Restoration of Whaingaroa (Raglan) Harbour

Report prepared for Northland Regional Council

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Contents

Executive Summary

This report summarises initiatives undertaken in the Whaingaroa Harbour catchment to improve water quality and the ecosystem health of the streams and harbour. The report covers the objectives, approach taken, what has been achieved, funding/resources used, how successful the initiatives have been in restoring the Harbour and its catchment, some discussion on why improvements may not be seen yet and the relevance to Northland.

The catchment of the Whaingaroa Harbour covers 525 km^2 and is located west of Hamilton. The catchment is dominated by dry-stock farming. In recent years dairy farming has increased and some of the steeper farmland has been converted to plantation forestry. The Harbour has a range of water quality problems including high sediment, nutrient and bacterial loads. This impacts on the health of the harbour and limits community use.

The restoration of the Whaingaroa Harbour is multi-facated and has involved many organisations and approaches over the last 16 years, the most significant being the restoration work of Whaingaroa Harbourcare, the Whaingaroa Catchment Management Project, the development of the *Whaingaroa Environment Catchment Plan* and the upgrade of the wastewater treatment system in Raglan.

A survey in 1994 which found a quarter of shellfish sampled were contaminated with bacteria, combined with local concern about the poor and deteriorating state of the harbour led to Whaingaroa Harbourcare being established in 1995. The main aim of Harbourcare is to stop sediment runoff from land and improve water quality. They have focused on riparian management in the catchment.

In their own nursery they propagate and grow 100,000 native plants a year from eco-sourced seeds. They provide the plants and people to plant them for free to landowners in the catchment. Environment Waikato helps landowners with fencing costs. Whaingaroa Harbourcare built interest by starting with a demonstration site (Wainui Reserve) which shows landowners the economic as well as environmental benefits from riparian management. They have since completely fenced and planted this relatively small catchment (Wainui Stream) and have now started riparian restoration throughout the entire Whaingaroa Catchment. Harbourcare's philosophy has always been to work with landowners who want to do it.

Over the last 16 years, they have grown and planted one million native trees in total along streams and harbour edges. An estimated 450 kilometres (at least 25%) of riparian areas in the entire Harbour catchment have been fenced and planted. Since 1995, over $3.7 million has been spent on riparian planting and fencing in the catchment. This funding has come from a range of sources, including, but not limited to, Environment Waikato, Waikato District Council, NZ Lottery Grant, WWF, Department of conservation and WEL Energy Trust.

In March 1996 Environment Waikato and others secured funds from the Sustainable Management Fund for a three year community-based environmental management project in the Whaingaroa Catchment. The aims of the project were to establish a multi-stakeholder group and produce a community-based catchment environmental management strategy. The multi-stakeholder group was established and operated as an informal network for five years. In November 2001 they became an Incorporated Society, the Whaingaroa Environment Centre.

One of the Environment Centre's objectives is to adopt, promote and monitor the *Whaingaroa Environment Catchment Plan*. The Plan is a very extensive and comprehensive document that was completed in 2002. It has a broad overall vision that covers all four well-beings. It sets out catchment focus areas, goals, targets, indicators and projects. The most relevant is catchment focus area two: "*Looking after our soils and the water quality of our rivers and harbour*". The goal for this is "*Landowners in the Catchment will implement land* *use practices that protect soils and water*". The Plan proposes a timeframe of at least 25 years to reach the goals and regular review of the Plan itself. Although to date very little has been implemented from the Plan, it is likely to be used in Environment Waikato planning shortly and the Environment Centre intend to review it in the near future.

The Waikato District Council was required to upgrade the Raglan Wastewater Treatment System to obtain their resource consent renewal for the discharge, as the existing system was regularly non-compliant with consent conditions. The system upgrade was carried out between 2005 and 2008. The upgraded system uses natural processes to treat wastewater collected, including ultra violet light treatment. The final discharge is into the harbour and restricted to an outgoing tide. The quality of the final discharge is required to meet high estuarine water quality standards. More recently, work commenced to replace the pipeline from the treatment plant to the discharge point in the harbour and there is further work proposed to upgrade pump stations and pipelines, to reduce the number of discharges outside of the outgoing tide timeframe.

In the 2009/2010 year the wastewater discharge was fully compliant with the enterococci and faecal coliform resource consent conditions, a significant improvement on previous years, due to the UV sterilisation. However, non-compliance is still being reported for suspended solids (due to high algal biomass in treatment ponds) and biochemical oxygen demand. Investigations are underway to reduce algal biomass. The cost of the upgrade was approximately $6 million (including pipeline replacement) and at least a further $700,000 is budgeted for pump station and pipeline upgrades.

Overall, results from the limited data and research carried out in the catchment shows no significant improvements in water quality and health at the sites monitored in catchment waterways and the Harbour. There is in fact results that suggest stream water quality has deteriorated at the sites monitored, particularly in terms of nutrient, sediment and bacterial levels.

Results from macroinvertebrate monitoring suggest that stream health has deteriorated at some sites monitored, particularly Wainui Stream, which has had significant riparian restoration. The reasons for the deterioration of macroinvertebrate communities in Wainui Stream is unclear but could be attributed to one or several of the following: increases in land-use intensity (ie greater stocking rates or shifts from sheep and beef to dairy), increased residential development in catchment, localised streambank erosion due to channel widening (natural process when a stream's riparian margins are restored to forest), ecological responses may not occur until a water quality/stream health threshold is reached or localised climatic effects. Unfortunately there is no routine water quality monitoring of Wainui Stream. This highlights the complexity of detecting changes in water quality and ecosystem health and attributing the cause, especially without a specifically designed monitoring programme.

Estuarine monitoring shows that harbour health in terms of biota has stayed relatively stable and is reasonably healthy. However, sediment deposition has continued to occur and has in fact increased in recent years. Data suggests that the Raglan wastewater treatment system upgrade has led to improvements in the quality of the discharge. Unfortunately bacterial data for the Harbour is limited, so how much of an effect this has had in terms of improving bacterial levels in the Harbour is unknown. What limited data that is available shows no change over time.

There are several possible reasons why improvements in water quality or stream/harbour health have not been detected. There is often multiple stressors occurring simultaneously and ecological responses do not necessarily correspond to improvements in habitat quality or water quality. It is likely that an ecological response may not occur until a threshold in water quality and/or habitat quality is reached and improvements can take several years to decades to show. The effectiveness of riparian management varies and in most cases should be used in conjunction with other management practices.

Also the inability to detect improvements in the available data, does not mean that no improvements have occurred and is more likely a reflection of the limitations with the data used. There is anecdotal evidence of improvements in the ecosystem health of the Harbour, for example, seagrass bed regeneration; and Wainui Stream eg, increased whitebait catches and the presence of Lamprey. It is possible that there have been some localised improvements in water quality (ie, Wainui stream) but without adequate data this is unknown.

This reinforces the importance of a well-designed monitoring programme to measure the effectiveness of restoration efforts. It also highlights the importance of setting realistic objectives, clearly communicating to key stakeholders on how long it could take to achieve these objectives and reporting on progress.

Although Northland has many harbours and estuaries with similar water quality problems to Whaingaroa Harbour, there is several differences such as catchment geology, harbour characteristics, rainfall, ecology/biodiversity, community uses and pressures that would need to be considered when looking at the transferability of the restoration efforts in Whaingaroa to Northland.

Introduction and background

This report summarises substantial initiatives started since 1995 in the Whaingaroa Harbour catchment that aim to improve water quality and the health of the streams and harbour. The report covers the objectives, approach taken, what has been achieved and what funding and resources have been used for each initiative. Then using available data and research this report looks at whether these initiatives to restore the harbour have been successful. Finally there is some brief discussion of lessons learnt, why improvements have not yet been detected and the relevance of the Whaingaroa Harbour example to Northland.

The catchment of the Whaingaroa Harbour covers 525 km^2 and is located west of Hamilton. Over the last century indigenous vegetation has been cleared from more than half of the catchment. The catchment is dominated by dry-stock farming (sheep and cattle). However, in recent years dairy farming has increased and some of the steeper farmland has been converted to plantation forestry (Environment Waikato 2002).

The harbour itself is an enclosed harbour with a narrow exit to the sea (Figure 1) and 220 kilometres of shoreline. The Harbour is relatively efficient at flushing in one tidal cycle, meaning that contaminants are mostly taken out to sea (Environment Waikato 2002, Environment Waikato 2005a).

Figure 1: Map of Whaingaroa Harbour and the main contributing streams and rivers.

Problem prior to restoration

Many small streams draining the steep catchment margins join to form larger rivers such as the Waingaro, Kerikeri, and Waitetuna (Figure 1). The cumulative effects of naturally unstable soils, extensive and intensive farming results in many of the rivers being silted with high levels of harmful bacteria in their lower reaches (Environment Waikato 2002).

Waikato District Health Board carried out a survey of bacterial levels in shellfish collected from the Harbour in 1994 (Waikato District Health Board 1995). They found elevated bacterial levels in approximately 25% of the shellfish sampled. Based on the results, to reduce public health risks, they recommended that shellfish should not be collected from around the mouths of rivers at any time and shellfish should not be collected for five days after heavy rain.

Ministry for the Environment (2001) summarises the historical problems with water quality and harbour health:

1. Sediment inputs

The deforested steeper headwaters of the catchment are prone to erosion and contribute considerable quantities of sediment to the harbour. Streams monitored at Whatawhata, in terrain similar to the Whaingaroa catchment, showed that pastoral streams produce about 230 tonnes of sediment/km^2/year, while streams in native forest produce about 45 tonnes of sediment/km^2/year (Environment Waikato 2011a). Average water turbidity and clarity in Waingaro, Waitetuna, and Ohautira Streams are well in excess of what is considered satisfactory, and have been so since monitoring began in 1993.

2. Bacterial contamination

Bacterial concentrations in catchment streams and the upper Whaingaroa Harbour have periodically been very high, for example, enterococci counts of 60,000/100 ml in the Ohauiti Stream have been recorded.

3. Impacts of high sediment and bacterial levels

Sedimentation has a significant impact on marine life in the harbour and high bacterial levels pose a human health risk.

4. Nutrient inputs

Compared to the levels of sediment and bacterial contamination, nitrogen and phosphorus levels are only marginally poorer than satisfactory, ie, nutrient levels are moderate to high while bacterial and sediment levels are high to very high (see Appendix A for detail on guidelines used).

Introduction to restoration efforts

The restoration of the Whaingaroa Harbour is multi-faceted and has involved many organisations and approaches over the last 16 years, including:

- restoration work of Whaingaroa Harbourcare
- Whaingaroa Catchment Management Project
- development of the *Whaingaroa Environment Catchment Plan*
- upgrade of the wastewater treatment system in Raglan.

Whaingaroa Harbourcare

Whaingaroa Harbourcare was established in 1995 in response to local concern about the poor and deteriorating state of the Harbour. Several concerned locals organised a public meeting to discuss the issue and the outcome from the meeting was an incorporated society and a committee to operate it. From here the restoration of Whaingaroa Harbour began. Harbourcare was established prior to the Whaingaroa Catchment Management Project and were one of the key stakeholders for the Project.

Whaingaroa Catchment Management Project

In March 1996 Environment Waikato (supported by Waikato District Council, Landcare Research, NIWA, Whaingaroa Kite Whenua Trust, and Waikato University) secured funds from the Sustainable Management Fund (SMF) for a three year project to initiate a community-based environmental management project in the Whaingaroa Catchment. The project was to look at the transferability of the multi-stakeholder, holistic, ecosystem and community-based models developed under the Atlantic Coastal Action Programme in North America to New Zealand. The project was the first formal attempt in New Zealand at establishing community-based, integrated environmental management on a catchment scale.

Kilvington (1998) covers the approach taken in the Project. It includes whether project objectives were achieved, how effective the approach was towards achieving the objectives, strengths and weaknesses of the approach taken and factors contributing to the success or failure. The relevant key findings of Kilvington (1998) are included in this report.

