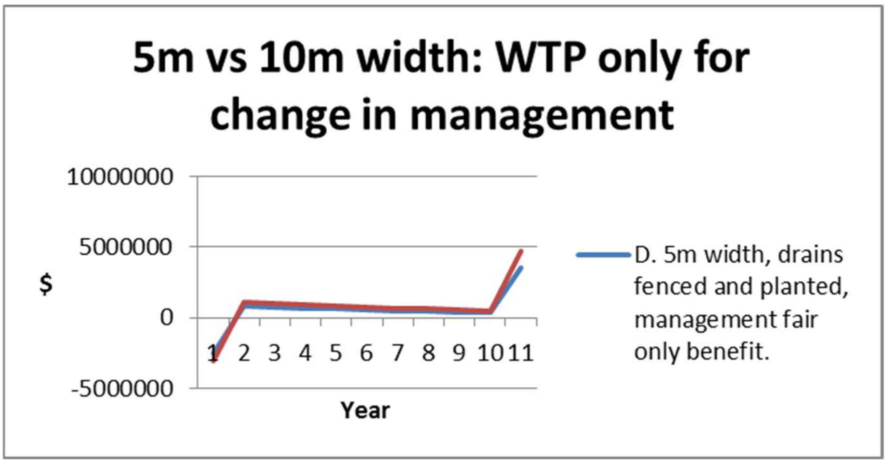

Figure 9: 5m vs 10m riparian restoration of Waiwiri stream with all drains and tributaries fenced and planted, the only benefit is willingness to pay for a change in management

9.2.6 Injection into local economy

Many of the costs of the Rolls-Royce scenario are benefits to the local economy. A 5m and 10m stream riparian width respectively contribute: $568,040 and $809,540 to local business for locally sourced plants, and $798,432 and $841,632 for locally sourced labour. These costs represent an initial injection into the local economy of $1.37 million for a 5m width, and $1.65 million for a 10m width.

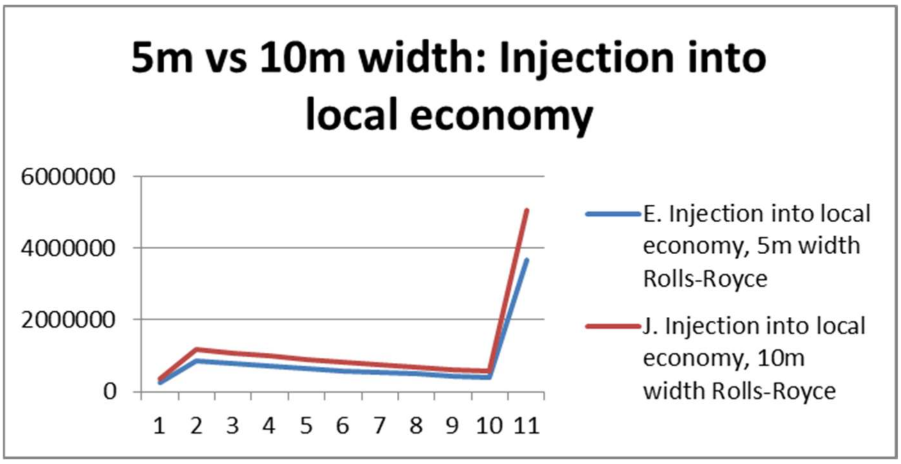

Figure 10: 5m vs 10m riparian restoration of Waiwiri stream with all drains and tributaries fenced and planted, local costs for plants and labour assumed injection into local economy rather than cost

9.2.7 An increase in rates of $1.00 per property per week

The last scenario assumes all costs of fencing, planting and labour for riparian restoration of the stream, tributaries and drains are covered by rates. The only benefit is that rates increase by $1.00 per property per week in perpetuity.

