Quantification of nitrogen leaching from gorse in the Lake Rotorua Catchment

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Executive summary

The objective of this investigation was to quantify nitrate leaching from all stands of gorse growing within the Lake Rotorua catchment. Study by Magesan, G. and Wang, H. (2008) indicated that gorse is a significant contributor of nitrate leaching to groundwater from two experimental sites at Wharenui Station and Tikitere Forest over two years, 2006 and 2007. For the purposes of quantifying gorse derived nitrogen leaching over the entire Lake Rotorua catchment, these 2006 and 2007 leaching results from the two sites were averaged and a generic gorse leaching coefficient of 50 kg N ha^{-1} was derived. This investigation assumes that this generic nitrate leaching coefficient (50 kg N ha^{-1}) can be extrapolated to all mature stands of gorse in the Rotorua catchment to estimate the total amount of nitrogen that gorse is contributing to groundwater in the catchment. As the attenuation of nitrogen is expected to be negligible when passing through groundwater to the lake (Rutherford K. pers. comm.), the amount leached at source results in an equal amount of input to the lake at time of arrival.

Gorse stands were categorised by maturity and density and mapped in order to quantify the gorse cover area in the catchment. Mapping results show that there are nearly 900 hectares of gorse in the Rotorua catchment. Of this, 864 ha is tall gorse in medium to dense stands which is assumed to be leaching nitrate to groundwater at a rate of 50 kg N ha^{-1}. Gorse that has been sprayed and appears to be dead is included in the calculated contributing gorse area as it is expected to break down and contribute to nitrate losses to groundwater.

This investigation concludes that approximately 43 tonnes of nitrogen derived from gorse is being leached to the groundwater in the Rotorua catchment each year. An earlier investigation using the same gorse survey methods in the Lake Okareka catchment (Environment Bay of Plenty Internal Report 2009/03) concluded that approximately 4 tonnes of nitrogen derived from gorse is being leached to the groundwater in that catchment each year.

Gorse derived nutrient loading to groundwater will subsequently enter Lake Rotorua and contribute to water quality degradation. Pine trees have a nutrient-loss signature typically around 3 kg N ha^{-1} so replacing gorse cover with pine trees will reduce the net nitrogen leaching from former gorse lands by approximately 41 tonnes. A far lesser amount of nitrogen-loss savings will be achieved if the land is returned to pastoral use.

This 43 tonne of nitrogen derived from gorse has not been accounted for previously as a nutrient input for Lake Rotorua.

This report concludes that gorse is a significant contributor to the Lake Rotorua's continuing eutrophic status and recommends that measures are taken to reduce or eliminate mature stands of gorse and encourage its replacement with a low nitrate leaching land use such as pine forest.

Contents

Part 1: Introduction

Water quality in several of the Rotorua lakes has been declining for the last 30 to 40 years due to the increasing nutrient loads, particularly nitrogen (N) and phosphorus (P), arising from various land use activities around the catchment (Parliamentary Commissioner for the Environment 2006). Lake Rotorua is subject to both regulatory provision (Rule 11) and a proposed non-regulatory provision (Environment Bay of Plenty - The Proposed Lake Rotorua and Rotoiti Action Plan, 2007). The intention of Rule 11 is to prevent increasing nutrient losses from land use, and the action plan proposes to reduce nutrient input so that water quality will improve.

Eutrophication has been the main cause of concern for the Rotorua lakes' water quality.

Eutrophication is the aging of a lake by biological enrichment of its water. In a young lake the water is cold and clear, supporting little life. Over time, streams and ground water drain into the lake introducing nutrients such as N and P. As the lake's fertility increases, plant and animal life flourish, and organic remains begin to be deposited on the lake bottom. Nutrients from land use activities also radically accelerate the aging process (Dyck et al. 1983).

Elevated nutrient levels stimulate toxic algae (blue-green algae and cyanobacteria) blooms which reduce available oxygen and clarity of water. As algae cells die and sink, they decompose on the lake bed using up oxygen in the bottom waters. A lack of oxygen in the bottom waters causes the lake bed sediments to release N and P. Therefore by reducing the nutrient concentrations in the water it is possible to reduce the nutrient releases from the lake bed.

Dissolved oxygen is an indicator of the health of freshwater ecosystems. Fish and other aquatic life require dissolved oxygen to breathe. When dissolved oxygen levels are depleted, aquatic animals can become stressed and die. Oxygen depletion is commonly caused by organic pollutants breaking down in waterways, elevated water temperatures or night-time respiration by dense algal blooms in nutrient-rich waters (MfE, 2009).These conditions affect the health and diversity of fish, plant and animal populations, limit recreational water use and can have implications for public health (Guinto et al. 2008).

In the past, lakes in many parts of the world have been severely polluted by sewage, agricultural and industrial inputs. Rotorua lakes are no exception to these past practices and land use activities. The prime contaminants were nitrate and phosphate, which also act as plant nutrients. These nutrients encourage the growth of aquatic organisms such as algae, and sometimes over stimulate the growth of algae, causing unsightly scum, films, foams and unpleasant odours (Figure 1).

Figure 1 Foam caused by the die off of summer algal bloom found on the shore near Mourea, Lake Rotorua (September, 1998). Source: Environment Bay of Plenty: Rotorua Lakes Algal Report (2000)

One of the recent studies suggested that a leguminous weed such as gorse (Ulex europaeus L.) could also contribute significant amounts of nitrate leaching that may result in degradation of groundwater quality (Magesan, G. and Wang, H. 2008). Gorse is the most common and widespread pest plant in New Zealand. It is well suited to growing in low-fertility soils, readily establishes over disturbed sites and germination of the seed is stimulated by fire. Once established, gorse rapidly forms dense infestations. In New Zealand conditions gorse flowers twice a year (i.e. the bright yellow flowers emerge in autumn and spring). It is the third largest family of flowering plants (Sprent, 2005). The hard-coated seeds remain viable in the soil for more than 30 years. Due to the long-lived nature of the seed, control of established infestations is expensive. On the positive note, gorse can function as a nursery species for the regeneration of indigenous vegetation, and is a valuable source of pollen for honeybees (Environment Bay of Plenty Fact sheet PP05).