Whaingaroa Environment Catchment Plan

The Plan is a very extensive and comprehensive document that was completed in 2002. Although it is an Environment Waikato publication the Plan currently sits with the Whaingaroa Environment Centre to implement (Environment Waikato 2002).

Raglan Wastewater Treatment System upgrade

The Waikato District Council holds resource consent to discharge up to 2600 m^3 of treated wastewater per day into the Raglan Harbour. The consent for the upgraded system was issued on 1 February 2005 (Environment Waikato 2009; Environment Waikato 2011b). The upgrade was carried out because:

- the community (particularly local iwi) wanted to see improvements to the system, in particular land disposal
- renewal of the resource consent for the discharge required an upgrade as the existing system (prior to 2005) was regularly non-compliant with consent conditions (R. Bax, Waikato District Council, pers. comm.).

Objectives

Whaingaroa Harbourcare

The main aim of the Harbourcare group is to stop sediment runoff from land and improve water quality (Whaingaroa Harbour Care 2011b). They have specifically restricted their aim to sediment to keep it simple and understandable; however, they are aware that their restoration efforts to reduce sediment will also work towards reducing other contaminants such as nutrients and bacteria (F. Lichtwark, Whaingaroa Harbourcare, pers. comm.) and therefore water quality overall.

Whaingaroa Harbourcares goal is to improve the quality of the water entering the harbour and by doing this hopefully improve the overall ecological state of the harbour. The group has decided to focus on what it considers will produce the most substantial and rapid improvements to water quality: the retirement of the harbour edge and the riparian margins of tributary waterways, gumland wetlands and the restoration of indigenous vegetation to those margins.

Whaingaroa Catchment Management Project

The aims of the project were to establish a multi-stakeholder group and produce a community-based catchment environmental management strategy. To develop the strategy the group of community stakeholders had to:

1. *agree upon issues affecting the sustainable management of natural and physical resources,*
2. *identify and direct investigations to clarify issues and/or cause and effect relationships,*
3. *initiate and support community-based action for achieving environmental objectives, and make recommendations to regulatory authorities for plan changes to achieve community objectives (Kilvington 1998).*

Whaingaroa Environment Catchment Plan

The Catchment Plan has an overall vision of:

> *The Whaingaroa Catchment will be a place where communities are healthy, vibrant and creative, adapting to social and economic changes, whilst maintaining healthy ecosystems, that provide livelihoods, sustenance and a sense of wellbeing and pride (Environment Waikato 2002).*

The Plan provides a framework of catchment focus areas, goals, targets, indicators and projects. There are four catchment focus areas that cover natural areas and wildlife, soils and water quality, fresh and saltwater fisheries and the development of town and rural areas.

The most relevant to this report is catchment focus area two: "*Looking after our soils and the water quality of our rivers and harbour*". The goal for this is:

> *Landowners in the Catchment will implement land use practices that protect soils and water.*

There are three targets for this goal:

1. Government Agencies and landowners are aware of the impacts of different types of land management on the environment and are encouraged to consider alternative management practices.

2. Government Agencies and landowners change their land management practices to those that have less detrimental impact on the soils and water in the Catchment.
3. District, Regional and National Government Agencies recognise the special natural values and recreational opportunities offered by land and water in the Whaingaroa Catchment and the need to sustain rural livelihoods. They support Catchment-based sustainable management initiatives.

There are many indicators and projects for these three targets. Two high priority projects for example are "*support the core functions of Whaingaroa Harbourcare as the key agency for habitat restoration in the catchment*" and "*support existing Care Groups in the catchment*" (Environment Waikato 2002).

Raglan Wastewater Treatment System upgrade

The Raglan system was upgraded to ensure wastewater quality continues to meet environmental requirements (Waikato District Council 2010a). As mentioned above the system prior to 2005 was regularly non-compliant with consent conditions and therefore to obtain the consent renewal an upgrade was required.

Approach taken

Whaingaroa Harbourcare

Harbourcare established a native plant nursery in Wainui Reserve. Fencing and planting was initially focused on Wainui Stream to create a demonstration site in Wainui Reserve (farm park managed by Waikato District Council). Initially Harbourcare approached well-known landowners in the catchment to fence off their riparian areas, which has advanced to where Harbourcare are now being approached voluntarily. Harbourcare's philosophy has always been to work with landowners who want to do it, in the timeframes that they want. Fencing and planting has now been started throughout the entire catchment including harbour and stream margins. In 2000, Harbourcare launched a 5-10 year strategic plan which included their overall approach to integrated catchment management, set priorities for riparian management and identified indicators for environmental improvement (Whaingaroa Harbourcare unpublished, Buchan 2007).

Harbourcare have promoted fencing and planting by emphasising the economic benefits to farmers. For example, reduced stock loss in wet areas, effects of parasites (eg, liver fluke) on stock, vet bills, soil loss and drain digger bills; increased land value and productivity, stock health and pasture quality. The demonstration site in Wainui reserve has shown that despite retiring and planting gullies and wet and steep areas (about one third of the area), the farm can now run almost double the number of cows it used to (Parliamentary Commissioner for the Environment 2004). Farmers have reported a 20% increase in milk production and greatly increased stocking rates and profits for sheep and beef farmers (Buchan 2007).

Riparian margin width

Initially riparian margins were created as wide as landowners would agree to, with the viewpoint that excluding livestock was better than nothing. However, now most riparian margins are at least seven metres wide. Seepage zones and riparian wetlands have also been fenced (Ministry for the Environment 2001).

Species selection and planting

Flax has been the main plant used in the fenced areas, with cabbage tree, manuka and karamu interspersed. Flax has been used because it is easy to produce (from seed or splitting mature plants), highly tolerant of a range of conditions and is largely not eaten by animal pests. All seed is eco-sourced locally. Plants are grown to a tall grade (50 cm or more) before planting to reduce plant mortality from competition with pasture species. There has been a 98% success rate with plantings to date (Bay of Islands Maritime Park Inc. 2009).

The primary aim with the initial round of planting is to establish a good cover of plant material (1 plant/m^2). Further planting is carried out in subsequent years as required to increase the diversity of species.

Planting and weed management

There is no formal weed control or plant maintenance plan. Sites are cleared prior to planting but post-planting maintenance only occurs where plant mortality is high. Kikuyu does invade riparian areas but is not a major problem (Bay of Islands Maritime Park Inc. 2009).

Other environmental management efforts

Although, Harbourcare have focused on riparian management because this is where they feel they can make the greatest gains they have also addressed other areas of concern in the catchment. For example, they have exerted pressure on the Waikato District Council to improve stormwater management (Ministry for the Environment 2001) and made submissions on regional policy documents (Buchan 2007, Whaingaroa Harbour Care 2011c).

Whaingaroa Catchment Management Project

Landcare Research were contracted to facilitate the establishment of a group that reflected the views of the various stakeholders within the catchment. The basis of the process was to cross traditional boundaries between formal (regulatory) and informal groups concerned with the management of a particular area, and to develop new relationships between different interest groups such as farming and fishing and those concerned primarily with issues of environmental health. It combined a top down and bottom up process, initiated and led by Environment Waikato and Landcare Research

Nine informal workshops were attended by community members from similar backgrounds (eg, recreational fishers, farmers, iwi) avoiding the potential for conflict and enabling participants to more freely express their views. The workshops were followed by an information day in November 1996 and a community meeting in March 1997. At this point, due to limited funding, Landcare Research stopped facilitating and the steering group (called Whaingaroa Environment) was formed. Kilvington (1998) reported that the steering group met regularly, convened public meetings to determine the future of the project, generated newsletters and engaged in a number of activities.

A key to the success of multi-stakeholder environmental management is that the community group established should represent the full range of interests within the catchment. The steering group has largely remained the same with some flexibility in membership as interest fluctuated with the various issues dealt with. The group has effective linkages with the main community sectors, including Whaingaroa Harbourcare, local schools and the farming and fishing sectors. However, they did not feel they were completely representative of the general community, particularly the northern end of the catchment and had concerns over the lack of iwi involvement in the process (Kilvington 1998).

The principal output of the project was the development of a catchment environmental strategy supported by community and local government. At the end of the Project (in terms of the life of the SMF funding) no strategy had been developed (Kilvington 1998). However, the multi-stakeholder group has remained active and since developed a strategy, the *Whaingaroa Environment Catchment Plan* (Environment Waikato 2002). For five years Whaingaroa Environment existed as an informal network becoming an Incorporated Society in November 2001, the Whaingaroa Environment Centre. One of the Centre's objectives is to adopt, promote and monitor the Plan.

Whaingaroa Environment Catchment Plan

This Plan came about because of the level of concern about what was happening to the environment in the catchment and the level of community motivation and action to do something about it. This was a result of the efforts of Whaingaroa Harbourcare and the steering group from the Whaingaroa Catchment Management Project. This community interest, initiative and commitment led Environment Waikato, with the support of Waikato District Council, NIWA and Mana Whenua, to support the development of a community based planning approach for the whole catchment under their Local Area Management Strategy (LAMS) programme (Environment Waikato 2002).

This plan was developed by Whaingaroa residents with assistance from Environment Waikato staff. It involved four years of collating information from and consultation with mostly the Whaingaroa community but also Environment Waikato, Waikato District Council and Department of Conservation. The plan was developed using the principles of Community-Based Environmental Management as defined in the Whaingaroa Catchment Management Project (Kilvington 1998). Therefore the Plan is very much what the community wants for the catchment and is not a council policy document (T. Balvert, Environment Waikato, pers. comm.).

The Plan proposes a timeframe of at least 25 years to try and reach the goals. The list of projects included in the Plan is a collection of actions already underway and new ones that can go ahead in the next two to three years. Within the Plan it recommends that the list of projects is reviewed annually to allow for support, promotion and implementation of new ideas and opportunities as they arise. It is also proposes to review the vision, goals, targets and indicators every three years to check they are still in line with the issues and community aspirations.

The Whaingaroa Environment Centre have adopted implementation of the Plan as one of their objectives as an incorporated society. However, this adoption does not imply exclusive ownership of the plan to the Environment Centre - they are merely guardians to ensure the plan stays alive. The Plan belongs to the whole community and can be used by any group or individual.

The Plan recommends that other stakeholder groups and key agencies should be approached to obtain formal endorsement of the Plan and its goals and vision. The Plan identifies that it is not a statutory document but that some kind of agreement in principle from agencies would be helpful.

Raglan Wastewater Treatment System upgrade

The system upgrade was started in 2005 and completed in 2008 (R. Bax, Waikato District Council, pers. comm.). The upgraded Raglan Wastewater Treatment System uses natural processes to treat wastewater collected from the Raglan community. Pre-screening removes solids, paper, plastics and material that will not pass through a 6mm screen. The wastewater then flows through a series of treatment ponds, which adds oxygen for the biological process of removing organic contamination. The treated effluent collects in a holding pond before passing through ultra violet (UV) light to sterilise bacterial pathogens (Waikato District Council 2011a).

The final discharge is into the harbour. Discharge times are restricted to an outgoing tide to ensure that tidal mixing is maximised. The quality of the final discharge is equivalent to high estuarine water quality standards (Table 1). Under consent conditions the point of compliance with the water quality standards is where the treated effluent enters the discharge pipeline (Environment Waikato 2011b). A display of the discharge flow rate can be viewed by the public on the outside of the UV building.

Table 1: Water quality standards set in the consent conditions for Raglan Wastewater Treatment Plant discharge (Environment Waikato 2011b).

Analyte	Median level does not exceed	Maximum level does not exceed
Suspended solids (SS)*	20 g/m^3	30 g/m^3
5-day biochemical oxygen demand (BOD_5)*	10 g/m^3	20 g/m^3
Faecal coliforms (FC)*	14 FC/100mL	43 FC/100mL
Enterococci (ENT)^	-	35 ENT/100mL

* For SS, BOD5 and FC the median level is for 12 consecutive monthly samples and the maximum level is for 9 out of 10 consecutive monthly samples.