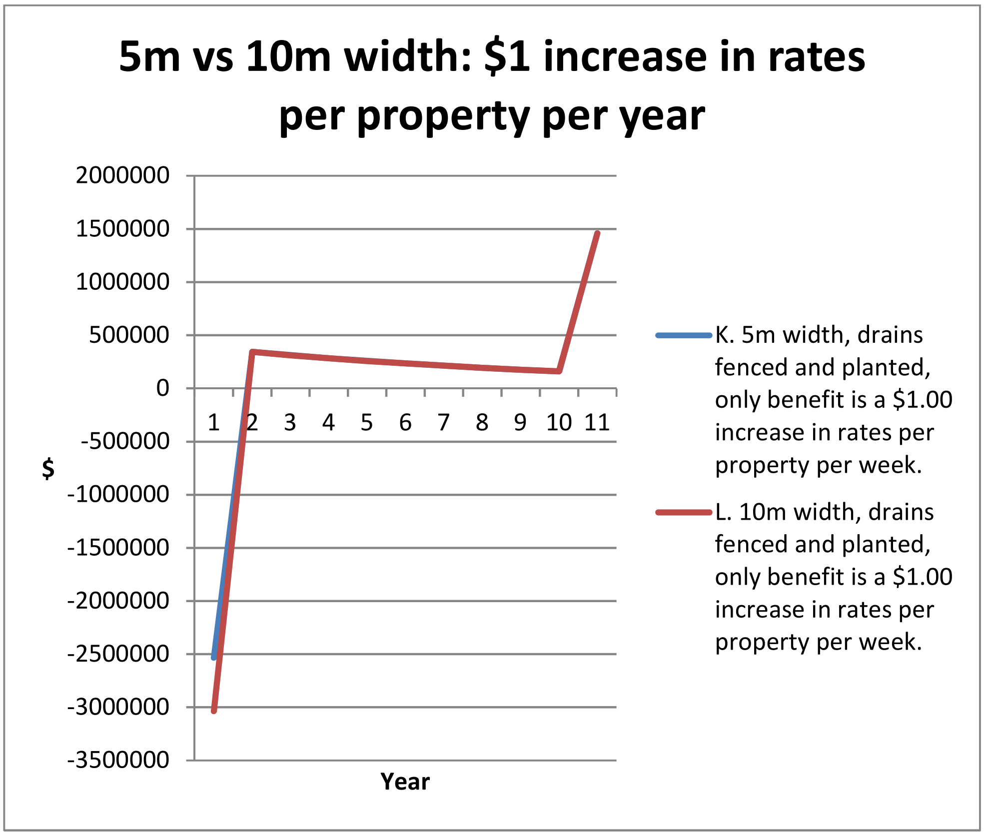

Figure 11: 5m vs 10m riparian restoration of Waiwiri stream with all drains and tributaries fenced and planted; only benefit is an increase in rates of $1 per property per wk

