Economic analysis of reducing nitrogen input into the Upper Waikato River catchment

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Prepared by Philip Journeaux[1], Tony Schischka[1], Yvonne Phillips[2]

([1]MAF Policy, [2]Waikato Regional Council)

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PO Box 2526

Pastoral House, 25 The Terrace

Wellington 6140

www.maf.govt.nz

Telephone: 0800 008 333
Facsimile: +64 4 894 0300

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1 Executive summary

The intent of this study was to estimate the cost effectiveness of reducing nitrogen inputs into the upper Waikato River catchment, such that they remained at the 2006 levels, in spite of a 1.5 percent per year increase in nitrate leaching due to the intensification in dairying. For reasons of simplicity, the analysis is sector-based for clarity, looks at dairying only and does not represent any policy direction. Caution is also noted, as there are a range of assumptions used, given the complexity and variability of farm management or the various issues discussed, assumptions were needed in order to derive relevant figures. In this respect therefore, the answers derived should be regarded as indicative or illustrative rather than absolute.

The problem definition indicates that a 42 percent reduction in nutrient input is required by 2030 in order to return the river to 2006 levels.

Two discount rates were used: a Treasury guideline figure of 8.0 percent real, as the "risk based rate" and a "risk free alternative" of 3.0 percent real.

Originally, the intent was to also include environmental benefits in the analysis. In the event this proved problematic given the lack of suitable data, and difficulties with the methodology in incorporating the lag effect, such that benefits were reduced significantly if discounted across these lag periods in the traditional way. Given this, the study is in effect a study in estimating the cost effectiveness of achieving a pre-determined level of reduced nitrogen inflow, within two scenarios. A section is included indicating an approach to calculating these environmental benefits.

Two main scenarios were considered to reduce nutrient input. Within these, it is important to note that:

- there are a large number of assumptions behind the figures generated, meaning they should be regarded as illustrative rather than absolute;
- the economic costs and benefits are in "real" cash, while the environmental benefits are not; and
- the environmental benefits accrue to the wider community rather than just the individual farmers. In other words they are public goods.

The first of the scenarios involved an intensive technology transfer programme to ensure adoption of a range of best management practices that would reduce nutrient input. These practices were:

- storage of dairy effluent to allow for better application to land when soil moisture levels are not saturated;
- no application of nitrogen fertiliser over the winter months (May/June/July);
- fencing off of streams and development of riparian margins;
- construction of a wintering pad/off-paddock facility;
- use of nitrification inhibitors; and
- reduced stocking rate.

It should also be noted that the situation on individual farms will invariably differ, such that costs and benefits may be greater or lesser than depicted in this study. Allowing for such variability would greatly add to the complexity of this study, and therefore the costs and benefits are based on the "average" farm situation.

Modelling work carried out would indicate that adoption of all these technologies could result in a 42 percent or possibly greater reduction in nutrient inputs. To achieve this all of the above practices would need to be adopted – it would not be a matter of “pick and mix”, and a key assumption is that all farmers would adopt these practices over the required period. Analysis of the costs and benefits involved gave the following results:

Table 1: Scenario 1 – Summary of results excluding stocking rate reduction*

	$ million	
	8.0%	3.0%
PV of Costs	291.3	409.5
PV of Economic benefits	153.0	265.7
Nett	–138.3	–143.8

* Discounted period was 20 years.

Table 2: Scenario 1 – Summary of results including stocking rate reduction*

	$ million	
	8.0%	3.0%
PV of Costs	312.8	447.2
PV of Economic benefits	378.3	661.3
Nett	65.4	214.1

* Discounted period was 20 years.

As can be seen from Table 1, the economic benefits were less than the economic costs. If a reduced stocking rate was also introduced, the equation alters such that benefits outweigh costs (Table 2). In noting this though, the reduced stocking rate is perhaps more a management issue rather than an environmental one.

Within the study it is assumed that farmers’ grazing management is sufficient to take advantage of any extra pasture grown.

The second scenario looked at a land use change via removing dairying and replacing it with forestry; both a production forestry regime and an energy farming regime. Within this scenario there was no restriction on dairying – the N leaching reduction was achieved via the land use change. For the production forestry scenario, the value of carbon was also included. This was an important consideration, as the profitability of the forestry regime without carbon was relatively low.

Within the production forestry scenario value-add multipliers were used to gauge the impact at the national level; as such a scenario would have significant impacts beyond the farm gate. A summary of the results are:

Scenario 2a – Summary of the production forestry regime:

Table 3: Forestry scenario farmgate level impact*

	$ million	
	8.0%	3.0%
PV of Costs	403	1689
PV of Economic benefits	120	1300
Net	–283	–389

* Discounted period was 56 years.