^ For enterococci the maximum level is for 5 of 6 consecutive weekly samples collected between 15 December and 30 January.

The pipeline from the treatment plant to the discharge point in the harbour was more recently replaced. Work to replace the pipe commenced in May/June 2010 (Waikato District Council 2011a). This will reduce the instances when pumping will be required outside of the outgoing tide timeframe (R. Bax, Waikato District Council, pers. comm.). In 2009/2010 the council discharged outside the normal consented times (basically an outgoing tide) on 12 of the 20 days permitted by the resource consent (Waikato District Council 2010b).

Other organisations/groups

There are two other landcare groups that have contributed to stream restoration in the catchment in the last 10 years but more recently these groups have disbanded. The Waitetuna Streamcare Group carried out fencing and planting of stream banks in the Waitetuna area of the Whaingaroa Catchment (Environment Waikato 2011a). Waitetuna Streamcare received $1000 from the Transpower Landcare Trust Grant Programme in 2006 for their riparian work in the Waitetuna Catchment (Farmers Info 2006). Starting in 2002 the Waikowhai Streamcare Group carried out restoration work in the urban Waikowhai Stream Catchment in Raglan (Waikato Biodiversity Forum 2006). There is also the Whaingaroa Beachcare Group which aims to restore damaged dunes along the ocean and harbour foreshore in Raglan and reduce human damage.

Local schools have had substantial involvement in catchment restoration, including planting and monitoring of streams in the catchment (Bay of Islands Maritime Park Inc. 2009, Whaingaroa Environment Centre 2011).

Many other organisations and agencies have made contributions to the restoration work in the catchment, mainly through business as usual, including New Zealand Landcare Trust, QEII Trust, DairyNZ, New Zealand Federated Farmers and Fonterra. For example, New Zealand Landcare Trust held a two day community workshop in Raglan in April 2010 as part of a one year SMF funded project called "*Hooked on native fish*". The aim of the workshop was to introduce our native fish, the streams they live in and the catchments surrounding the streams. They also covered the benefits of riparian planting and examples of fish passage (New Zealand Landcare Trust 2010a, New Zealand Landcare Trust 2010b). Fonterra signed the Dairying and Clean Streams Accord with Environment Waikato in 2003.

What have they achieved?

Whaingaroa Harbourcare

Harbourcare have existed for over 15 years, they employ four full time staff during the growing and planting season and are now fully established as a self-sustaining society (F. Lichtwark, Whaingaroa Harbourcare, pers. comm.).

Since the Harbourcare group started in 1995:

- by 1999/2000, they had planted 50,000 plants mostly in the Wainui and Opotoru catchments and donated additional plants to farmers who had fenced their riparian margins (Environment Waikato 2011a)
- by 2001, more than 100,000 plants have been planted and over 100 kilometres of fencing established (Ministry for the Environment 2001)
- by October 2004, they were planting 100,000 plants a year and had planted nearly 650,000 plants in total (Parliamentary Commissioner for the Environment 2004)
- now in 2011, they have grown and planted one million native trees in total along streams and harbour edges within the catchment (Whaingaroa Harbour Care 2011b)
- more than 40 farmers have participated by fencing and planting an estimated 450 kilometres of riparian areas (Whaingaroa Harbour Care 2011a)
- more than 90% of landowners are doing or have done riparian management and at least 25% of the entire Harbour catchment has been fenced and planted (F. Lichtwark, Whaingaroa Harbourcare, pers. comm.).

The planting is reasonably well spread throughout the entire catchment, with the biggest effort in the Opotoru Estuary catchment (this includes Wainui Stream). Planting has been done in the Waitetuna, Te Uku, Waingaro, Te Akau and Ohautira catchments (F. Edwards, Whaingaroa Harbourcare, pers. comm.).

There has been a definite attitude and behavioural change in the wider community towards riparian management as a result of Harbourcare's efforts (Ministry for the Environment 2001 and Bay of Islands Maritime Park Inc. 2009).

In 2002 Harbourcare received a Green Ribbon Award from the Ministry for the Environment for their large-scale riparian management efforts. The restoration of the Whaingaroa Harbour and the work of Harbourcare are well known throughout New Zealand and are often used as an example of what can be achieved (Ministry for the Environment 2001, Parliamentary Commissioner for the Environment 2004, Gregory 2007, Buchan 2007, Bay of Islands Maritime Park Inc. 2009).

Whaingaroa Catchment Management Project

The Project was successful in terms of establishing a multi-stakeholder group called Whaingaroa Environment (now called Whaingaroa Environment Centre) that went a long way towards identifying catchment issues and investigations to clarify these and, as discussed above, although the strategy was not developed during the life of the SMF funding it has since been developed.

During the life of the SMF project the group organised and facilitated informal workshops, a number of community meetings and information days, attended events and produced newsletters, a website and public displays to promote community involvement and interest in environmental concerns and activities around the catchment. It was also noted in Kilvington (1998) that the group had played an important and successful role in promoting the activities of Harbourcare with residents and farmers who were less receptive to Harbourcare's work.

The Project has been successful in terms of increasing community involvement in and awareness of environmental management.

The multi-stakeholder group has remained active for over 14 years and became an incorporated society in 2001.

Whaingaroa Environment Catchment Plan

Although to date there has been very little implementation of the Plan, it is a comprehensive document that addresses all four well-beings, that is likely to be used and reviewed in the near future. Since the Plan was released in 2002 its main uses have been as a source of information for other publications and as evidence tabled at meetings to strengthen people's position on an issue within the catchment (F. Lichtwark, Whaingaroa Harbourcare, pers. comm.). The Plan has not yet been implemented as intended or reviewed and has not been formally endorsed by any other groups or agencies.

The Whaingaroa Environment Centre intends to review the Plan in the near future, possibly to simplify and shorten it (K. Parlane, Whaingaroa Environment Centre, pers. comm.). The Plan is also likely to be used by Environment Waikato shortly, as they have just established a Catchment Rating System for the West Coast Zone, which includes the Whaingaroa Catchment. A strategic plan will be developed for the zone which sets out the issues, needs, priorities and actions for the foreseeable future for the waterways in the zone. The existing Whaingaroa Environment Catchment Plan is likely to feed into this "zone plan" (T. Balvert, Environment Waikato, pers. comm.).

Raglan Wastewater Treatment System upgrade

In the 2009/2010 year the wastewater discharge was fully compliant with both the enterococci and faecal coliforms standards in the resource consent conditions, which was reported as a significant improvement on previous years, due to the UV sterilisation (Environment Waikato 2011b).

However, the suspended solid (SS) and biochemical oxygen demand (BOD_5) levels were not fully compliant (Environment Waikato 2011b). Median BOD_5 for 2009/10 was 12 g/m^3 similar to 11 g/m^3 in 2008/09 (consent condition is median does not exceed 10 g/m^3). Two high BOD_5 results were recorded of 24 g/m^3 in December 2009 and 26 g/m^3 in June 2010 (consent condition is maximum of 20 g/m^3). Median SS for 2009/10 was 75 g/m^3, up from 58.5 g/m^3 in 2008/09. The maximum recorded value was 130 g/m3 in December 2009 (consent condition is maximum of 30 g/m^3).

Algal growth in the roadside holding pond in summer is suspected to be the main cause for the high SS levels that exceed the standards. A project to trial an ultrasound device claimed to reduce algae levels was approved and installed in mid-September 2010 for a three month period (Environment Waikato 2011b).

Stormwater infiltration, causing wastewater overflows, still occurs in the upgraded system. For example, to reduce the risk of the ponds at the treatment plant overtopping due to heavy rain, the council had to discharge approximately 25,000 m^3 of treated wastewater outside the normal outgoing tide timeframes over six days in June 2010 (Waikato District Council 2010b) – the council is permitted to discharge outside of the outgoing tide on up to 20 days a year. A project is currently underway to increase wastewater pump station storage to minimise wastewater overflows and another project is programmed to start in the next two months which includes on-going replacement of wastewater pump stations and the pipe network (R. Bax, Waikato District Council, pers. comm.).

What funding and resources have been used?

Whaingaroa Harbourcare

In total, about two million dollars has been spent on riparian planting (excluding fencing costs) in the catchment since 1995 (F. Edwards, Whaingaroa Harbourcare, pers. comm.). This funding has come from a range of sources. The Lottery Grants Board and Environment Waikato provided initial one-off funding of about $60,000 to enable the group to construct the plant nursery. Since 2002 Environment Waikato has granted $40,000 per year to operate the nursery (T. Balvert, Environment Waikato, pers. comm.) and since June 2004 Waikato District Council has funded approximately $140,000 in total for weed and plant maintenance and the provision or planting of plants (R. Bax, Waikato District Council, pers. comm.). This funding covers the cost of employing full time staff during the growing and planting season, including an operational manager. However, over the 16 years there has also been substantial work carried out by unpaid workers, including Community Taskforce workers (a working scheme of the former New Zealand Employment Service) and community volunteers. Harbourcare also own a vehicle and trailer. Now that Harbourcare can generate its own income it has reduced its reliance on government funding and voluntary contributions (Ministry for the Environment 2001).

Environment Waikato provides funding towards fencing. Council staff meet with farmers to discuss buffer strips and fencing requirements, which since 2002 has been approximately 20 to 30% of a full time Land Management Officer (T. Balvert, Environment Waikato, pers. comm.). The council funds up to 35% of the fencing, alternative water supply and/or stock crossing costs. This requires the farmer to enter into a contract with the council which covers, for example, fence maintenance and indefinite stock exclusion from the riparian strip. Landowners are required to construct the fencing and can use their time (labour) to offset their 65% contribution towards costs. Whaingaroa Harbourcare provides the plants and the staff to put them into the ground to landowners for free. Since 2002 Environment Waikato has granted $593,639 to private landowners for riparian management, which has been predominately for fencing costs (T. Balvert, Environment Waikato, pers. comm.). As this is 35% of all costs (ie, cost of materials and labour), when combined with the landowners contribution the total cost of this work is in the region of $1.7 million.

The largest funders have been Environment Waikato, followed by Waikato District Council, Work and Income and the WEL Energy Trust (Buchan 2007). Funding has also been received from the Habitat Protection Fund (WWF – New Zealand) and Department of Conservation. Funding received from the Habitat Protection Fund although less than 10% of Whaingaroa Harbourcare's total funding package has been very important (Buchan 2007). There are very few agencies that allow funding to be used to cover employment. The WWF funding was used to top-up wages paid by Taskforce Green and later, the Community Employment Organisation Scheme.

Whaingaroa Catchment Management Project

The original proposal to the SMF included research on the harbour and its catchment to develop a better understanding of the biophysical processes occurring, and to provide better information on the environmental issues that had already been identified by the community (Kilvington 1998). However, SMF funding was only approved for the process of initiating a community-based management strategy (to a maximum of 20% of real costs); therefore no new biophysical research has been carried out within this project. The total SMF funding approved for the three years was $150,000 (E. Delahunty, Ministry for the Environment, pers. comm.). It is unclear whether all of this funding was actually used, given that the project did not meet all objectives within the project timeframe.

Other resources provided in the past include resources from Environment Waikato to produce newsletters, for small projects and staff to assist with facilitation and Waikato District Council has made office space available in the Raglan service centre. There have been concerns raised that the resources the Whaingaroa Environment Centre receives might be at the expense of funding more action-oriented work such as that undertaken by Whaingaroa Harbourcare (Kilvington 1998).

Whaingaroa Environment Catchment Plan

The development of the Plan was funded and supported by Environment Waikato as part of the development of a Local Area Management Strategy (LAMS) for the catchment however the exact cost of producing the plan is unknown. The majority of the cost is likely to be the in-kind time given by Raglan residents, Waikato District Council, Environment Waikato and Department of Conservation staff.