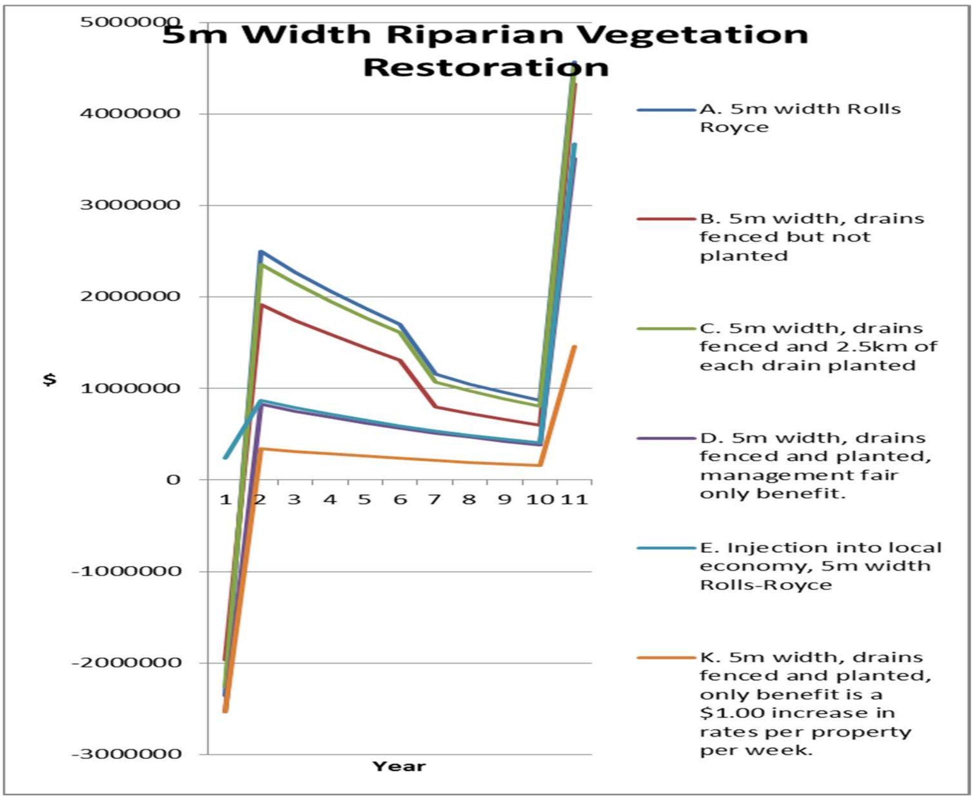

Figure 12: 5m riparian restoration of Waiwiri stream, a comparison of scenarios

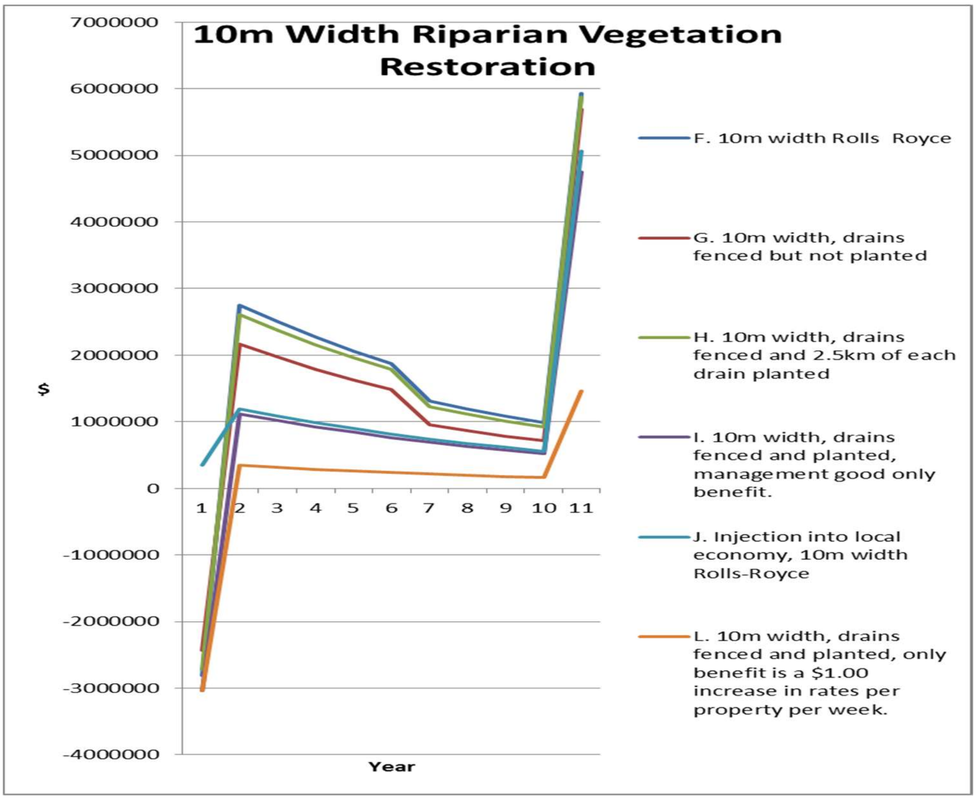

Figure 13: 10m riparian restoration of Waiwiri stream, a comparison of scenarios

9.2.8 Summary

Table 20: Present value of total costs and total benefits, net present value (NPV), and benefit cost ratio (BCR) for all 12 riparian restoration scenarios considered for cost benefit analysis

	5m Width						10m Width					
Scenario	A	B	C	D	E	K	F	G	H	I	J	L
PV (total costs)	2,538,479	2,153,527	2,447,090	2,538,479	1,172,008	2,538,479	3,045,650	2,660,698	2,954,261	3,045,650	1,394,478	3,045,650
PV (total benefits)	19,189,143	15,290,471	18,263,588	8,764,779	10,572,812	3,646,148	22,178,159	18,279,487	21,252,604	11,849,981	14,384,276	3,646,148
NPV ($)	16,650,664	13,136,944	15,816,498	6,226,300	9,400,804	1,107,669	19,132,509	15,618,789	18,298,343	8,804,331	12,989,797	600,498
BCR	7.56	7.10	7.46	3.45	9.02	1.44	7.28	6.87	7.19	3.89	10.32	1.20

The first scenario considered is one in which no action takes place in the Waiwiri catchment, which imposes a cost on society of almost $11 million. Subsequent scenarios assume that both a width of 5m or 10m on both sides of the stream are retired, fenced and planted, and all drains and tributaries are fenced. At the most, 5m and 10m riparian restoration of the Waiwiri stream will cost $2.5 million and $3 million respectively; however, the cost of either of these projects could be recovered within three years of project implementation. Furthermore, it is questionable whether some costs are actually costs, as locally sourced plants and labour are an injection into the local economy.

10. ADDITIONAL BENEFITS OF RIPARIAN PLANTING

Riparian planting complements freshwater attributes to be managed, and thus community objectives for freshwater identified by choice experiment. Some benefits of riparian planting have been monetised and considered by the preceding cost benefit analyses. However, there are many more benefits of riparian planting which have not been quantified: carbon absorbed, indigenous Māori values, and farm benefits.

10.1 Carbon absorbed

A substantial amount of carbon is absorbed in the woody biomass of new tree plantings (Schoeneberger, 2009). Project Twin Streams (PTS) of Auckland New Zealand was a riparian restoration project which extended 10,000 ha and 56km of stream bank (KL Hall & CM Helsel, 2009). PTS involved planting a total of 778,250 native trees, it was anticipated that the trees would absorb carbon emissions from over 33,837 cars doing an average of 15,000km per year (Project Twin Streams, 2011). There is potential for this benefit to be monetized by the Kyoto Protocol which allows a claim for a credit of any carbon absorbed as a result of afforestation and reforestation (van Kooten, 2000) if they meet certain criteria.

10.2 Indigenous Māori Values

According to Townsend, Tipa, Teirney, and Niyogi (2004), cultural values of significance for freshwater include: mauri (life force), mahinga kai (food works), kaitiakitanga (guardianship), wai taonga (treasured water) and ki uta ki tai (catchment management). Interpreting cultural values is challenging; these are briefly addressed here.

10.2.1 Mauri: Life Force

Mauri is multi-dimensional with components tangible and intangible, physical and spiritual. Despite challenge in interpretation, there is some agreement that all living things possess Mauri mutually complementing spiritual existence and physical state, extended to the Mauri of the system (Durie, 1998; Harmsworth, Young, Walker, Clapcott, & James, 2011; Townsend et al., 2004).

10.2.2 Mahinga Kai: Food Works

Mahinga kai is also interpreted as traditional food sources. Food sources associated with tribal areas are a source of mana for iwi/ hapū immediate to those sources (Majurey, Atkins, Morrison, & Hovell, 2010).

10.2.3 Kaitiakitanga: Guardianship

Kaitiakitanga has several connotations: guardianship, preservation, conservation, fostering, protecting, sheltering (Marsden & Henare, 1992). Kaitiakitanga is an obligation to ensure a resource for future generations (Durie, 1998).

10.2.4 Wai Taonga: Treasured Water

Taonga are valued because of their associations (H. Smith, 2008). Wai taonga are significant because they are waters from which resources are gathered, waters of breeding or migratory habitats, or waters which are the location of significant species or taonga (Townsend et al., 2004).

10.2.5 Ki Uta Ki Tai: Catchment Management

Ki uta ki tai is commonly understood to mean from mountains to the sea, hence catchment management. It is becoming increasingly understood by Māori that the condition of our water bodies is determined by processes of the catchment and all interrelated components therein (Tipa, 2009).

10.3 Farm Benefits

There is a myth lingering with some farmers that retiring farm land for riparian planting is costly based on an assumption of reduced productivity (Gwerder, 2013; Morgan, 2012). However, farmers all over New Zealand have experienced significant benefits such as increases in productivity in addition to those already described. To increase support for best management farming practice such as riparian planting, feedback demonstrating the effectiveness of the investment of time and money is essential (Morgan, 2012).