Nitrogen is often the most growth-limiting nutrient in both terrestrial and aquatic systems (Magesan, G. and Wang, H. 2008). Leguminous plants such as gorse have evolved to cope with growing under nitrogen-limiting conditions because of their ability to establish endosymbiosis with soil bacteria, collectively called Rhizobia (Van de Velde et al. 2006), leading to the formation of nitrogen-fixing root nodules (Sprent, 2005). By forming this symbiotic relationship between the plant and the bacteria, the plant provides ammonia in exchange for carbohydrates. Therefore gorse can actually improve soil fertility as it has nitrogen fixing rhizobium.

Early studies by Egunjobi (1969) found that total accumulation of nitrogen as well as soil nitrogen content was higher in ecosystems dominated by gorse than in later successional ecosystems. In areas where the nitrogen supply exceeds the ecosystem demand, some of the accumulated nitrogen in soils can be lost to ground water, lakes, and streams (Aber et al. 1998). The addition of nitrogen to an aquatic system may stimulate plant growth to the detriment of that system (Dyck et al. 1983). To further understand earlier work on gorse derived nitrogen, Environment Bay of Plenty commissioned a study that was undertaken by Scion and reported by Magesan, G. and Wang, H. (2008). This study revealed that gorse can be a significant contributor to nitrogen loadings in groundwater, and subsequently to the lakes.

In 2009, the extent of gorse cover in the Lake Okareka Catchment was reported (Environment Bay of Plenty, 2009). This led to, the current work to survey the extent of gorse cover in the Lake Rotorua catchment.

1.1 Purpose

The objectives of this investigation are:

- To quantify and categorise the actual distribution of gorse in Lake Rotorua catchments, and
- To estimate the amount of nitrate leaching to groundwater from gorse stands in the Lake Rotorua catchments.

Part 2: Method

2.1 Quantifying the distribution of gorse

Gorse patches in this investigation were categorised on their age (old, medium or young) and spatial variation (dense, medium or scattered) - refer to photographic examples in Appendix 2. The age of each gorse patch mapped was estimated by its height along with its relative density. The three methods used for obtaining land cover information were:

- 2006 Rural Aerial photography maps from Environment Bay of Plenty's geospatial programme 'geoview'.
- Local/Environment Bay of Plenty office staff knowledge of properties.
- Fieldwork done on the properties, and in the cases where access was not permitted, viewed and estimated from neighbouring properties.

The field survey aimed to visit every property in the catchment so that a visual observation could be made on the gorse. Each patch of gorse was then assigned a number (Refer to example Field Sheet, Appendix 3).

During onsite visual mapping, the survey also noted the surrounding vegetation and if the patch had been sprayed, burnt or mulched and if there was any evidence of re-growth. The percentage cover, height (metres) and slope were estimated and also noted in the survey. The polygons which were marked out on the aerial photography were then transferred into geoview where a layer was created and an attributed table added. The area of the patch and the actual amount of the gorse in each patch was able to be quantified electronically within the geoview programme.

2.2 Categorisation and scoring percentage

Qualitative categorisation was used to differentiate the nitrogen contributing categories of gorse from the non-contributing categories. Maturity was used to distinguish the contributing i.e. the old and medium maturity gorse from the non-contributing i.e. the young N-leaching gorse as it was judged in the field by its height and its relative density - refer to photographic examples in Appendix 2.

The scoring percentages which were assigned to each patch of gorse and entered into the programme geoview, were best guess estimates of gorse cover in that patch. For example, a one hectare patch of medium density and age may have consisted of 50 percent gorse, 35% scrub and 15% pasture. This resulted in a 50% coverage which was entered into the field sheet (refer to example Field Sheet, Appendix 3) and a final gorse cover of 0.5 hectares which was summed with all of the other gorse patches (within geoview) to find the total area of gorse in the Lake Rotorua catchment. It should be noted that due to the qualitative nature of the data collected there is likely to be an associated error in the surveyed areas of gorse found. This error is assumed to be +/- 5%.

2.3 Estimation of nitrate leaching (from previous study)

Environment Bay of Plenty commissioned a study that was undertaken by Scion and reported by Magesan, G. and Wang, H. (2008). Experimental sites were at Wharenui Station and Tikitere Forest in Rotorua Lakes catchments. Magesan, G. and Wang, H. (2008) estimated nitrogen leaching results for these two sites based on monthly drainage volumes, and the nitrate concentration measured in soil water (using suction cup samplers) under the gorse stands. The estimated values were 59 and 64 kg N ha^{-1} for Wharenui Station and Tikitere Forest sites respectively for the period from March to December 2006. From January to October 2007, the estimated values were 36 and 40 kg N ha^{-1} for the same Wharenui Station and Tikitere Forest sites respectively. Differences in the amount leached were due to the difference in the drainage between the two years, particularly in the autumn season when nitrate concentrations are greater than in other seasons.

For both periods of the study, the total rainfall was below the long term rainfall average (15 year average) obtained from NIWA (Figure 2).