Raglan Wastewater Treatment System upgrade

The cost of the upgrade was in the order of $5.5 million, plus the more recent replacement of the discharge pipeline was $400,000 and at least a further $700,000 is budgeted to increase pump station storage and replace pump stations and pipelines (R. Bax, Waikato District Council, pers. comm.). This cost was solely met by Waikato District Council (through a loan) which is in turn covered by ratepayers and developers (R. Bax, Waikato District Council, pers. comm.). To help cover these costs Waikato District Council is proposing to increase targeted water and wastewater rates in Raglan from 1 July this year by $87 per year (Waikato District Council 2011b).

Has the restoration work been successful?

This section uses available data and research to determine whether there have been any changes in water quality or ecosystem health in both the harbour or stream catchments. Unfortunately, there is limited baseline data to compare more recent data to and there is no monitoring programme in place with the specific purpose of measuring the effectiveness of restoration efforts.

Harbour health

The Whaingaroa Harbourcare report substantial improvements in the health of the harbour on their website:

> *After a decade of riparian management, we've seen water quality improve dramatically in the Whaingaroa harbour. Whitebait catches have increased from 1/2 cup per day to 1/2 bucket per day. Likewise recreational fishing catches have improved. Mudflats previously barren of life are now teeming with crabs, shellfish & wading birds (Whaingaroa Harbour Care 2011a).*

There is also photographic evidence of the improvements, including natural regeneration of seagrass beds, for example:

Photo source: Whaingaroa Harbourcare

A MAF survey undertaken in 1990 found that on average, recreational fishers were catching one fish every 18 hours compared to surveys in 2006 that showed an average of one fish every two hours (Buchan 2007). In 1990 the local fish resource supported three commercial fisherman, by 2003 this had increased to eight (Buchan 2007).

Estuarine health

Environment Waikato have monitored five sites in the Whaingaroa Harbour routinely since April 2001 as part their Regional Estuary Monitoring Programme. Sediment characteristics and benthic macrofauna communities are monitored as indicators of estuarine health. They have looked at temporal changes in the sediments and macrofauna communities for the five year period from April 2001 to April 2006 (Environment Waikato 2008a). Their next trend analysis for a 10-year period will be carried out after April 2011. However, some results from the latest report (Environment Waikato 2010a) can be compared to the five year trends.

Between 2001 and 2006 sediment mud content increased at all five sites in Whaingaroa Harbour. The greatest increase was at the Haroto Bay site from an average of 6.6% to an average of 32%. The average proportion of mud in samples from Haroto Bay in October 2008 was 63% and in April 2009 was 54% (Environment Waikato 2010a), much higher than in 2006. At Okete Bay, sediment mud content has increased from 2.7% in April 2001 to 18.5% in October 2004 (Environment Waikato 2008a) and to 44% in October 2008 (Environment Waikato 2010a). Environment Waikato (2008a) contributes these significant increasing trends in mud levels to an increase in catchment run-off (presumably an increase of sediment in catchment run-off). Both of these sites are located in a sheltered arm of the Harbour and therefore less-exposed to wave action and more susceptible to sediment accumulation (Environment Waikato 2005a).

Both total organic carbon content and total nitrogen levels in sediment showed fluctuations at all sites between 2001 and 2006, but no clear increasing or decreasing trends (Environment Waikato 2008a)

The lowest abundances of macrofauna individuals were found at the two sites with the highest sediment mud content (Haroto Bay and Okete Bay). The differences in macrobenthic community assemblages between monitoring sites was found to be related to sediment mud content. However, at all sites in the Harbour at least some indicator species known to be intolerant to higher sediment mud content were found and no clear declining trends in sensitive species were observed over time. Environment Waikato (2008a) concludes that at some sites in Whaingaroa Harbour, macrobenthic diversity and abundance are likely to be adversely affected by sediment mud content, but levels of fine sediment have not yet reached levels where all sites, or all sensitive species, are affected.

Catchment water quality

Three sites in the catchment are routinely monitored as part of Environment Waikato's State of the Environment River Monitoring Programme. They are Ohautira Stream, Waingaro River and Waitetuna River. The sites are all located in the lower reaches of these three rivers. These sites have been sampled monthly since January 1993 and are sampled for a range of analytes such as temperature, oxygen, pH, conductivity, clarity, nutrients and bacterial levels (only tested every three months).

Comparison of water quality with guidelines

The number of samples meeting Environment Waikato's guidelines for satisfactory and excellent water quality from 1993 to 2010 at each of the three sites was assessed (see Appendix A for guidelines used and Appendix B for results). Many of the results are irrelevant; however there are a few points worth noting.

Ammoniacal nitrogen levels met the excellent guideline of 0.1 mg/L (which is based on levels toxic to biota) on all sampling occasions at all sites in all years, except one sample in 2008 for Waingaro and Waitetuna sites.

Clarity is poor at all three sites and shows no sign of improvement over time. At Ohautira clarity levels did not meet the satisfactory guideline of 1.6 metres (which is based on visibility for recreational use) on any sampling occasion over the 18 years; at Waingaro it met the guideline on nine sampling occasions in total and at Waitetuna on 12 occasions.

The number of samples meeting the satisfactory guidelines for total nitrogen and total phosphorus (which are based on levels that lead to nuisance plant growth) fluctuates over the 18 years for all three sites and like clarity shows no sign of improvement over time (Figures 2, 3 and 4).

If you only consider the nutrient (excluding ammoniacal nitrogen), bacteria (*Escherichia coli)*, clarity and turbidity results the water quality at all three sites is satisfactory to below satisfactory on all sampling occasions over the 18 years, except one sample in 1998 for total nitrogen which met the excellent guideline at all three sites.

The number of samples meeting the guidelines for temperature (which are based on temperatures for fish spawning) fluctuates over time and shows no sign of improvement for all three sites. All sampling occasions for the Ohautira and Waitetuna sites met the satisfactory guideline of 80% dissolved oxygen saturation (based on oxygen levels required for aquatic biota) over the 18 years. However, in terms of the excellent guideline of 90% at these two sites and Waingaroa compared to either guideline, the number of samples meeting the dissolved oxygen guidelines fluctuates over time and shows no sign of improvement.

Figure 2: Percentage of samples at Ohautira Stream site meeting Environment Waikato's "satisfactory" guidelines for total nitorgen and total phosphorus.

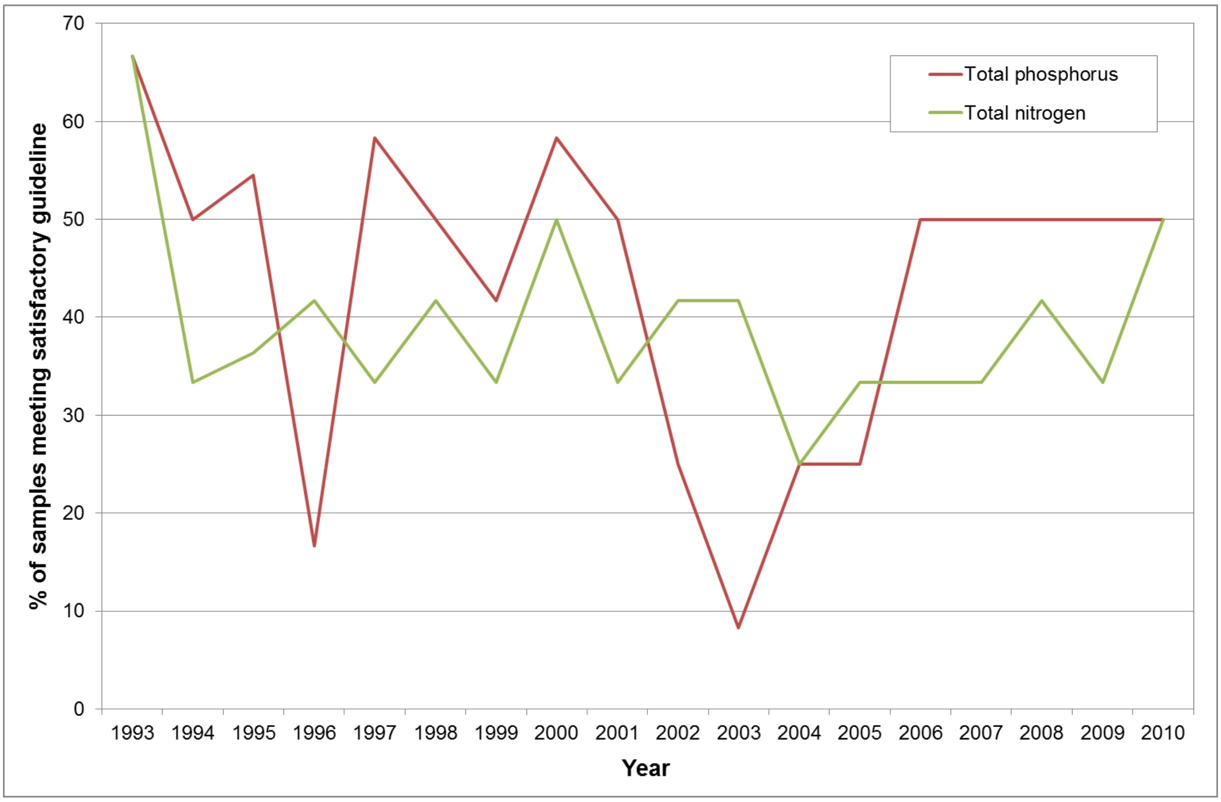

Figure 3: Percentage of samples at Waingaro River site meeting Environment Waikato's "satisfactory" guidelines for total nitorgen and total phosphorus.

Figure 4: Percentage of samples at Waitetuna River site meeting Environment Waikato's "satisfactory" guidelines for total nitorgen and total phosphorus.

Trends over time

A trend analysis on all suitable data from the three water quality sites was carried out to look for significant changes in water quality over time (see Appendix C for trend methods used and Appendix D for detailed results).

For the majority of analytes at the three sites there was no significant trends detected (Table 2). Overall, of the 18 statistically significant (*p-value* < 0.05) trends found, more were deteriorating trends in water quality (11) than improving (6). Of the significant trends if only those that have a rate of change greater than 1% of the median per year are considered environmentally meaningful, then of eight trends five are deteriorating and three are improving. This is consistent with what Environment Waikato (2008b) found for data up to 2007.

The three improving trends were for dissolved colour at all three sites. Environment Waikato (2008b) suggests that the decreases are a result of the historic drainage of wetland areas:

> *"Drainage associated with historic catchment development may have caused a reduction in the export of dissolved organic carbon from areas of drained wetlands, such that we are currently seeing part of the tailing-off in the loads of these highly-coloured compounds. While the overall decrease in dissolved colour may therefore represent an improvement in visual water quality, it may result from a deterioration in wetland condition."*

Environmentally meaningful increasing trends were found for both total nitrogen and nitrate-nitrite nitrogen (NNN) at the Ohautira site. Environment Waikato (2008b) concluded many of the increases in nitrogen in rivers throughout the Waikato region are likely to be a result of increased leaching losses from pastoral farmland following intensification in recent decades.

Environmentally meaningful increasing trends were found for NNN, enterococci and turbidity in Waitetuna River. Interestingly, Waitetuna River flows into the inlet where the sites with the highest proportion of mud content and large increases in this mud content over time were found as part of the estuarine monitoring programme (Okete Bay and Haroto Bay sites). The increasing trend in turbidity levels supports the conclusion that there has been an increase in sediment entering the Harbour (particularly in this area) through catchment run-off.

Table 2: Summary of trend results. Red arrow indicates deteriorating trend, blue arrow indicates improving trend. Two arrows is a statistically significant and environmentally meaningful trend, while one arrow means the trend is statistically significant but not necessarily environmentally meaningful (ie the rate of change is small). Dash indicates no significant trend. NS = not sampled. Note: it is unclear whether an increase in pH is an improvement or deterioration.