Dairy case studies which have engaged in retiring land for riparian management (fencing and planting) have experienced an increase in productivity. Over an eight year study of the Waiokura catchment Taranaki with riparian management, an increase in productivity by almost 25% to 1262 kg/ ha milk solids were observed, in addition to an improvement in water quality (Bedford, 2009). After 17 years of riparian management, production on farms has doubled (Barclay, 2012). Dairy farmer Andrew Hayes of Horsham Downs north of Hamilton, has maintained stocking rates and experienced high productivity in milk solids since riparian management, 1500 kg/ ha compared to an industry average of 978 kg/ ha (Shepheard, 2012).

More effective farm and stock management is the advantage of riparian fencing and planting experienced by farmers. In the Toenepi catchment south of Morrinsville, benefits noted by farmers are: less time retrieving stock stuck in drains; increased milk quality; and reduced risk of mastitis (Dairy InSight, 2007). In Taranaki farmers attribute the following to riparian management: increased shelter for stock; safer stock movement; mitigation of milk fever, liver lurk and stock loss[20].

Furthermore, are the benefits of riparian management that are not attributable to farm management, but still praised by farmers. The unexpected aesthetic improvements of a more peaceful farm surrounded by trees[21], with potential to increase the value of property (S. Parkyn, Wright-Stow, & Quinn, 2003) as observed by landowners in the Whaingaroa Harbour Raglan (Barclay, 2012). As well as recreational values: trout, ducks and salmon spawning in Ohapi creek, Canterbury[22]; eeling and canoeing at Wrights stream, Canterbury[23] and Waiokura stream, Taranaki (Dairy InSight, 2007).

Farmers have acknowledged that land retired for riparian management is unproductive anyway, and for dairy farmer Steve Poole of Taranaki, riparian fencing and planting is a matter of common-sense (Dairy InSight, 2007). In the absence of riparian fencing and planting, farmers across New Zealand have experienced significant costs. In Raglan costs were associated with stock losses, drain digging and weed control (Buchanan, 2013). Likewise, in Canterbury, prior to riparian fencing and planting, participants of the living streams project experienced higher costs for drain clearing[24], and proliferation of aquatic weeds[25]. In addition was angst about losing stock in water ways[26].

[20] http://www.trc.govt.nz/riparian-case-studies
[21] http://www.trc.govt.nz/riparian-case-studies
[22] http://ecan.govt.nz/get-involved/local-projects-community-groups/living-streams/case-studies/Pages/ohapi-creek.aspx
[23] http://ecan.govt.nz/get-involved/local-projects-community-groups/living-streams/case-studies/Pages/wrights-stream.aspx
[24] http://ecan.govt.nz/get-involved/local-projects-community-groups/living-streams/case-studies/Pages/boundary-drain.aspx
[25] http://ecan.govt.nz/get-involved/local-projects-community-groups/living-streams/case-studies/Pages/boggy-creek.aspx
[26] http://www.trc.govt.nz/riparian-case-studies: Joe and Karen Gwerder, 2013; and Adrian Hofmans, 2007; Steve Poole, 2007

11. CONCLUSIONS

This report demonstrates that riparian vegetation restoration has the potential to restore freshwater ecosystems, and a project of this kind for the Waiwiri catchment has a positive dollar value. Freshwater attributes to be managed as dictated by the freshwater reform are indicative of community objectives identified by choice experiment. Research confirms that riparian vegetation is an effective means of managing freshwater attributes and mitigating relative processes of degradation which impinge on freshwater ecosystems. As a method of managing freshwater attributes, riparian vegetation restoration will also achieve community objectives identified by the choice experiments discussed.

A project of riparian vegetation restoration requires significant planning; fundamental are the purpose of planting and land characteristics to determine the width of land to be retired, fencing and plant selection. Alternative scenarios were considered for a riparian restoration width of 5m and 10m. A positive dollar value for a riparian vegetation restoration project for Waiwiri stream and catchment was maintained, despite the increased costs considered by the “Rolls Royce” scenario, and reducing the benefits to only a change in management or a $1.00 increase in rates per property per week. Furthermore, locally sourced plants and labour as costs are questionable, as these “costs” are in fact injections into the local economy. Other benefits of a riparian vegetation restoration project not considered by the cost-benefit analysis are carbon absorbed, indigenous Māori values, and farm benefits.

12. RECOMMENDATIONS

- Māori values were briefly considered however further research required to investigate cultural values for freshwater;
- Choice modeling of Māori values for freshwater;
- Engagement with land owners in the catchment towards riparian vegetation restoration projects;
- Engagement with council to plan for an appropriate course of action for riparian vegetation restoration of Waiwiri stream and catchment.