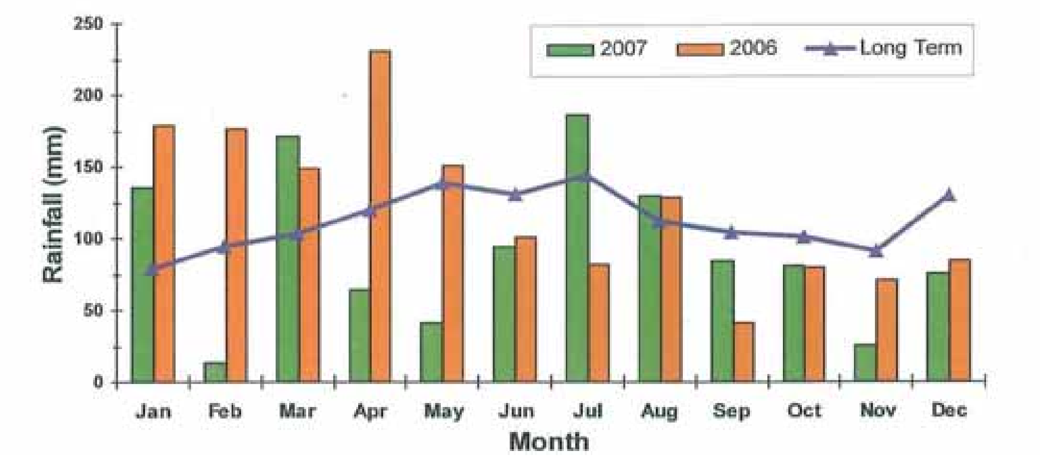

Figure 2 Mean monthly rainfall for 2006 and 2007, and 15 year average. From Magesan, G. and Wang, H. (2008)

Here in this report, for the purpose of quantifying gorse derived nitrogen leaching, these 2006 and 2007 leaching results from the two sites were averaged and a generic gorse leaching coefficient of 50 kg N ha^{-1} was derived. The leaching rates from gorse are comparable with those of dairy farming in the Lake Rotorua catchment which were found to be 58 kg N ha^{-1} in 2005/2006 (Smeaton and Ledgard, 2005). This investigation assumes that the derived generic nitrate leaching coefficient (50 kg N ha^{-1}) for gorse can be extrapolated to all mature stands of gorse in the whole catchment area of Lake Rotorua to estimate the total amount of nitrogen that gorse is contributing.

It should be noted that drainage rates around the wider catchment of the lake are likely to be higher than in the trial sites where the leaching coefficient was derived as the rainfall Isohyets increase markedly in the northern and western areas of the Lake Rotorua catchment.

Field investigations by Magesan, G. and Wang, H. (2008) showed that gorse has minimal roots in the soil below a depth of 75 cm. When nitrate moves below the gorse roots it is likely to be leached through to ground water. That means that a substantial amount of N can enter the groundwater. To protect the lakes water quality Magesan, G. and Wang, H. (2008) recommends that an effective method needs to be developed to eliminate gorse in the Rotorua lakes catchments.

Recommendations for gorse management are reached via a Strengths, Weaknesses, Opportunities, and Threats (SWOT) analysis to evaluate and rank the options for controlling or eliminating gorse (Table 1).

Part 3: Results

The Lake Rotorua catchment has a groundwater catchment area of 65,538 ha (Proposed lakes Rotorua and Rotoiti Action Plan, 2007). There are 896 hectares of gorse in the Lake Rotorua Catchment (Figure 3). Of these 896 hectares, 864 hectares is composed of tall gorse in medium to dense stands. Currently, this is the mature fraction of gorse area (1.4% of Rotorua's vegetation cover) that is attributing to nitrate leaching to groundwater in the catchment. By comparison gorse accounts for 3.7% of vegetation cover in the Lake Ōkāreka catchment (Environment Bay of Plenty Internal Report 2009/03).

Magesan, G. and Wang, H. (2008) reported that the estimated nitrogen leaching from gorse over two years at two sites (Tikitere and Wharenui) averaged about 50 kg N ha^{-1}. They also reported that the lowest rate of N leaching in the two years was 36 kg N ha^{-1} (Wharenui Station in 2007) and the highest rate was 64 kg N ha^{-1} (Tikitere forest in 2006). Given there is 864 ha of mature gorse, amount of nitrogen contributing to leaching is estimated to be in the range from 31.4 to 55.3 tonnes annually.

Rainfall data from the two trial sites (Figure 2) suggest that the estimate of leaching (50 kg N ha^{-1}) occurred in two years with below average rainfall and drainage at both sites. We can therefore postulate that leaching around Lake Rotorua's catchment could be potentially higher, perhaps equal to or higher than the maximum rate of 64 kg N ha^{-1} reported by Magesan, G. and Wang, H. (2008) at Tikitere in 2006. However for the purpose of this report we have used the trial average of 50 kg N $ha^{-1}yr^{-1}$ for calculating the total nitrogen losses from gorse to ground water in the Rotorua catchment.

50 Kg N/ha/yr (gorse leaching rate) x 864ha (mature gorse area) = 43.2 tonnes N / yr.

This 43 tonne of nitrogen derived from gorse has not previously been accounted for as a nutrient input for lake Rotorua. The original nutrient reductions targets derived for the lake's draft Action Plan were calculated using a land use model that attributed nutrient losses to each land use type using typical export coefficient comparable to the losses predicted by the OVERSEER® Nutrients Budgets model . In this catchment estimation land use model, gorse was measured with scrub cover i.e. not differentiated and was allocated an N-discharge of just 4kgN – loss ha^{-1} yr^{-1} rather than the known 50 kg N $ha^{-1}yr^{-1}$ for the mature gorse proportion. The 43 tonne disclosed by this report needs to be regarded as a new identity not previously accounted for and cannot be perceived as a quantity that relieves the land user nutrient reduction requirements (i.e. the 170 tonnes of nitrogen, input to the lake that is to be removed from land use sources over the next ten years) in any way. To avoid an increase in the nutrient load reduction target for the Lake Rotorua catchment, gorse will have to be replaced with native or exotic vegetation or similar low nitrogen and phosphorous exporting land uses.