Analyte	Ohautira Stream	Waingaroa River	Waitetuna River
Temperature	–	–	–
Dissolved oxygen (% saturation)	↓	↑	↓
Dissolved oxygen (mg/L)	–	↑	–
Conductivity	–	–	–
Clarity (m)	–	–	↓
Turbidity	–	–	↑↑
Dissolved colour (G340)	↓↓	↓↓	↓↓
pH	–	↑	–
Ammoniacal nitrogen	↓	–	–
Nitrate-nitrite nitrogen (NNN)	↑↑	↑	↑↑
Total nitrogen	↑↑	↑	↑
Dissolved reactive phosphorus	–	–	–
Total phosphorus	–	–	–
Escherichia coli	–	NS	–
Enterococci	–	NS	↑↑
Faecal coliforms	–	NS	–

Assessment of riparian management effectiveness

Parkyn et al. (2003) assessed nine riparian management sites in the Waikato region in March 2000. The sites had been fenced and planted for periods ranging from 2 to 24 years. Each site was compared to unplanted control reaches upstream or to nearby streams where the riparian zone was grazed by livestock. Two of these sites were in the Whaingaroa Catchment.

Overall, they found the fenced and planted sites showed quite a few improvements compared to the unplanted control sites and that improvements could occur quite quickly. However, responses were variable across streams (Parkyn and Davies-Colley 2003). In general, the fenced and planted sites showed rapid improvements in visual water clarity and channel stability, but nutrient and faecal contamination responses were variable. Macroinvertebrate community health only improved at three of the nine sites. Improvement in macroinvertebrate communities was strongly linked to decreases in water temperature, suggesting that restoration of in-stream fauna would only be achieved after canopy closure, with long buffer lengths, and protection of headwater tributaries (Parkyn et al. 2003).

The first planted site in the Whaingaroa Catchment was a small cobble-bottomed stream (named Raglan) which had only been fenced and planted with natives for two years. There was a 200m length of riparian planting with an average width of 12.7 metres. At this site both total nitrogen and dissolved reactive phosphorus was at least 10% lower at the planted site and stream bank and channel stability was better than at the unplanted control site. However, faecal inputs (*Escherichia coli*) were over 70% higher at the planted site. Parkyn et al. (2003) suggest that this could be as a result of faecal contamination being stored in stream bottom sediments and released during disturbance events. There was no difference in clarity, water temperature and macroinvertebrate community health between the planted and unplanted sites (Parkyn et al. 2003).

The other site in the Whaingaroa Catchment was the soft-bottomed Waitetuna Stream which had been fenced and planted with willows for six years. The length of riparian planting was 1.6 kilometres and the average width was 7.2 metres. At this site there was no difference in dissolved reactive phosphorus, temperature, stream stability and macroinvertebrate community health between the planted and unplanted sites (Parkyn et al. 2003). Total nitrogen was over 30% higher and clarity was 20% lower at the planted site compared to the control. Parkyn et al. (2003) suggest that the increases in nutrients could be as a result of a loss in the stream’s nutrient processing ability with reduced periphyton and macrophyte growth associated with more shade.

Catchment stream health

Local observations of the Wainui Stream suggest that stream life has already increased noticeably (Ministry for the Environment 2001). For example, the Lamprey, which is a rare species that will not survive with sedimentation, is now present in streams in the catchment (Bay of Islands Maritime Park Inc. 2009) and whitebait catches had increased in 1999 (Whaingaroa Harbourcare unpublished).

Macroinvertebrate community health

Environment Waikato monitors macroinvertebrates at three sites in the Whaingaroa Harbour catchment annually as part of their Regional Ecological Monitoring of Streams programme. The sites are Wainui Stream at Wainui Reserve, Waitetuna Stream at Ohautira Road and Mangaokahu Stream at Cogswell Road. These sites have been monitored since 1996. Trends over time have been assessed for two periods: 1996 to 2005 (Environment Waikato 2006) and 1996 to 2007 inclusive (Environment Waikato 2010b). The graphs from Environment Waikato 2006 and 2010b reports are available in Appendix E.

For the Wainui Stream site, which is the stream that has had the most restoration work carried out on it, the monitoring site is located in an area fenced and planted with native riparian vegetation. Of the four indicators of macroinvertebrate community health assessed by Environment Waikato (2006) two were stable, one showed a "possible decline" and the other a "probable decline" between 1996 and 2005 (Environment Waikato 2006).The results for the 1996 to 2007 period were similar (Environment Waikato 2010b) with one of three indicators showing a stable trend, one a definite decline and the other a "probable decline".

Three other sites in Environment Waikato's monitoring programme (outside of Whaingaroa Catchment) had improvements in habitat quality that showed corresponding improvements in ecological condition. It is unclear why ecological condition (based on the macroinvertebrate indicators) has declined at the Wainui site when habitat quality (through riparian planting) has improved. It could be that a threshold needs to be passed in terms of water quality before an ecological response will occur (Environment Waikato 2010b). Unfortunately there is no long-term water quality dataset for this stream. However, there is some evidence that residential development in the catchment increased between 2002 and 2007 (Environment Waikato 2010b) and as discussed above, Parkyn et al. (2003) found ecological responses may be dependent on having long buffer lengths with canopy closure and protecting headwater tributaries. There is also evidence that stream channels widen following riparian planting as Environment Waikato (2010b) discuss:

> *"riparian planting can initially lead to a period of bank instability and potentially declining ecological condition from sedimentation until a new 'shaded' channel morphology is achieved (Davies-Colley 1997; Collier et al. 2001). In support of this, local reports suggest that stream widening has occurred".*

Environment Waikato (2010b) also highlight that a declining trend was detected at a nearby reference site which may indicate that a larger-scale phenomena unrelated to human factors may be influencing changes in macroinvertebrate communities, such as localised climatic events.

The Waitetuna Stream site fluctuated over time but showed no statistically or ecologically significant increasing or decreasing trends for all indicators for both time periods (Environment Waikato 2006, Environment Waikato 2010b). The Mangaokahu site also fluctuated over time and although two of four indicators showed declining trends for the 1996 to 2005 (Environment Waikato 2006), there was no significant trends for the 1996 to 2007 period (Environment Waikato 2010b).

Recreational water quality

Environment Waikato has sampled two sites in Whaingaroa Harbour as part of their Recreational Bathing Monitoring Programme, usually every second summer: Motor camp (Putoetoe Point) and Ngarunui Beach. Unfortunately, this sampling was stopped after the 2008/09 summer.

At the two sites bacterial water quality is predominately excellent and suitable for recreational use the majority of time (Environment Waikato 2011c, Environment Waikato 2011d). There is no clear change over time in summer recreational water quality between 1994/95 and 2008/09 at the two sites sampled (Table 3 and Figures 5 and 6).

Table 3: Median enterococci reading for the two recreational bathing sites sampled in Whaingaroa Harbour for each summer between 1994/95 and 2008/09. NA = Not sampled.

	94/95	95/96	96/97	00/01	02/03	04/05	06/07	08/09
Motor camp	4	1	3.5	3.5	3.5	5	2.5	4.5
Ngarunui Beach	NS	NS	1	1	1	1	1	1

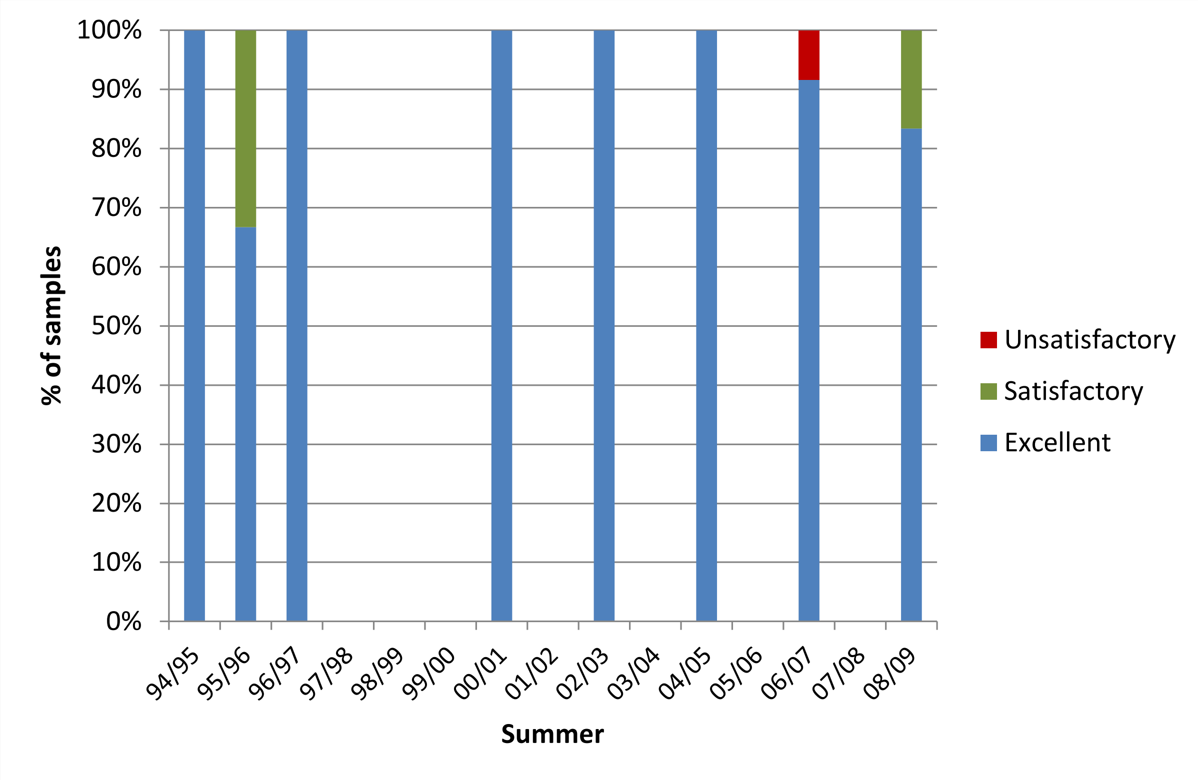

Figure 5: Percentage of samples each summer that meet Environment Waikato guidelines for recreational water quality (See Appendix A) at the Motor camp site. Number of samples per summer is 12, except for 1994/95 is 10 samples, 1995/96 is 3 and 1996/97 is 8 samples.

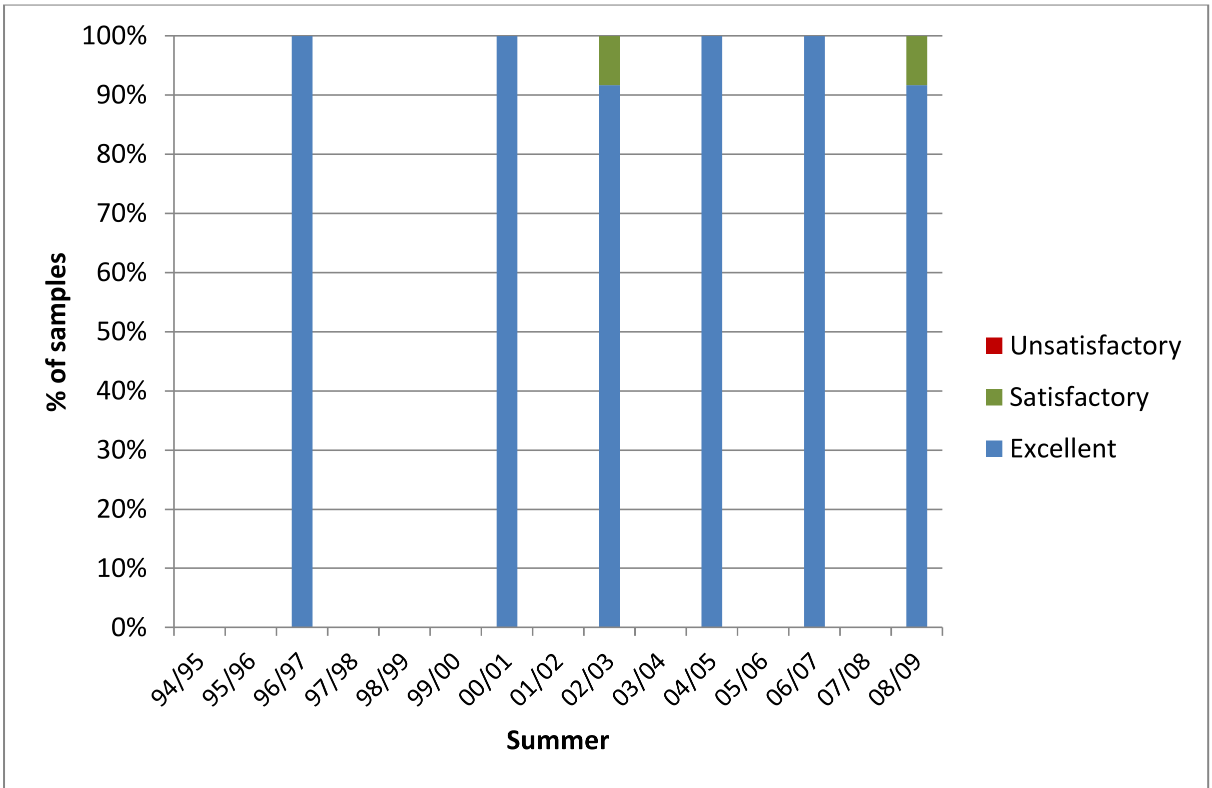

Figure 6: Percentage of samples each summer that meet Environment Waikato guidelines for recreational water quality (See Appendix A) at the Ngarunui Beach site. Number of samples per summer is 12, except for 1996/97 is 8 samples.