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14. APPENDICES

14.1 CBA of 5m riparian vegetation restoration of Waiwiri stream, all drains and tributaries fenced and planted.

A. 5m width Rolls Royce											
Assumptions	*5m either side of stream retired, permanently fenced and vegetated; 2m either side of all drains retired, permanently fenced and vege*										
	Initial labour a cost not a benefit						**Levin Households 2001**		7293	**Interest**	10%
Year	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
COSTS											
Annualised cost of planted riparian		496	496	496	496	496	496	496	496	496	4956
Waiwiri Stream											
Opportunity cost	153732										
Fencing Stream (materials)	216776										
Weed control	63958										
Plants	241500										
Drains											
Fencing tributaries (materials)	732776										
Drain plants	326540										
Labour											
Stream fencing labour	159079										
Drain fencing labour	537740										
Stream planting labour	43200										
Drain planting labour	58412										
Total costs	2533714	496	496	496	496	496	496	496	496	496	4956
PV (total costs)	2533714	451	410	372	339	308	280	254	231	210	1911
BENEFITS											
Kaitiaki	41600	41600	41600	41600	41600	41600	41600	41600	41600	41600	416000
Soil retention	128891	128891	128891	128891	128891	128891	128891	128891	128891	128891	1288910
Stock loss	4251	4251	4251	4251	4251	4251	4251	4251	4251	4251	42510
Stock health	4251	4251	4251	4251	4251	4251	4251	4251	4251	4251	42510
10% chance of algal bloom		320892	320892	320892	320892	320892	320892	320892	320892	320892	320892
Change in tributary water quality		634491	634491	634491	634491	634491	634491	634491	634491	634491	634491
Management fair		911625	911625	911625	911625	911625	911625	911625	911625	911625	9116250
Vegetation to native species		700128	700128	700128	700128	700128					
Total benefits	178993	2746129	2746129	2746129	2746129	2746129	2046001	2046001	2046001	2046001	11861563
PV (total benefits)	178993	2496481	2269528	2063207	1875643	1705130	1154914	1049922	954475	867704	4573146
PV(benefits minus costs) $	-2354721	2496030	2269118	2062835	1875305	1704822	1154634	1049668	954243	867494	4571235
NPV ($)	**16,650,664**										

14.2 CBA of 5m riparian vegetation restoration of Waiwiri stream, drains and tributaries fenced but not planted.

B. 5m width, drains fenced but not planted											
Assumptions	*5m either side of stream retired, permanently fenced and vegetated; 2m either side of all drains retired and permanently fenced only.*										
	Hence no change in tributary water quality.					**Levin Households 2001**		7293	**Interest**		10%
Year	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
COSTS											
Annualised cost of planted riparian		496	496	496	496	496	496	496	496	496	4956
Waiwiri Stream											
Opportunity cost	153732										
Fencing Stream (materials)	216776										
Weed control	63958										
Plants	241500										
Drains											
Fencing tributaries (materials)	732776										
Drain plants											
Labour											
Stream fencing labour	159079										
Drain fencing labour	537740										
Stream planting labour	43200										
Drain planting labour											
Total costs	2148762	496	496	496	496	496	496	496	496	496	4956
PV (total costs)	2148762	451	410	372	339	308	280	254	231	210	1911
BENEFITS											
Kaitiaki	41600	41600	41600	41600	41600	41600	41600	41600	41600	41600	416000
Soil retention	128891	128891	128891	128891	128891	128891	128891	128891	128891	128891	1288910
Stock loss	4251	4251	4251	4251	4251	4251	4251	4251	4251	4251	42510
Stock health	4251	4251	4251	4251	4251	4251	4251	4251	4251	4251	42510
10% chance of algal bloom		320892	320892	320892	320892	320892	320892	320892	320892	320892	320892
Change in tributary water quality											
Management fair		911625	911625	911625	911625	911625	911625	911625	911625	911625	9116250
Vegetation to native species		700128	700128	700128	700128	700128					
Total benefits	178993	2111638	2111638	2111638	2111638	2111638	1411510	1411510	1411510	1411510	11227072
PV (total benefits)	178993	1919671	1745155	1586505	1442277	1311161	796761	724328	658480	598618	4328522
PV (benefits minus costs) $	-1969769	1919220	1744746	1586133	1441939	1310853	796481	724073	658249	598408	4326611
NPV ($)	**13,136,944**										

14.3 CBA of 5m riparian vegetation restoration of Waiwiri stream, all drains and tributaries fenced, maximum of 2.5km of each planted.

C. 5m width, drains fenced and 2.5km of each drain planted											
Assumptions	*5m either side of stream retired, permanently fenced and vegetated; 2m either side of all drains retired, permanently fenced and 2.5km of each drain planted. Initial labour a cost not a benefit.*						Levin Households 2001		7293	Interest	10%
Year	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
COSTS											
Annualised cost of planted riparian		496	496	496	496	496	496	496	496	496	4956
Waiwiri Stream											
Opportunity cost	153732										
Fencing Stream (materials)	216776										
Weed control	63958										
Plants	241500										
Drains											
Fencing tributaries (materials)	732776										
Drain plants	249018										
Labour											
Stream fencing labour	159079										
Drain fencing labour	537740										
Stream planting labour	43200										
Drain planting labour	44545										
Total costs	2442325	496	496	496	496	496	496	496	496	496	4956
PV (total costs)	2442325	451	410	372	339	308	280	254	231	210	1911
BENEFITS											
Kaitiaki	41600	41600	41600	41600	41600	41600	41600	41600	41600	41600	416000
Soil retention	128891	128891	128891	128891	128891	128891	128891	128891	128891	128891	1288910
Stock loss	4251	4251	4251	4251	4251	4251	4251	4251	4251	4251	42510
Stock health	4251	4251	4251	4251	4251	4251	4251	4251	4251	4251	42510
10% chance of algal bloom		320892	320892	320892	320892	320892	320892	320892	320892	320892	320892
Change in tributary water quality		483861	483861	483861	483861	483861	483861	483861	483861	483861	483861
Management fair		911625	911625	911625	911625	911625	911625	911625	911625	911625	9116250
Vegetation to native species		700128	700128	700128	700128	700128					
Total benefits	178993	2595499	2595499	2595499	2595499	2595499	1895371	1895371	1895371	1895371	11710933
PV (total benefits)	178993	2359545	2145041	1950037	1772761	1611601	1069888	972625	884205	803822	4515072
PV (benefits minus costs) $	-2263332	2359094	2144631	1949665	1772422	1611293	1069608	972371	883973	803612	4513161
NPV ($)	**15,816,498**										

14.4 CBA of 5m riparian vegetation restoration of Waiwiri stream, all drains and tributaries fenced and planted, management fair only benefit.