If pine trees replaced the gorse, this land use itself will eventually leach up to 3 kg N ha^{-1} resulting in up to 2.6 tonnes of nitrogen per year. The net result would be around 41 tonnes of nitrogen removed by a gorse to pine tree conversion process.

43.2 tonnes N from Gorse – 2.6 tonnes N from Pines = 40.6 tonnes N (net from land use).

If the gorse land is converted to pasture the net gains will be considerably less depending on the type and intensity of live stock animals grazed and additionally the phosphate loss will be elevated particularly on any steep land.

The Proposed Lake Rotorua and Rotoiti Action Plan (2007) states that in 2005, 547 tonnes/year of nitrogen was discharged from the catchment into Lake Rotorua. This will increase in the future up to 746 tonne/year at steady state. Steady state is when any groundwater lag period is used up and there are no future increases in nutrient loads if the amount of nutrient loss from land use stays the same.

Currently the overall percentage of gorse derived nitrogen inputs into Lake Rotorua based on the 2005 total nitrogen input figures (547 tonnes N) for Lake Rotorua is approximately 7.9%

43.2 tonnesN / yr x 100
547 tonnes N lake input 2005 = 7.9% of total nitrogen is derived form gorse

Nitrogen, in the form of nitrate, entering ground water is subject to ‘attenuation’ in some catchments (i.e. the natural removal of nitrogen from groundwater before it reaches its destination). However in the Lake Rotorua catchment there is generally no indication that attenuation is occurring as demonstrated by the quantities of nitrogen measured in streams being similar to the quantity predicted by the OVERSEER® Nutrients Budgets model to be leached from the land surface. This suggests that in most stream catchments the amount of nitrogen attenuation is no larger than the uncertainty of the stream measurements and the predicted leaching. The one exception is the Puarenga Stream, which happens to have a large number of wetlands, where stream measurements are significantly lower than the quantity predicted by the OVERSEER® Nutrients Budgets model to be leached from the land surface (K. Rutherford. pers comm). Without attenuation a net loss of 40.6 tonnes of nitrogen from land use to groundwater is likely to result in the same amount entering the lake albeit up to 58 years later.