Discussion

Lessons learnt

A consistent theme throughout all of these restoration facets is the lack of accurate baseline information and an on-going monitoring programme in the catchment specifically designed to measure success (Ministry for the Environment 2001, Environment Waikato 2002, Kilvington 1998, Buchan 2007). Kilvington (1998) highlights this as a weakness for the Whaingaroa Catchment Management Project several times in her report, for example:

> *"Science and research input into resolving fundamental questions about ecosystem health and management is a founding element of the ACAP process. In the Whaingaroa Catchment Management Project this element was lacking with a result that anecdotal and speculative claims could not be verified or supported."*

For a project to progress effectively there needs to be clear objectives from the start. Lack of clarity over objectives and priorities in the Whaingaroa Catchment Management Project led to cyclic discussions at meetings, a perceived failure to maintain public interest and made it difficult to obtain and utilise funding/resources (Kilvington 1998). It is important to identify the values that the community want to restore so that clear objectives can be set and management actions that will lead to these objectives being met can be identified and prioritised. The *Whaingaroa Environment Catchment Plan* does this to a certain degree.

Delays in progress and/or collapse can occur when too much is trying to be achieved. For example, in part, the Plan has not been implemented to date because it is too long and complex, it has too many actions in it and the actions need better prioritisation (K. Parlane, Whaingaroa Environment Centre, pers. comm.). There have been other stream care groups start up in the catchment that have not survived. It is unclear why, but part of Whaingaroa Harbourcare's success can be attributed to the fact that they started off small (ie, they focused on one relatively small stream) and grew from there.

The success of all the above work, at least in part, is due to the on-going commitment and time given by a couple of people for the entire 16 years (M. Frank, Whaingaroa Harbourcare, pers. comm.). It was highlighted by the steering group in the Whaingaroa Catchment Management Project that a paid coordinator was a critical need (Kilvington 1998).

Why have improvements not been detected yet?

It is far from ideal to use the available monitoring data to measure the success of restoration efforts in the Whaingaroa Harbour catchment, however, other than visual observations (anecdotal evidence), this is currently the only way possible. However, the available monitoring data does show that changes in water quality and ecological data are complex. There is often multiple stressors occurring simultaneously and ecological responses do not necessarily correspond to improvements in habitat quality. It is likely that an ecological response may not occur until a threshold in water quality and/or habitat quality is reached and improvements can take several years to decades to show. The effectiveness of riparian management varies and in most cases should be used in conjunction with other management practices. These points are discussed in more detail below.

Effectiveness of riparian management

Different riparian vegetation types can be used depending on what is trying to be achieved. For example, grasses and sedges are more effective at stabilising banks and filtering phosphorus than trees and shrubs, while trees are important for creating canopy cover to shade the stream and provide leaf litter to the stream system (Ministry for the Environment 2001, Harding et al. 2004, Ministry of Agriculture and Forestry 2004). Therefore, if your objectives are to improve stream water quality and reduce contaminants reaching the estuary than a strip of grasses on the stream bank is most likely required, while if your aim is to improve stream ecosystem health than riparian trees are important. A diversity of riparian plants including different species, sizes and forms, with different leaf shapes will improve the food available to instream fauna (Collier and Winterbourn 2000, Ministry for the Environment 2001). Shade from riparian vegetation is likely to be more effective at regulating temperature in smaller headwater streams, which are more susceptible to heating and riparian vegetation has little shading effect in stream channels wider than 15 - 20 m (Harding et al. 2004).

Research has shown that there is a period of bank instability, as riparian vegetation shifts from grass dominated to trees and shrubs, the stream channel naturally widens to its original forested width - in some cases this could take as long as 25 years (Davies-Colley 1997, Auckland Regional Council 2001a, Ministry for the Environment 2001, Harding et al. 2004, Ministry of Agriculture and Forestry 2004, Environment Waikato 2010b). If a period of erosion is acceptable while the channel widens then shade levels approaching 90% will result in light and temperature conditions close to native forest levels. If not acceptable, shade levels should be no higher than 50-70%. Shade levels of less than 70% will also retain some instream macrophyte growth, which is important substrate for invertebrate colonisation in sandy bottomed streams (Ministry for the Environment 2001).

As discussed earlier, riparian shading has also been shown to reduce the nutrient attenuation within the stream reach as instream plants are shaded out, leading to nutrient levels staying the same or increasing after riparian planting (Auckland Regional Council 2001a, Parkyn et al. 2003, Harding et al. 2004, Ministry of Agriculture and Forestry 2004). To negate the impacts of this and the natural widening of the stream channel, it is recommended that riparian planting is best started in the headwaters and moved down the catchment (Auckland Regional Council 2001a, Harding et al. 2004).

In many cases, riparian management alone will not be entirely successful. For example, riparian vegetation and stock exclusion can reduce phosphorus and sediment inputs but is less effective at filtering nitrogen and faecal contamination (Auckland Regional Council 2001b, Ministry for the Environment 2001, Ministry of Agriculture and Forestry 2003, Harding et al. 2004, Ministry of Agriculture and Forestry 2004, Collins 2005). Nitrogen is most effectively managed on the farm with best management practices eg, nutrient budgeting.

Delayed response to restoration efforts

It may take several years, even decades, before improvements are seen in water quality and/or stream/harbour ecosystem health following riparian restoration. The time it takes to see improvements varies greatly from one catchment to the next, depending on many factors such as land use intensity, riparian strip width and length, riparian vegetation type and catchment topography and geology. Research has shown that it can be at least 20 years before improvements are seen in some water quality analytes and biological communities (Collier and Winterbourn 2000, Auckland Regional Council 2001b, Ministry for the Environment 2001, Harding et al. 2004, Ministry of Agriculture and Forestry 2004) and for some analytes, as discussed above, riparian management alone may never be enough.

There is evidence that there are critical levels for most contaminants. For example, low levels of nutrients can benefit stream systems by increasing primary and secondary productivity without substantially changing invertebrate community structure but above a critical level negative impacts start to occur (Collier and Winterbourn 2000, Harding et al 2004). It is likely that the reverse happens following restoration, in that a threshold has to be reached with respect to improvements in water quality before an ecological response will occur (Environment Waikato 2010b).

On top of all this, sedimentation in estuaries will continue until sediment inputs from the catchment is less than the estuary sediment flushing rate to sea. Although sediment inputs into catchment streams may have been reduced through riparian planting, transport of sediment already settled on the streambed down these catchments into the estuary will continue for several years. Again this varies from catchment to catchment and is dependent on many factors (Auckland Regional Council 2001a, Harding et al. 2004, Environment Waikato 2005b).

With all this in mind it is not completely surprising that improvements in water quality or stream/harbour health have not yet been detected when using the available monitoring data for the Whaingaroa Catchment. This reinforces the importance of a well-designed monitoring programme to measure the effectiveness of restoration efforts. It also highlights the importance of setting realistic objectives, clearly communicating to key stakeholders on how long it could take to achieve these objectives and reporting on progress (Harding et al. 2004, Ministry for the Environment 2001).

Relevance to Northland

Northland has 14 harbours and many smaller estuaries, most of which have similar water quality problems to Whaingaroa Harbour, including high sediment and nutrient inputs and faecal contamination (Northland Regional Council 2008). However, there are potentially several differences such as catchment geology, harbour characteristics, rainfall, ecology/biodiversity, community uses and pressures that need to be considered when looking at the transferability of the restoration efforts in Whaingaroa to Northland. Some examples are provided below.

Whaingaroa Harbour is relatively small (33 km^2), shallow, the mean freshwater input is small and the flushing is relatively efficient with an estimated residence time of 1.1 days (Environment Waikato 2005a) compared to some of Northland's Harbours. For example, Whangarei Harbour is 100 km^2 and has a residence time ranging from 24 days in winter to 120 days in summer (Biosecurity New Zealand 2006). All of Northland's major rivers discharge into harbours, providing very high freshwater input in areas of limited mixing (Northland Regional Council 2008).

Northlands warm climate and high rainfall provides ideal conditions for weeds and pests (Northland Regional Council 2008), for example, Whaingaroa Harbourcare have not found kikuyu to be an issue with their plantings, while this is often problematic in Northland.

One significant difference is the prevalence and importance of the aquaculture industry in Northland, while there is none in Whaingaroa Harbour. There is over 700 hectares of marine farms scattered throughout Northland's harbours (Northland Regional Council 2011a) and for this industry one of the greatest concerns is faecal contamination. While Whaingaroa Harbourcare have focused on reducing sediment inputs in catchment run-off through riparian management and the Raglan Wastewater Treatment System has been upgraded, both of which will go a long way to reducing faecal inputs, there is other potential sources of faecal contamination. For example, onsite wastewater systems (septic tanks) and farm dairy effluent discharges, both of which are significant pressures in Northland (Northland Regional Council 2008).

In terms of the approach taken in Whaingaroa there is no clear reason why it would not be successful in Northland. There is already several examples of Landcare Groups, community driven projects and other initiatives in Northland that have achieved substantial restoration gains on the ground, some even with corresponding improvements in water quality. For example, the Lake Omapere Management and Restoration Project led to significant improvements in lake water quality through intensive integrated catchment management (Ministry for the Environment 2010). Some initiatives in Northland are very similar to the approach taken by Whaingaroa Harbourcare. For example, a plant nursery in Waipu established an annual scheme in 2007 to provide native plants free to people in Northland as long as the primary purpose of the planting is to improve the environment. This year there are 8000 plants available, for which Northland Regional Council has contributed about $6000 (Northland Regional Council 2011b).

Conclusion

Since 1995, there has been four major restoration initiatives in the Whaingaroa Catchment that collectively are working towards improving water quality and the health of the Harbour. They are the restoration work of the Whaingaroa Harbourcare group, the Whaingaroa Catchment Management Project, the development of the *Whaingaroa Environment Catchment Plan* and the upgrade of the wastewater treatment system in Raglan. Since 1995, collectively these initiatives have cost over ten million dollars in total and hundreds of hours every year of inkind time from the Whaingaroa Harbourcare and Environment Centre members, council staff, the Raglan community, farmers and others.

Overall, results from the limited data and research carried out in the catchment shows no significant improvements in water quality and health at the sites monitored in catchment waterways and the Harbour. There is in fact results that suggest that water quality has deteriorated in three catchment streams at the sites monitored, particularly in terms of nutrient, sediment and bacterial levels. However, these sites are in the lower reaches of these catchments and therefore substantial areas of riparian management are required before any changes may be detected. There are also results that suggest there has been a deterioration in stream ecosystem health at some monitored sites, in particular Wainui Stream, which has had significant riparian restoration. This highlights the complexity of detecting changes in water quality and ecosystem health and attributing the cause, especially without a purpose designed monitoring programme.