D. 5m width, drains fenced and planted, management fair only benefit.

Assumptions	*5m either side of stream retired, permanently fenced and vegetated; 2m either side of all drains retired, permanently fenced and plan*									
	Initial labour a cost not a benefit, and fair management the only benefit					**Levin Households 2001**		7293	**Interest**	10%
Year	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
COSTS											
Annualised cost of planted riparian		496	496	496	496	496	496	496	496	496	4956
Waiwiri Stream											
Opportunity cost	153732										
Fencing Stream (materials)	216776										
Weed control	63958										
Plants	241500										
Drains											
Fencing tributaries (materials)	732776										
Drain plants	326540										
Labour											
Stream fencing labour	159079										
Drain fencing labour	537740										
Stream planting labour	43200										
Drain planting labour	58412										
Total costs	2533714	496	496	496	496	496	496	496	496	496	4956
PV (total costs)	2533714	451	410	372	339	308	280	254	231	210	1911
BENEFITS											
Management fair		911625	911625	911625	911625	911625	911625	911625	911625	911625	9116250
PV (Management fair)	0	828750	753409	684917	622652	566047	514589	467808	425280	386618	3514709
PV (benefits minus costs) $	-2533714	828299	752999	684545	622314	565740	514309	467553	425049	386408	3512798
NPV ($)	**6,226,300**										

14.5 CBA of 5m riparian vegetation restoration of Waiwiri stream, all drains and tributaries fenced and planted, local costs a benefit as an injection into local economy.

E. Injection into local economy, 5m width Rolls-Royce											
	5m width rolls royce, with plants and labour an injection into local economy and hence a benefit to local economy.										
Assumptions	*Other benefits include kaitiaki and management fair.*						***Levin Households 2003***		7293	***Interest***	10%
Year	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
COSTS											
Operating costs (WRISS A10, 10)		496	496	496	496	496	496	496	496	496	4956
Waiwiri Stream											
Opportunity cost	153732										
Fencing Stream (materials)	216776										
Weed control	63958										
Drains											
Fencing tributaries (materials)	732776										
Total costs	1167243	496	496	496	496	496	496	496	496	496	4956
PV (total costs)	1167243	451	410	372	339	308	280	254	231	210	1911
BENEFITS											
Locally sourced plants											
Stream plants	241500										
Drain plants	326540										
Labour											
Stream fencing labour	159079										
Drain fencing labour	537740										
Stream planting labour	43200										
Drain planting labour	58412										
Kaitiaki	41600	41600	41600	41600	41600	41600	41600	41600	41600	41600	416000
Management fair		911625	911625	911625	911625	911625	911625	911625	911625	911625	9116250
Total benefits	1408072	953225	953225	953225	953225	953225	953225	953225	953225	953225	9532250
PV (total benefits)	1408072	866568	787789	716172	651066	591878	538071	489155	444686	404260	3675095
PV (benefits minus costs) $	240829	866118	787380	715800	650727	591570	537791	488901	444455	404050	3673184
NPV ($)	**9,400,804**										

14.6 CBA of 5m riparian vegetation restoration of Waiwiri stream, all drains and tributaries fenced and planted, only benefit is an increase in rates of $1.00 per week per property.

K. 5m width, drains fenced and planted, only benefit is a $1.00 increase in rates per property per week.											
	5m either side of stream retired, permanently fenced and vegetated; 2m either side of all drains retired, permanently fenced and plan										
Assumptions	*Initial labour a cost not a benefit, and fair management the only benefit*					**Levin Households 2001**		7293	**Interest**		10%
Year	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
COSTS											
Annualised cost of planted riparian		496	496	496	496	496	496	496	496	496	4956
Waiwiri Stream											
Opportunity cost	153732										
Fencing Stream (materials)	216776										
Weed control	63958										
Plants	241500										
Drains											
Fencing tributaries (materials)	732776										
Drain plants	326540										
Labour											
Stream fencing labour	159079										
Drain fencing labour	537740										
Stream planting labour	43200										
Drain planting labour	58412										
Total costs	2533714	496	496	496	496	496	496	496	496	496	4956
PV (total costs)	2533714	451	410	372	339	308	280	254	231	210	1911
BENEFITS											
$1.00 increase in rates		379236	379236	379236	379236	379236	379236	379236	379236	379236	3792360
PV ($1 increase in rates)	0	344760	313418	284926	259023	235476	214069	194608	176916	160833	1462119
PV (benefits minus costs) $	-2533714	344309	313009	284553	258685	235168	213789	194354	176685	160623	1460208
NPV ($)	**1,107,669**										