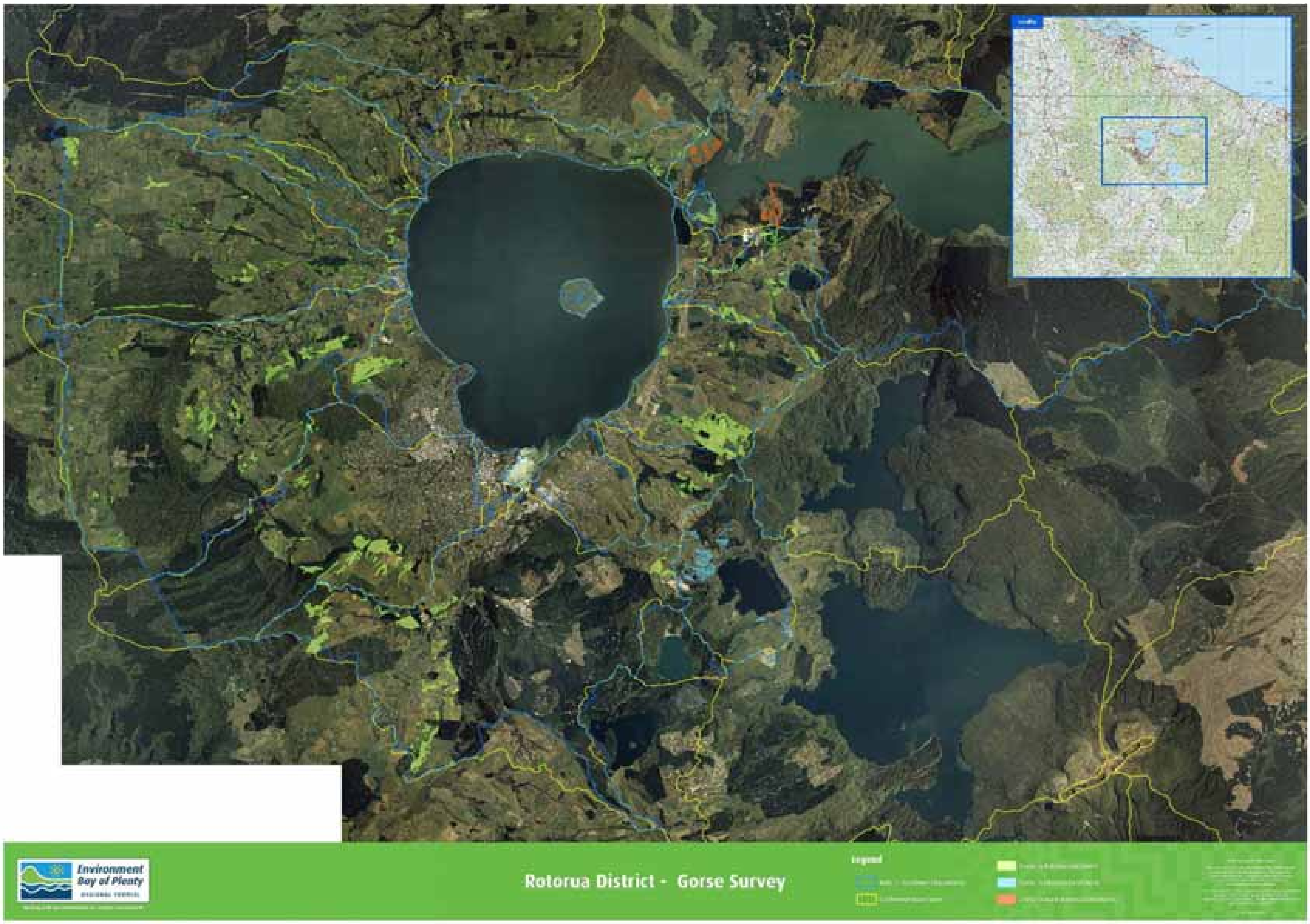

Figure 3 Map showing the gorse coverage in the Rotorua Catchment

Table 1 Revised evaluation of Options table

Option	Proven	Nitrogen	Phosphorous	Risk	Cost	Time	Other Values	Other catchment	Rank
Multiplier	3	2.5	2.5	2	2	1	1	1	
Removal of gorse	B	A	E	C	A	A	A	A	1
Sewerage (280)	A	B*	A	C	F	A	C	C	4~
		A(1.9)	B(0.01)						
Sewerage (200)	A	D*	C	C	F	A	C	C	8
		C(1.3)	D						
Cartage	A	A(2.3)	A(0.02)	D	F	A	D	D	6
O/S nutrient stripping	B	C(1.4)	E(0.01)	C	F	A	C	C	12
200 ha pasture to forest	A	D(0.9)	B(0.05)	B	D	B	B	C	3
400 ha pasture to forest	A	B(1.8)	A(0.10)	D	D	B	D	C	4~
100 ha pasture to lifestyle	A	E(0.35)	E(0.01)	B	A	B	B	C	7
200 ha converted Buy -sell	A	D(0.9)	B(0.05)	C100	A	B	B	C	2
Riparian**	A	E	E	B	F	A	B	C	9~
Hypolimnetic Discharge & treatment	C	E(0.01)	C(0.03)	C	A	A	C	D	9~
Wetlands	B	E(0.3)	E(0.01)	C	A	A	B	C	11

The new option of gorse removal ranks above all other options based on the evaluation of nutrient reduction criteria. For detail on derivation of this table see Appendix 1.

Part 4: Discussion

4.1 Lake Rotorua Water Quality

Lake Rotorua is a nutrient-enriched lake and classified as eutrophic. This is, to a large extent, the result of anthropogenic effects of excess nutrients via urbanisation and land development from bush for livestock farming in the lake's large catchments.

All land uses within the catchment of Lake Rotorua affect the lake by way of nutrient loss. However some land uses have a much greater nutrient loss 'footprint' than others. Nutrient loss depends on the land use type, the location of the land use (slope, climate), and land use management (Proposed Lakes Rotorua and Rotoiti Action Plan, 2007).

The Rotorua lake on average is 11 metres deep and has a maximum depth of 45 metres. Because it is shallow and open to wind currents, the lake water column regularly mixes by wind. Temperature variations can cause lake surface waters to warm, forming two non-mixing layers. Lake Rotorua's water column stratifies intermittently throughout the summer, especially if the weather is calm and warm. Rapid fluctuations in water quality can result from this temporary stratification. Because of this, the lake is being continuously monitored and research is ongoing. Trophic Level Index (TLI) is used as monitoring tool as it links to Environment Bay of Plenty's land use restriction rule. The higher the TLI the lower the water quality. Lake Rotorua's current three year TLI average is 4.7 while the target TLI is 4.2. To meet the target TLI the N reduction target must increase over time as N inputs from groundwater increase over time.

Two aspects for consideration when assessing the long-term nutrient reduction goals are: nutrient concentrations in the water and the nitrogen phosphorus ratio (N/P). It is this release of nutrients (particularly P) that can significantly alter the N/P ratio, driving it downwards to a level that favours the development of cyanobacteria/blue-green algal blooms.

The ratio of N/P in Lake Rotorua during 2008/2009 was 12 which is within the 'balanced' range of 10 – 15 (J. McIntosh pers. comm). The best technical advice taken from the Proposed Lake Rotorua and Rotoiti Action Plan is to reduce both the nitrogen and the phosphorus inputs into the lake whilst ensuring that any action taken will not increase any nutrient input/release.

Lake Rotorua catchment loads were estimated using land use nutrient loss coefficients at 783 tonne/year of nitrogen and 40 tonne/year of phosphorus discharged annually from the catchments into the lake (Proposed Lake Rotorua and Rotoiti Action Plan, 2007). This action plan also states that the estimated 'sustainable' nutrient input to Lake Rotorua is 435 tonnes/year of nitrogen and 37 tonnes/year of phosphorus which over time should lower Lake Rotorua's TLI to 4.2.

These sustainable nutrient inputs were discussed by the Action Plan working party and the 2017 nutrient reduction targets of 250 tonnes/year of nitrogen and 10 tonnes/year of phosphorus were set. Achieving these targets would make no noticeable difference to the lake TLI in the short term (up to 10 years) although algal blooms should subside but overall lake quality would improve gradually over the following decades if the targets are achieved.

Malcolm Short, Chairman, Rotorua lakes and lands trust states that ”Rotorua’s future depends on our land and water. The wealth and wellbeing of the district and its people will continue to depend heavily on making the most of farming, forestry and tourism to generate jobs and income”. Weeds such as gorse threaten these values due to its unproductive land use and nitrogen losses to ground water which continue to degrade the water quality of our lakes and rivers (Proposed Lakes Rotorua and Rotoiti Action Plan, 2007).

Because most nitrogen inputs to Lake Rotorua are human-induced, most of the sources can be managed to reduce their input into the lake. Gorse is one of these nitrogen inputs that are able to be managed. Replacing gorse with forestry or other low intensity land uses may offer both economic advantages for landowners and a considerable environmental advantage for lake water quality.