Estuarine monitoring shows that harbour health in terms of biota has stayed relatively stable and is reasonably healthy. However, sediment deposition has continued to occur and has in fact increased in recent years. Data suggests that the wastewater treatment system upgrade has led to improvements in the quality of the discharge. However, how much of an effect this has had in terms of improving bacterial levels in the Harbour is unknown. What limited data that is available shows no change over time.

There are several possible reasons why improvements in water quality or stream/harbour health have not been detected in the available data. The effectiveness of riparian management varies depending on what objectives are trying to be achieved and in most cases should be used in conjunction with other management practices to be successful. There is often multiple stressors occurring simultaneously and ecological responses do not necessarily correspond to improvements in habitat quality or water quality. It is likely that an ecological response may not occur until a threshold in water quality and/or habitat quality is reached and improvements can take several years to decades to show.

Also the inability to detect improvements in the available data, does not mean that no improvements have occurred and is more likely a reflection of the limitations with the data used. There is anecdotal evidence of improvements in the health of the Harbour, for example, seagrass bed regeneration; and Wainui Stream eg, increased whitebait catches and the presence of Lamprey. It is possible that there has been some localised improvements in water quality (eg, in Wainui stream) but without data this is unknown.

The lack of baseline data and a monitoring programme specifically designed to measure the effectiveness of restoration is one of the few limitations with the initiatives that have been carried out in Whaingaroa. The report findings also highlight the importance of setting realistic objectives, clearly communicating to key stakeholders on how long it could take to achieve these objectives and reporting on progress.

Although Northland has many harbours and estuaries with similar water quality problems to Whaingaroa Harbour, there are several differences such as catchment geology, harbour characteristics, rainfall, ecology/biodiversity, community uses and pressures that would need to be considered when looking at the transferability of the restoration efforts in Whaingaroa to Northland.

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Appendix A: Guidelines used

Score system used in Ministry for the Environment 2001

The scale used for categorising water quality in the Ministry for the Environment 2001 publication is as follows (see page 135 of Ministry for the Environment 2001 for more detail):

Bacteria

Enterococci (n/100ml): >6 = moderate; >33 = high; >150 = very high.

Faecal coliforms (n/100ml): >40 = moderate; >200 = high: >1000 = very high.

Nutrients

Nitrate (g/m^3): >0.1 = moderate; >0.5 = high; >2 = very high.

Total phosphorus (g/m^3): >0.01 = moderate; >0.04 = high; >0.1 = very high.

Sediment

Turbidity (NTU): >2 = moderate; >5 = high; >10 = very high.

Suspended solids (g/m^3): >4 = moderate; >10 = high; >20 = very high.

Environment Waikato guidelines for catchment water quality

There are two guideline values for each analyte. The less stringent values define water that is "satisfactory" for the desired use (Environment Waikato 2010c). These are mostly based on existing national and other guidelines and standards.

Table 4: Environment Waikato guidelines and standards for physico-chemical water quality for ecological health and for human uses of water (Environment Waikato 2010c).

Ecological health	**Relevance**	**Satisfactory**	**Excellent**
Dissolved oxygen (% saturation)	Aquatic life (breathing)	>80	>90
pH	Aquatic life (acidity)	6.5–9	7–8
Turbidity (NTU)	Plant growth (clarity)	<5	<2
Ammoniacal nitrogen (mg/L)	Aquatic life (toxicity)	<0.88	<0.1
Temperature (May-Sept)	Fish (spawning)	<12	<10
(Oct-Apr)	Fish (spawning)	<20	<16
Total phosphorus (mg/L)	Nuisance plant growth	<0.04	<0.01
Total nitrogen (mg/L)	Nuisance plant growth	<0.5	<0.1
Human uses - recreation	**Relevance**	**Satisfactory**	**Excellent**
Baseflow water clarity (m)	Visibility	>1.6	>4
Escherichia coli (n/100 mL)	Human health	<550	<55

Environment Waikato guidelines for recreational water quality

Excellent is an enterococci reading of < 28/100mL, satisfactory is 28 – 280/100mL and unsatisfactory is >280/100mL (Environment Waikato 2011c, Environment Waikato 2011d).

Appendix B: Results for comparison of water quality with guidelines

Table 5: Percentage of samples that meet the "satisfactory" guidelines for the Ohautira Stream site. NS = Not sampled. Usually 12 sampling occasions a year except for *E. coli* which is 4, * = 11 sampling occasions and ^ = 7 sampling occasions.

	DO%	pH	Turbidity	NH4	TP	Clarity	*E. coli*	Temp	TN
1993	100	NS	NS	100	50	0	NS	100	75
1994	100	NS	NS	100	50	0	NS	100	92
1995	100	NS	0^	100	25	0	NS	92	83
1996	100	NS	0	100	25	0	NS	83	58
1997	100	NS	0	100	58	0	NS	92	75
1998	100	100	8	100	25	0	25	75	67
1999	100	100	0	100	17	0	50	83	67
2000	100	100	0	100	33	0	100	100	83
2001	100	100	0	100	17	0	50	83	67
2002	100	100	0	100	33	0*	25	92	58
2003	100	100	0	100	8	0	50	92	50
2004	100	100	8	100	50	0	50	100	50
2005	100	100	8	100	25	0*	50	92	58
2006	100	100	0	100	42	0	50	100	58
2007	100	100	17	100	25	0	50	83	67
2008	100	100	8	100	50	0	25	83	58
2009	100	100	8	100	33	0	50	100	50
2010	100	100	0	100	50	0	100	92	67

Table 6: Percentage of samples that meet the "excellent" guidelines for the Ohautira Stream site. NS = Not sampled. Usually 12 sampling occasions a year except for *E. coli* which is 4, * = 11 sampling occasions and ^ = 7 sampling occasions.

	DO%	pH	Turbidity	NH4	TP	Clarity	*E. coli*	Temp	TN
1993	100	NS	NS	100	0	0	NS	67	0
1994	100	NS	NS	100	0	0	NS	58	0
1995	92	NS	0^	100	0	0	NS	50	0
1996	100	NS	0	100	0	0	NS	50	0
1997	100	NS	0	100	0	0	NS	67	0
1998	92	100	0	100	0	0	0	58	8
1999	83	75	0	100	0	0	0	50	0
2000	92	100	0	100	0	0	0	58	0
2001	92	100	0	100	0	0	0	50	0
2002	100	83	0	100	0	0*	0	58	0
2003	92	92	0	100	0	0	0	50	0
2004	100	92	0	100	0	0	0	92	0
2005	100	67	0	100	0	0*	0	67	0
2006	83	83	0	100	0	0	0	50	0
2007	100	92	0	100	0	0	0	42	0
2008	58	83	0	100	0	0	0	25	0
2009	92	100	0	100	0	0	0	58	0
2010	100	100	0	100	0	0	0	42	0

Table 7: Percentage of samples that meet the "satisfactory" guidelines for the Waingaro Stream site. NS = Not sampled. Usually 12 sampling occasions a year except * = 11 sampling occasions and ^ = 6 sampling occasions.

	DO%	pH	Turbidity	NH4	TP	Clarity	Temp	TN
1993	100	NS	NS	100	67	0	58	67
1994	83	NS	NS	100	50	0	75	33
1995	100*	NS	0^	100*	55*	0*	58*	36*
1996	92	NS	0	100	17	0	58	42
1997	100	NS	8	100	58	8	67	33
1998	92	100	25	100	50	8	75	42
1999	100	100	8	100	42	8	50	33
2000	100	100	17	100	58	17	67	50
2001	100	100	8	100	50	0	67	33
2002	100	100	8	100	25	9*	67	42
2003	92	100	0	100	8	0	58	42
2004	100	100	8	100	25	0	92	25
2005	92	92	17	100	25	9*	67	33
2006	100*	100	0	100	50	0	67	33
2007	100	100	8	100	50	0	58	33
2008	92	100	17	100	50	0	58	42
2009	100	100	17	100	50	17	67	33
2010	100	100	17	100	50	0	58	50

Table 8: Percentage of samples that meet the "excellent" guidelines for the Waingaro Stream site. NS = Not sampled. Usually 12 sampling occasions a year except * = 11 sampling occasions and ^ = 6 sampling occasions.

	DO%	pH	Turbidity	NH4	TP	Clarity	Temp	TN
1993	83	NS	NS	100	0	0	33	0
1994	58	NS	NS	100	0	0	25	0
1995	64*	NS	0^	100*	0*	0*	42*	0*
1996	67	NS	0	100	0	0	17	0
1997	75	NS	0	100	0	0	33	0
1998	83	100	0	100	0	0	25	8
1999	83	75	0	100	0	0	25	0
2000	75	100	0	100	0	0	8	0
2001	75	75	0	100	0	0	8	0
2002	67	92	0	100	0	0*	42	0
2003	67	92	0	100	0	0	25	0
2004	83	100	0	100	0	0	50	0
2005	83	75	0	100	0	0*	25	0
2006	73*	92	0	100	0	0	33	0
2007	67	92	0	100	0	0	33	0
2008	67	92	0	92	0	0	0	0
2009	92	100	0	100	0	0	25	0
2010	92	100	0	100	0	0	25	0

Table 9: Percentage of samples that meet the "satisfactory" guidelines for the Waitetuna Stream site. NS = Not sampled. Usually 12 sampling occasions a year except * = 11 sampling occasions and ^ = 7 sampling occasions.

	DO%	pH	Turbidity	NH4	TP	Clarity	Ecoli	Temp	TN
1993	100	NS	NS	100	50	0	NS	83	75
1994	100	NS	NS	100	92	0	NS	100	50
1995	100	NS	0^	100	58	0	NS	67	50
1996	100	NS	8	100	58	0	NS	75	42
1997	100	NS	33	100	83	8	NS	92	58
1998	100	100	42	100	50	8	50	75	67
1999	100	100	33	100	50	25	25	67	42
2000	100	100	33	100	67	25	100	100	67
2001	100	100	17	100	42	0	50	75	50
2002	100	100	17	100	42	9*	0	92	42
2003	100	100	17	100	42	0	25	83	42
2004	100	100	8	100	58	8	100	100	42
2005	100	100	17	100	33	0*	25	92	50
2006	100	100	17	100	58	0	25	92	42
2007	100	100	8	100	58	0	50	83	67
2008	100	100	17	100	58	8	50	75	50
2009	100	100	8	100	50	9*	50	92	42
2010	100	100	0	100	58	0	75	92	58

Table 10: Percentage of samples that meet the "excellent" guidelines for the Waitetuna Stream site. NS = Not sampled. Usually 12 sampling occasions a year except * = 11 sampling occasions and ^ = 7 sampling occasions.

	DO%	pH	Turbidity	NH4	TP	Clarity	Ecoli	Temp	TN
1993	100	NS	NS	100	0	0	NS	42	0
1994	100	NS	NS	100	0	0	NS	50	0
1995	100	NS	0^	100	0	0	NS	50	0
1996	92	NS	0	100	0	0	NS	42	0
1997	92	NS	0	100	0	0	NS	42	0
1998	92	100	0	100	0	0	0	42	8
1999	83	83	0	100	0	0	0	42	0
2000	92	100	0	100	0	0	0	33	0
2001	100	100	0	100	0	0	0	25	0
2002	100	92	0	100	0	0*	0	42	0
2003	92	92	0	100	0	0	0	42	0
2004	100	100	0	100	0	0	0	75	0
2005	100	67	0	100	0	0*	0	42	0
2006	100	92	0	92	0	0	0	50	0
2007	100	92	0	100	0	0	0	33	0
2008	67	75	0	100	0	0	0	17	0
2009	92	92	0	100	0	0*	0	33	0
2010	100	92	0	100	0	0	0	25	0

Appendix C: Trend methods used

Trend analysis was carried out on data from January 1993 to February 2011 (inclusive) for dissolved oxygen (% saturation), clarity, dissolved reactive phosphorus, ammoniacal nitrogen, nitrate-nitrite nitrogen, total kjedahl nitrogen, total nitrogen, total phosphorus and temperature. All analytes, except microbiological indicators, are monitored monthly. For some analytes the dataset is slightly shorter due to changes in laboratory methods (see Environment Waikato 2008b for more detail). The following data was used for these analytes for the trend analysis:

- Dissolved colour (G340) – January 1996 to February 2011
- Conductivity – January 1998 to February 2011
- Dissolved oxygen (mg/L) – February 1993 to February 2011
- *Escherichia coli* – Quarterly from March 1998 to December 2010 at Ohautira and Waitetuna only
- Enterococci – Quarterly for full time period at Ohautira and Waitetuna only
- Faecal coliforms - Quarterly from March 1998 to December 2010 at Ohautira and Waitetuna only
- pH - January 1998 to February 2011
- Turbidity – June 1995 to February 2011.