14.7 CBA of 10m riparian vegetation restoration of Waiwiri stream, all drains and tributaries fenced and planted.

F. 10m width Rolls Royce											
Assumptions	*10m either side of stream retired, permanently fenced and vegetated; 2m either side of all drains retired, permanently fenced and vegetated. Initial labour a cost not a benefit*						**Levin Households 2001**		*7293*	**Interest**	*10%*
Year	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
COSTS											
Annualised cost of planted riparian		991	991	991	991	991	991	991	991	991	9912
Waiwiri Stream											
Opportunity cost	307464										
Fencing Stream (materials)	216776										
Weed control	127932										
Plants	483000										
Drains											
Fencing tributaries (materials)	732776										
Drain plants	326540										
Labour											
Stream fencing labour	159079										
Drain fencing labour	537740										
Stream planting labour	86400										
Drain planting labour	58412										
Total costs	3036120	991	991	991	991	991	991	991	991	991	9912
PV (total costs)	3036120	901	819	745	677	615	560	509	462	420	3822
BENEFITS											
Kaitiaki	83200	83200	83200	83200	83200	83200	83200	83200	83200	83200	832000
Soil retention	128891	128891	128891	128891	128891	128891	128891	128891	128891	128891	1288910
Stock loss	4251	4251	4251	4251	4251	4251	4251	4251	4251	4251	42510
Stock health	4251	4251	4251	4251	4251	4251	4251	4251	4251	4251	42510
2% chance of algal bloom		233376	233376	233376	233376	233376	233376	233376	233376	233376	233376
Change in tributary water quality		634491	634491	634491	634491	634491	634491	634491	634491	634491	634491
Management good		1232517	1232517	1232517	1232517	1232517	1232517	1232517	1232517	1232517	12325170
Vegetation to native species		700128	700128	700128	700128	700128					
Total benefits	220593	3021105	3021105	3021105	3021105	3021105	2320977	2320977	2320977	2320977	15398967
PV (total benefits)	220593	2746459	2496781	2269801	2063455	1875869	1310131	1191028	1082753	984321	5936968
PV(benefits minus costs) $	-2815527	2745558	2495962	2269056	2062778	1875253	1309571	1190520	1082290	983900	5933147
NPV ($)	**19,132,509**										

14.8 CBA of 10m riparian vegetation restoration of Waiwiri stream, drains and tributaries fenced but not planted.

G. 10m width, drains fenced but not planted											
Assumptions	*10m either side of stream retired, permanently fenced and vegetated; 2m either side of all drains permanently fenced only.* *Initial labour a cost not a benefit*						**Levin Households 2001**		7293	**Interest**	10%
Year	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
COSTS											
Annualised cost of planted riparian		991	991	991	991	991	991	991	991	991	9912
Waiwiri Stream											
Opportunity cost	307464										
Fencing Stream (materials)	216776										
Weed control	127932										
Plants	483000										
Drains											
Fencing tributaries (materials)	732776										
Drain plants											
Labour											
Stream fencing labour	159079										
Drain fencing labour	537740										
Stream planting labour	86400										
Drain planting labour											
Total costs	2651168	991	991	991	991	991	991	991	991	991	9912
PV (total costs)	2651168	901	819	745	677	615	560	509	462	420	3822
BENEFITS											
Kaitiaki	83200	83200	83200	83200	83200	83200	83200	83200	83200	83200	832000
Soil retention	128891	128891	128891	128891	128891	128891	128891	128891	128891	128891	1288910
Stock loss	4251	4251	4251	4251	4251	4251	4251	4251	4251	4251	42510
Stock health	4251	4251	4251	4251	4251	4251	4251	4251	4251	4251	42510
2% chance of algal bloom		233376	233376	233376	233376	233376	233376	233376	233376	233376	233376
Change in tributary water quality											
Management good		1232517	1232517	1232517	1232517	1232517	1232517	1232517	1232517	1232517	12325170
Vegetation to native species		700128	700128	700128	700128	700128					
Total benefits	220593	2386614	2386614	2386614	2386614	2386614	1686486	1686486	1686486	1686486	14764476
PV (total benefits)	220593	2169649	1972408	1793098	1630089	1481900	951977	865434	786758	715235	5692345
PV (benefits minus costs) $	-2430575	2168748	1971589	1792354	1629412	1481284	951418	864925	786296	714814	5688523
NPV ($)	**15,618,789**										

14.9 CBA of 10m riparian vegetation restoration of Waiwiri stream, all drains and tributaries fenced, maximum of 2.5km of each planted.

H. 10m width, drains fenced and 2.5km of each drain planted

Assumptions	*10m either side of stream retired, permanently fenced and vegetated; 2m either side of all drains retired, permanently fenced and 2.5km of each drain planted. Initial labour a cost not a benefit.*						**Levin Households 2001**		7293	**Interest**	10%
Year	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
COSTS											
Annualised cost of planted riparian		991	991	991	991	991	991	991	991	991	9912
Waiwiri Stream											
Opportunity cost	307464										
Fencing Stream (materials)	216776										
Weed control	127932										
Plants	483000										
Drains											
Fencing tributaries (materials)	732776										
Drain plants	249018										
Labour											
Stream fencing labour	159079										
Drain fencing labour	537740										
Stream planting labour	86400										
Drain planting labour	44545										
Total costs	2944731	991	991	991	991	991	991	991	991	991	9912
PV (total costs)	2944731	901	819	745	677	615	560	509	462	420	3822
BENEFITS											
Kaitiaki	83200	83200	83200	83200	83200	83200	83200	83200	83200	83200	832000
Soil retention	128891	128891	128891	128891	128891	128891	128891	128891	128891	128891	1288910
Stock loss	4251	4251	4251	4251	4251	4251	4251	4251	4251	4251	42510
Stock health	4251	4251	4251	4251	4251	4251	4251	4251	4251	4251	42510
2% chance of algal bloom		233376	233376	233376	233376	233376	233376	233376	233376	233376	233376
Change in tributary water quality		483861	483861	483861	483861	483861	483861	483861	483861	483861	483861
Management good		1232517	1232517	1232517	1232517	1232517	1232517	1232517	1232517	1232517	12325170
Vegetation to native species		700128	700128	700128	700128	700128					
Total benefits	220593	2870475	2870475	2870475	2870475	2870475	2170347	2170347	2170347	2170347	15248337
PV (total benefits)	220593	2609523	2372294	2156630	1960573	1782339	1225104	1113731	1012483	920439	5878894
PV (benefits minus costs) $	-2724138	2608622	2371474	2155886	1959896	1781724	1224545	1113223	1012021	920019	5875072
NPV ($)	**18,298,343**										