4.2 Gorse control

There are various options available to manage gorse and an effective gorse control programme may require a combination of methods. Control strategies with specific objectives may be eradication, temporary suppression to allow the establishment of forestry or control along property boundaries. As with all weeds, a well fertilised sward of pasture that is not overgrazed or pugged will be more resistant to gorse invasion than poorly managed pasture (Environment Bay of Plenty Fact sheet PP05).

The best return on gorse control expenditure – for the purpose of reducing its contribution to the nutrient loading of Rotorua lakes – will be to eliminate tall, dense stands of gorse of medium to old maturity. This type of gorse stand has a greater ability to accumulate nitrogen due to its high annual leaf litter production compared to other types of gorse stands (Magesan, G. and Wang, H. 2008). Young and scattered gorse stands have smaller nitrate losses to ground water. This is due to its annual leaf litter production being smaller and the uptake of available nitrogen for growth of the young plants (Egunjobi, 1969).

All gorse control operations require sustained follow-up treatments for the best results. To reduce the risk of re-infestation it is recommended that land owners be encouraged to convert gorse areas to forestry rather than pastoral uses.

4.3 Conversion of gorse stands to forestry

There are distinct benefits of converting gorse to forestry. Pine trees have a proven ability to compete with gorse re-growth. Other exotic species and natives are generally slower to emerge and are more likely to succumb to competition from gorse. Planting Pine GF19 is a cost effective option. Standard stocking rates range from 900 to 1100 stems per hectare (sph). However with a higher stocking rate of 1400 sph, greater ground cover will be achieved and it is likely to inhibit gorse re-growth. Gorse will resurge with each thinning of the pine plantation, but will die off as the pine canopy closes after each thinning.

The main benefit of converting gorse to forestry is the reduced N-loss signature of this land use. Magesan, G. and Wang, H. (2008) compared gorse infested study sites with nearby P.radiata forests and found that only 0.8 and 0.7 kg N ha^{-1} was leached from the P.radiata stands on Wharenui Station (about 20 year old pine stands) and Tikitere Forest sites (about seven year old pine stands), respectively. Forestry is generally attributed around 3 kg N ha^{-1} in the Overseer programme. Another benefit is the reduced risk of re-infestation under forestry. A relatively high stocking rate (1400 sph) reduces the light available to the soil, stops germination of the gorse seed bank and also limits the growth of gorse which can not tolerate shade.

Given the distinct benefits of conversion of gorse stands to forestry, several questions need to be answered such as; how should this conversion approach be undertaken?, what method should be used?, and on what timescale?.

4.4 Soil/plant disturbance and nitrate leaching

Conversion of gorse stands to forestry needs to be done relatively quickly to minimize the nitrogen losses to the groundwater. An elevated nitrogen spike is expected to occur shortly after the treatment of the gorse as the vigorously growing young trees can take up only a part of available nitrogen. The remaining available nitrogen could be mitigated by growing grass or other short-term crops.

Studies on nitrate leaching spikes have been done around the rotation of forestry plantations. Similar patterns could be expected following the decomposition of felled, sprayed or roller crushed gorse. A short time interval between the removal or spraying of gorse stands and the planting of the forestry means new plantings could use some of the accumulated nitrogen from both the biomass and soil resulting in minimal nitrate leaching. The young trees being in a development stage would use available nitrogen to increase the trees' primary productivity, becoming a nitrogen sink.

In forest ecosystems, several factors interact to determine whether nitrogen is lost via nitrate leaching following forest disturbance. Vitousek et al. (1982) suggests these include pre-disturbance rates of net N mineralization, soil nutrient cycling processes that may delay nitrate production, and vegetation re-growth.

Scott et al. (1998) studied how the interactions between C and N cycling processes in soils from New Zealand plantation forest influenced soil nitrogen production and the implications for post harvest losses of mineral-N. Their results indicate that increased soil N status increase N losses via nitrate leaching after forest harvest but the magnitude of loss may be reduced by altering the size and quality of soil C inputs post harvest. Their study showed that on nutrient-poor sites such as typical gorse dominated ecosystems, which have rapid rates of C and N turnover, sudden removal of major C inputs could disrupt the N cycle, leading to potentially greater N losses. The results of this study could suggest some insight on how to manage and control gorse.

In New Zealand plantation forests dominated by *P. radiata*, previous experiments have suggested that residual slash may increase the size of the soil nitrate pool in the first year post-harvest (Smith et al. 1994). The same could be assumed for gorse, that if the conversion or management approach was to clear fell the gorse then it would be highly likely that residual slash from the gorse may increase the size of the soil nitrate pool, thus leaving it to be leached to the ground water. Therefore this management strategy is likely to cause a spike in nitrogen losses.

4.5 Implementation of proposed change

Implementation of a land use change from gorse to forestry could be difficult on some properties in the Lake Rotorua catchment for a number of reasons. Conversion to forestry is limited due to the competitive and inherent financial gains of potential subdivision and the land owners falsely perceived ability to intensify their land use due to gorse removal while still complying with the regulatory provision i.e. Rule 11 benchmarking.

The land owner perception of having an ability to intensify their land use comes from the idea that with a reduction in N losses occurring with the removal of gorse, there is room to increase production and remain within the properties nutrient benchmark. This is an incorrect perception as Environment Bay of Plenty decided not to account for gorse leaching as a part of the property nutrient benchmarking process, as this would unfairly reward owners with undesirable land management practices. Also such intensification of farming on former gorse covered land would lead to increased phosphorus losses.

Although subdivision could have substantial financial and environmental benefits, in most situations it is unlikely to go ahead in the near future or be sufficient as a single action/pathway forward. This is due to the current financial climate, the restrictive nature of District Council consent processes and the large extent of gorse cover in the catchment.