Trend analysis was carried out using Time Trends version 3.0. The Seasonal Kendall test was used to check for trends. All water quality data was flow adjusted using a LOWESS smoothing with a 30% span. Following Environment Waikato (2008b) flow data from NIWA site 41301 (TIDEDA) on Marokopa catchment was used to adjust for flow. As discussed in Environment Waikato (2008b) this flow site is not in any of the catchments of the three water quality sites but provides an approximation of the dependence of water quality on flow but possibly with some uncertainty. There are now flow recorders in two of the three water quality site catchments but the records are too short for analysis at this stage.

Trends were recorded as being statistically significant if the *p-value* was less than 0.05. Trends were also assessed for environmental significance using the magnitude of the trend compared to the raw median for the entire dataset. A trend was considered to be environmentally meaningful if the rate of change per year was greater than 1% of the median.

Appendix D: Trend results

Table 11: Trend results for Ohautira Stream site. Results shown in italics are statistically significant (ie, *p-value* < 0.05). Results shown in bold are also environmentally meaningful (ie, the rate of change per year is greater than 1% of the median). Results shown in red/pink are seen as a deterioration in water quality and results shown in green are seen as an improvement.

Analyte	p-value	Median annual slope	Median	% change/year
Dissolved oxygen (% saturation)	*0.01*	*-0.10*	*94.8*	*-0.10*
Dissolved colour (G340)	***0.000009***	***-0.13***	***5.03***	***-2.51***
Clarity (m)	0.08	0.005	0.70	0.66
Conductivity	0.96	0	13.7	0
Dissolved oxygen (mg/L)	0.50	-0.007	10.1	-0.07
Dissolved reactive phosphorus (mg/L)	0.82	0	0.02	0
Escherichia coli (n/100mL)	0.74	-0.38	505	-0.07
Enterococci (n/100mL)	0.28	2.26	90	2.51
Faecal coliforms (n/100mL)	0.48	-5.32	600	-0.89
Ammoniacal nitrogen (mg/L)	*0.0000002*	*-0.00004*	*0.01*	*-0.41*
Nitrate nitrite nitrogen (mg/L)	***0.0002***	***0.004***	***0.24***	***1.76***
pH	0.41	0	7.3	0
Total Kjedahl nitrogen (mg/L)	***0.02***	***0.002***	***0.16***	***1.25***
Total nitrogen (mg/L)	***0.00002***	***0.01***	***0.42***	***1.46***
Total phosphorus (mg/L)	0.41	0.00009	0.04	0.21
Turbidity (NTU)	0.90	-0.08	10.5	-0.80
Temperature (deg. C)	0.74	0.01	12.9	0.11

Table 12: Trend results for Waingaro River site. Results shown in italics are statistically significant (ie, *p-value* < 0.05). Results shown in bold are also environmentally meaningful (ie, the rate of change per year is greater than 1% of the median). Results shown in red/pink are seen as a deterioration in water quality, results shown in green are seen as an improvement and for results shown in blue it is unclear whether it is an improvement or deterioration. NS = Not sampled.

Analyte	p-value	Median annual slope	Median	% change/year
Dissolved oxygen (% saturation)	*0.003*	*0.16*	*93.55*	*0.17*
Dissolved colour (G340)	***0.0003***	***-0.15***	***8.25***	***-1.85***
Clarity (m)	0.41	-0.001	0.76	-0.19
Conductivity	0.18	0.03	14.4	0.19
Dissolved oxygen (mg/L)	*0.049*	*0.02*	*9.6*	*0.22*
Dissolved reactive phosphorus (mg/L)	0.09	-0.00008	0.01	-0.70
Escherichia coli (n/100mL)	NS			
Enterococci (n/100mL)	NS			
Faecal coliforms (n/100mL)	NS			
Ammoniacal nitrogen (mg/L)	0.37	0	0.01	0
Nitrate nitrite nitrogen (mg/L)	*0.01*	*0.001*	*0.35*	*0.41*
pH	*0.004*	*0.01*	*7.4*	*0.17*
Total Kjedahl nitrogen (mg/L)	***0.003***	***0.004***	***0.26***	***1.44***
Total nitrogen (mg/L)	*0.002*	*0.01*	*0.64*	*0.85*
Total phosphorus (mg/L)	0.40	0.0002	0.04	0.40
Turbidity (NTU)	0.14	0.06	9.59	0.68
Temperature (deg. C)	0.60	0	15.10	0

Table 13: Trend results for Waitetuna River site. Results shown in italics are statistically significant (ie, *p-value* < 0.05). Results shown in bold are also environmentally meaningful (ie, the rate of change per year is greater than 1% of the median). Results shown in red/pink are seen as a deterioration in water quality and results shown in green are seen as an improvement.

Analyte	p-value	Median annual slope	Median	% change/year
Dissolved oxygen (% saturation)	*0.02*	*-0.09*	*96.35*	*-0.10*
Dissolved colour (G340)	***0.000003***	***-0.15***	***5.72***	***-2.65***
Clarity (m)	*0.04*	*-0.01*	*0.78*	*-0.84*
Conductivity	0.93	0	10.1	0
Dissolved oxygen (mg/L)	0.31	-0.01	10.0	-0.09
Dissolved reactive phosphorus (mg/L)	0.07	-0.00009	0.01	-0.76
Escherichia coli (n/100mL)	0.74	-3.21	590	-0.54
Enterococci (n/100mL)	***0.01***	***6.78***	***130***	***5.21***
Faecal coliforms (n/100mL)	0.52	-7.16	600	-1.19
Ammoniacal nitrogen (mg/L)	0.48	0	0.01	0
Nitrate nitrite nitrogen (mg/L)	***0.002***	***0.003***	***0.28***	***1.01***
pH	0.57	0	7.3	0
Total Kjedahl nitrogen (mg/L)	0.053	0.002	0.18	1.19
Total nitrogen (mg/L)	*0.004*	*0.004*	*0.48*	*0.89*
Total phosphorus (mg/L)	0.53	0.0001	0.04	0.32
Turbidity (NTU)	***0.001***	***0.17***	***8.74***	***1.95***
Temperature (deg. C)	0.44	0.025	14.20	0.18

Appendix E: Trends in macroinvertebrate indicators

Figure 6: Trends in macroinvertebrate indicators from 1996 to 2005 extracted from Environment Waikato (2006). Note: There is no x-axis labels but each data point represents one year from 1996 to 2005. Sites are: 1172-6 = Wainui Stream, 1247-3 = Waitetuna River and 413-2 = Mangaokahu Stream. EPT = Ephemeroptera, Plecoptera and Trichoptera (species sensitive to pollution). MCI = Macroinvertebrate Community Index. ECS = Ecological Condition Score (calculated from 17 macroinvertebrate metrics). Solid data points = "probable-clear" trend, while hollow data points = "possible" trend. Red indicates a deteriorating trend, while blue indicates stable conditions.

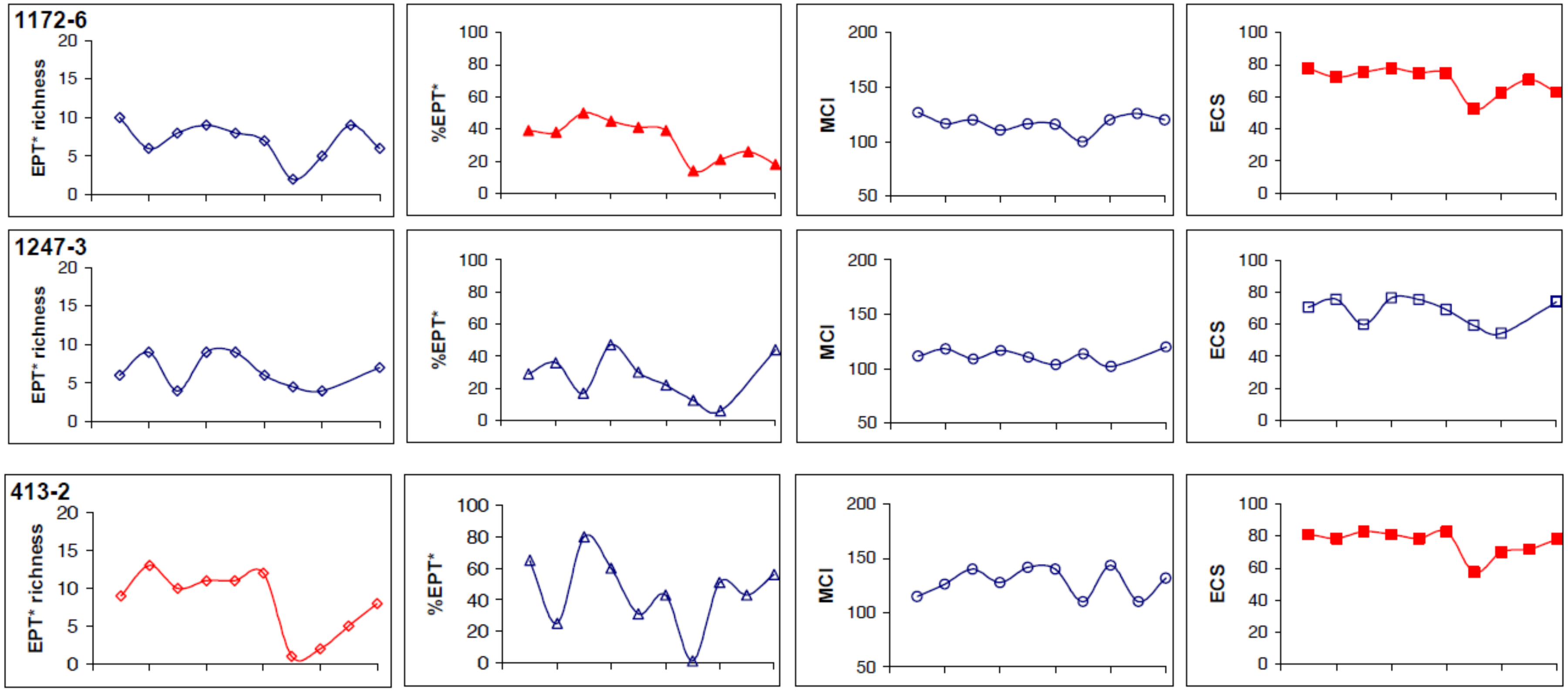

Figure 7: Trends in macroinvertebrate indicators from 1996 to 2008 extracted from Environment Waikato (2010b). Note: There is no x-axis labels but each data point represents one year from 1996 to 2008 (duplicate points in one year compare different sampling methods). Sites are: 1172-6 = Wainui Stream, 1247-3 = Waitetuna River and 413-2 = Mangaokahu Stream. EPT = Ephemeroptera, Plecoptera and Trichoptera (species sensitive to pollution). MCI = Macroinvertebrate Community Index. APSM = Average Score Per Metric (average of three metrics). Solid data points = "clear" trend, while hollow data points = "probable" trend. Red indicates a deteriorating trend, while blue indicates stable conditions.