14.10 CBA of 10m riparian vegetation restoration of Waiwiri stream, all drains and tributaries fenced and planted, management fair only benefit.

I. 10m width, drains fenced and planted, management good only benefit.											
	10m either side of stream retired, permanently fenced and vegetated; 2m either side of all drains retired, permanently fenced and pla										
Assumptions	*Initial labour a cost not a benefit, and good management the only benefi*						**Levin Households 2001**		7293	**Interest**	10%
Year	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
COSTS											
Annualised cost of planted riparian		991	991	991	991	991	991	991	991	991	9912
Waiwiri Stream											
Opportunity cost	307464										
Fencing Stream (materials)	216776										
Weed control	127932										
Plants	483000										
Drains											
Fencing tributaries (materials)	732776										
Drain plants	326540										
Labour											
Stream fencing labour	159079										
Drain fencing labour	537740										
Stream planting labour	86400										
Drain planting labour	58412										
Total costs	3036120	991	991	991	991	991	991	991	991	991	9912
PV (total costs)	3036120	901	819	745	677	615	560	509	462	420	3822
BENEFITS											
Management good		1232517	1232517	1232517	1232517	1232517	1232517	1232517	1232517	1232517	12325170
PV(Management good)	0	1120470	1018609	926008	841826	765296	695724	632476	574978	522708	4751887
PV (benefits minus costs) $	-3036120	1119569	1017790	925264	841149	764681	695164	631967	574516	522287	4748065
NPV ($)	**8,804,331**										

14.11 CBA of 10m riparian vegetation restoration of Waiwiri stream, all drains and tributaries fenced and planted, local costs a benefit as an injection into local economy.

J. Injection into local economy, 10m width Rolls-Royce

Assumptions	*10m width rolls royce, with plants and labour an injection into local economy and hence a benefit to local economy. Other benefits include kaitiaki and management good.*						**Levin Households 2003**		*7293*	**Interest**	*10%*
Year	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
COSTS											
Operating costs (WRISS A10, 10)		991	991	991	991	991	991	991	991	991	9912
Waiwiri Stream											
Opportunity cost	307464										
Fencing Stream (materials)	216776										
Weed control	127932										
Drains											
Fencing tributaries (materials)	732776										
Total costs	1384948	991	991	991	991	991	991	991	991	991	9912
PV (total costs)	1384948	901	819	745	677	615	560	509	462	420	3822
BENEFITS											
Locally sourced plants											
Stream plants	483000										
Drain plants	326540										
Labour											
Stream fencing labour	159079										
Drain fencing labour	537740										
Stream planting labour	86400										
Drain planting labour	58412										
Kaitiaki	83200	83200	83200	83200	83200	83200	83200	83200	83200	83200	832000
Management good		1232517	1232517	1232517	1232517	1232517	1232517	1232517	1232517	1232517	12325170
Total benefits	1734372	1315717	1315717	1315717	1315717	1315717	1315717	1315717	1315717	1315717	13157170
PV (total benefits)	1734372	1196106	1087369	988518	898652	816957	742688	675171	613792	557992	5072659
PV (benefits minus costs) $	349423	1195205	1086550	987773	897975	816341	742128	674662	613329	557572	5068837
NPV ($)	**12,989,797**										

14.12 CBA of 10m riparian vegetation restoration of Waiwiri stream, all drains and tributaries fenced and planted, only benefit is an increase in rates of $1.00 per week per property.

L. 10m width, drains fenced and planted, only benefit is a $1.00 increase in rates per property per week.											
	10m either side of stream retired, permanently fenced and vegetated; 2m either side of all drains retired, permanently fenced and pla										
Assumptions	*Initial labour a cost not a benefit, and good management the only benefi*						**Levin Households 2001**		7293	**Interest**	10%
Year	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
COSTS											
Annualised cost of planted riparian		991	991	991	991	991	991	991	991	991	9912
Waiwiri Stream											
Opportunity cost	307464										
Fencing Stream (materials)	216776										
Weed control	127932										
Plants	483000										
Drains											
Fencing tributaries (materials)	732776										
Drain plants	326540										
Labour											
Stream fencing labour	159079										
Drain fencing labour	537740										
Stream planting labour	86400										
Drain planting labour	58412										
Total costs	3036120	991	991	991	991	991	991	991	991	991	9912
PV (total costs)	3036120	901	819	745	677	615	560	509	462	420	3822
BENEFITS											
$1.00 increase in rates		379236	379236	379236	379236	379236	379236	379236	379236	379236	3792360
PV ($1 increase in rates)	0	344760	313418	284926	259023	235476	214069	194608	176916	160833	1462119
PV (benefits minus costs) $	-3036120	343859	312599	284181	258346	234860	213509	194099	176454	160413	1458297
NPV ($)	**600,498**										