Often land owners are not going to want to eliminate gorse until they are in the process of applying for subdivision resource consent, where the elimination of gorse may become a good mitigation measure which they perceive will help them gain resource consent.

A possible way around this would to be to create an entitlement system that would build on current working relationships with owners and plant native species. This would be at a cost to both the owner and Environment Bay of Plenty with an incentive for the land owners that mitigation actions taken now could be used in the future when applying for resource consent (i.e. an entitlement). This could work for both parties as Environment Bay of Plenty meets targets for nitrogen reduction for the lake quickly and effectively also gaining land use change that would be locked up in reserves while the land owner/s would have gained mitigation they can use for future resource consent applications with the added bonus of mature trees which add value to the land when sub divided.

Part 5: Conclusions and recommendations

Mature gorse in the Rotorua catchment is a significant source of nitrogen-loss to groundwater and consequently to Lake Rotorua with gorse derived nitrogen accounting for 7.9% of the total nitrogen inputs into Lake Rotorua.

Forty-three tonnes per annum of the 547 tonnes of nitrogen entering Lake Rotorua is attributable to gorse. All land uses have a nitrogen-loss signature but pine forestry has one of the lowest and if gorse is replaced with pine trees the net potential for nitrogen-loss savings through this conversion is around 41 tonnes.

The 43 tonne disclosed by this report needs to be regarded as a new identity not previously accounted for and cannot be perceived as a quantity that relieves the land user nutrient reduction requirements (i.e. the 170 tonnes of nitrogen, input to the lake that is to be removed from land use sources over the next ten years) in any way.

It is recommended that Environment Bay of Plenty devise strategies to encourage the conversion of all mature gorse areas to forestry. A far lesser amount of nitrogen-loss savings will be achieved if the land is returned to pastoral use.

Gorse to Pine conversion strategies need to consider the risks of nitrogen-loss spikes during conversion and how these may be best managed.

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Appendices

Appendix 1 – Evaluation of nutrient reduction options (Lake Okareka Catchment Management Action Plan, 2004)

Criteria for evaluation

Is the options proven?

(low risk)	A	Well proven – results known and tried in full operation.
	B	Principles understood. Variable percent of nutrient removed in known examples.
(high risk)	C	Limited field trials with variable success.
	D	Untried – no scientific support.

What percent of the nitrogen reduction target can the option achieve?

	(%)
A	81 – 100
B	61 – 80
C	41 – 60
D	21 – 40
E	0 – 20

What percent of the phosphorus reduction target can the option achieve?

	(%)
A	81 – 100
B	61 – 80
C	41 – 60
D	21 – 40
E	0 – 20

What is the level of risk in implementing the option?

A	Able to implement with certainty (consents not required/gained, landowners likely to give approval, good community support).
B	High likelihood of being implemented (possible public process required, appeals likely, uncertain whether landowners agree).
D	High probability of not being able to be implemented (adverse reaction known, lack of community support).
E	Unrealistic to expect implementation.

What is the cost per tonne of dominant nutrient removed?

	($ million)
F	$2.5
E	$2.1 – 2.5
D	$1.6 – 2.0
C	$1.1 – 1.5
B	$0.6 – 1.0
A	$<0.5

The Group discussed in detail the best way to try and cost both nitrogen and phosphorus. In the end it was decided to use the dominant nutrient. Where reductions in both nutrients are achieved it is not possible to split the cost per nutrient.

What is the timeframe for reduction in nutrient impacts from this option?

(years)

A 0 - 5
B 6 - 10
C 11 - 30
D 31+

Will the option impact other values positively or negatively?

A There will be significant positive impacts on other values.

B There will be some positive impacts on other values.

C No significant impact on other values.

D There will be some negative impacts on other values.

E There will be significant negative impacts on other values.

Other values

Include values of things like wetlands, reserves, landscape, fisheries or economic growth.

Will it adversely/positively impact another catchment?

A Significant Positive Impacts reduce another catchments nutrient level.

B Moderate Positive Impacts.

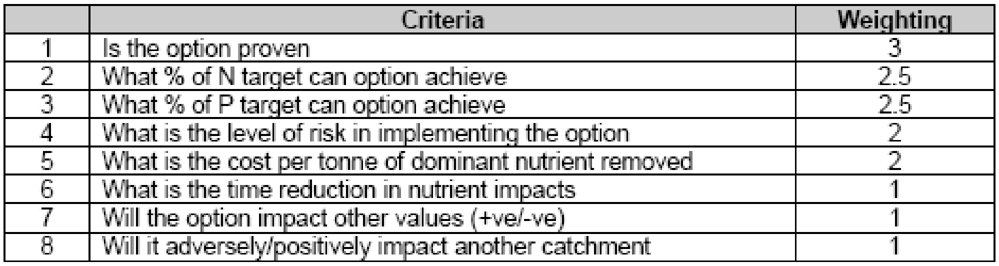
C No Impacts.

D Moderate Negative Impacts.

Weighting

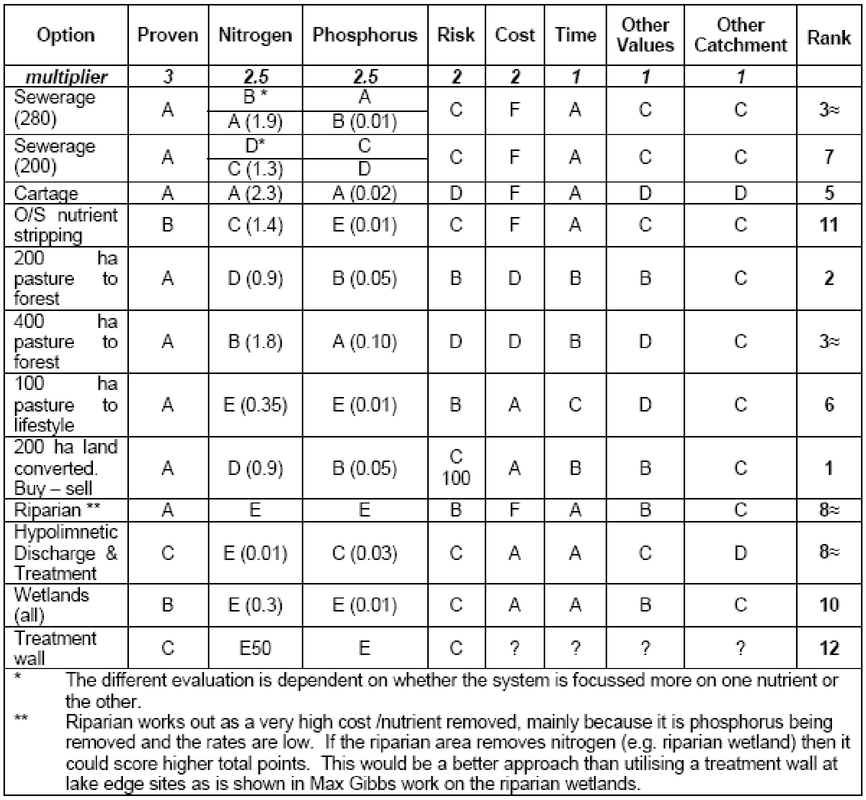
For the purposes of ranking a points system was applied however the working party felt that a written description was of more relevance when the information was presented to the wider community. The weightings indicate the significance that the working party considered appropriate for each criteria.

Evaluation Criteria



	Criteria	Weighting
1	Is the option proven	3
2	What % of N target can option achieve	2.5
3	What % of P target can option achieve	2.5
4	What is the level of risk in implementing the option	2
5	What is the cost per tonne of dominant nutrient removed	2
6	What is the time reduction in nutrient impacts	1
7	Will the option impact other values (+ve/-ve)	1
8	Will it adversely/positively impact another catchment	1

(Lake Okareka Catchment Management Action Plan, 2004)



Option	Proven	Nitrogen	Phosphorus	Risk	Cost	Time	Other Values	Other Catchment	Rank
multiplier	***3***	***2.5***	***2.5***	***2***	***2***	***1***	***1***	***1***	
Sewerage (280)	A	B * A (1.9)	A B (0.01)	C	F	A	C	C	**3≈**
Sewerage (200)	A	D* C (1.3)	C D	C	F	A	C	C	**7**
Cartage	A	A (2.3)	A (0.02)	D	F	A	D	D	**5**
O/S nutrient stripping	B	C (1.4)	E (0.01)	C	F	A	C	C	**11**
200 ha pasture to forest	A	D (0.9)	B (0.05)	B	D	B	B	C	**2**
400 ha pasture to forest	A	B (1.8)	A (0.10)	D	D	B	D	C	**3≈**
100 ha pasture to lifestyle	A	E (0.35)	E (0.01)	B	A	C	D	C	**6**
200 ha land converted. Buy – sell	A	D (0.9)	B (0.05)	C 100	A	B	B	C	**1**
Riparian **	A	E	E	B	F	A	B	C	**8≈**
Hypolimnetic Discharge & Treatment	C	E (0.01)	C (0.03)	C	A	A	C	D	**8≈**
Wetlands (all)	B	E (0.3)	E (0.01)	C	A	A	B	C	**10**
Treatment wall	C	E50	E	C	?	?	?	?	**12**

* The different evaluation is dependent on whether the system is focussed more on one nutrient or the other.

** Riparian works out as a very high cost /nutrient removed, mainly because it is phosphorus being removed and the rates are low. If the riparian area removes nitrogen (e.g. riparian wetland) then it could score higher total points. This would be a better approach than utilising a treatment wall at lake edge sites as is shown in Max Gibbs work on the riparian wetlands.

Appendix 2 – Gorse category examples

Photo 1 Scattered gorse

Photo 2 Medium gorse

Photo 3 Dense gorse

*See exemplary field survey filled out for each photo, photo number corresponds to patch number.

Appendix 3 – Field recording sheet (example)

Catchment: Rotorua
Property ID:
Address: 123 Main Road
Contact: Mobile: 021 345 6789
Home:
Email:

Sub-Catchment: Utuhina
Name: Blogs
Onsite date:

Gorse Patch number	B=Burnt S=Sprayed	Re-growth Y/N	Area of patch (ha)	Percentage cover (%)	Actual Amount of gorse. (ha)	Approx Height (m)	Maturity Estimation			Slope	Spatial variation: D=Dense M=Moderate S=Scattered	Land – use. (D,Dr,S,F,L,B)	Vegetation in adjacent area (P,NF,EF,Sc,BB, SW)
							Y	M	O				
1	n/a	n/a		5		1	*			40	S	S,B	P,NF,Sc, BB
2	n/a	n/a		40		2		*		40	M	S,B	P,NF
3	n/a	n/a		95		3			*	40	D	L	NF,EF,SW
4													
5													
6													
7													
8													
9													
10													
11													
12													
13													
Total: Average:													

NOTES: Broom and other legumes? Seeps?

KEY:

O=Old
M=Medium
Y= Young

L = Lifestyle block
S = Sheep
Dr = Deer
D =Dairy
F = Forestry
B = Beef

BB = Blackberry
EF = Exotic Forest
NF = Native Forest
P = Pasture
Sc = Scrub
SW = Swamp/ Wetland