Table 4: Forestry scenario national level impact using multipliers*

	$ million	
	8.0%	3.0%
PV of Costs	3214	13451
PV of Economic benefits	1193	9350
Nett	–2021	–4101

* Discounted period was 56 years.

Scenario 2b – Summary of the energy farming regime:

Table 5: Energy farming scenario*

	$ million	
	8.0%	3.0%
PV of Costs	426	1643
PV of Economic benefits	92	245
Net	–334	–1398

* Discounted period was 22 years.

The farm/forest gate figures show that the forestry benefits are less than the costs (loss of dairying). The use of multipliers to show the wider implications of such a land use change magnifies this differential.

For the energy farming scenario, the overall effect is again negative.

There are significant issues around valuing environmental costs and benefits, and more research is required within New Zealand around biodiversity values and ecosystem services, so as to more accurately estimate these values. Within this study some values have been calculated, but the base data is scarce and the figures derived are very much illustrative.

2 Purpose

The original purpose of this analysis was to consider the economic costs and benefits, including environmental benefits, of reducing nitrogen inflows into the upper Waikato River, and then maintaining these in the face of increasing dairy production. However, given difficulties in calculating the environmental benefits it is in effect a study in estimating the cost effectiveness of achieving a pre-determined level of reduced nitrogen inflow, within two scenarios.

The difficulties in calculating environmental benefits arose due to a combination of the scarcity of good information in this area, meaning some stretched extrapolations were made, and the effects of lag periods on groundwater flows, which reduced benefits significantly if discounted in the traditional way. Nevertheless, a section is included on this in order to demonstrate a possible approach to valuing environmental benefits.

For reasons of simplicity, this study looks at dairying only.

While the intent is to reduce nitrogen inflows, the strategies discussed would also have some impact on phosphate and microbial inflows into the river. This study concentrates on nitrogen inflows however, as most of the data available relates to nitrogen.

It should be noted that this is a technical as opposed to a policy document, and does not attempt to investigate optimal land use within the catchment.

3 Background

Over recent years, concerns have been raised as to the level of nutrient and microbial inflows into the Waikato River. The river itself can be considered as two distinct sections:

- The area between Taupo and Karapiro Dam, which contains the eight hydro lakes where river flows are controlled, and where it can take several weeks for the water to flow from Taupo to Karapiro, compared with two to three days prior to the dams being built; and
- The section downstream of Karapiro where flow is not controlled. The Waipa river flows into this section, and the water takes three–four days to flow from Karapiro to the sea (Vant, 2007).

While there are issues with water quality in the section downstream of Karapiro, this study will concentrate on the water quality issues in the first section. Within this section, nitrate levels have increased three percent per year from 1993 to 2006. Phosphate levels have also increased at six of the ten monitored sites (Vant, 2007).

4 Problem definition

Vant (2006), based on some assumptions (detailed below) calculated the level of nitrogen reduction required if the river was to remain in the same (2006) state:

1. Assuming no forestry conversions within the catchment, dairy farms continue to intensify at 1.5 percent per year, and sheep and beef remain constant, the nitrogen loading in the hydro lakes will increase by 33 percent by 2030.
2. If all planned conversions from forestry to pasture (approximately 70 000 hectares) occur as planned, dairy intensifies at 1.5 percent per year and sheep and beef remain constant, the nitrogen loadings in the hydro lakes will increase by 70 percent by 2030.

However, approximately half the forestry conversions had already occurred by 2009, which means that the level of nitrate leaching into the river will be higher than estimated in scenario (1) above.

Vant (2006) assumed an average nitrate leaching figure of 36 kgN/ha from dairy farms in 2006. If this compounds forward at 1.5 percent, the figure reaches 51 kgN/ha by 2030. In order to maintain the river at its "current" (2006) level therefore, it would be necessary to cap nitrogen leaching at the current 36 kgN/ha rate. This is further complicated by two factors:

- the conversion of approximately half the intended forestry area within the catchment. If this is taken into account, the nitrogen cap would have to reduce down to 30 kgN/ha; and
- the original figures were calculated as at 2006. If these are updated to 2009, the average leaching figure is now 38 kgN/ha.

While there are a number of possible strategies that could be used to achieve this, the one modelled in this report is to allow farms to intensify at current levels, but introduce mitigation strategies such that average leaching in 2030 is equal to 30 kgN/ha. This is a 42 percent reduction[1].

Two of the key assumptions underlying the Vant (2006) calculations were:

- that there is no change in the 300 tonnes/year outflow of nitrogen from the Taupo catchment due to the impact of EW's Variation 5 plan; and
- Nitrogen leaching from sheep and beef properties reduces down from 13-15 kgN/ha/year to 12 kg/N/ha/year and is held there by best practice.

In the absence of either of these assumptions the amount of N leaching from dairy land would have to be further reduced.

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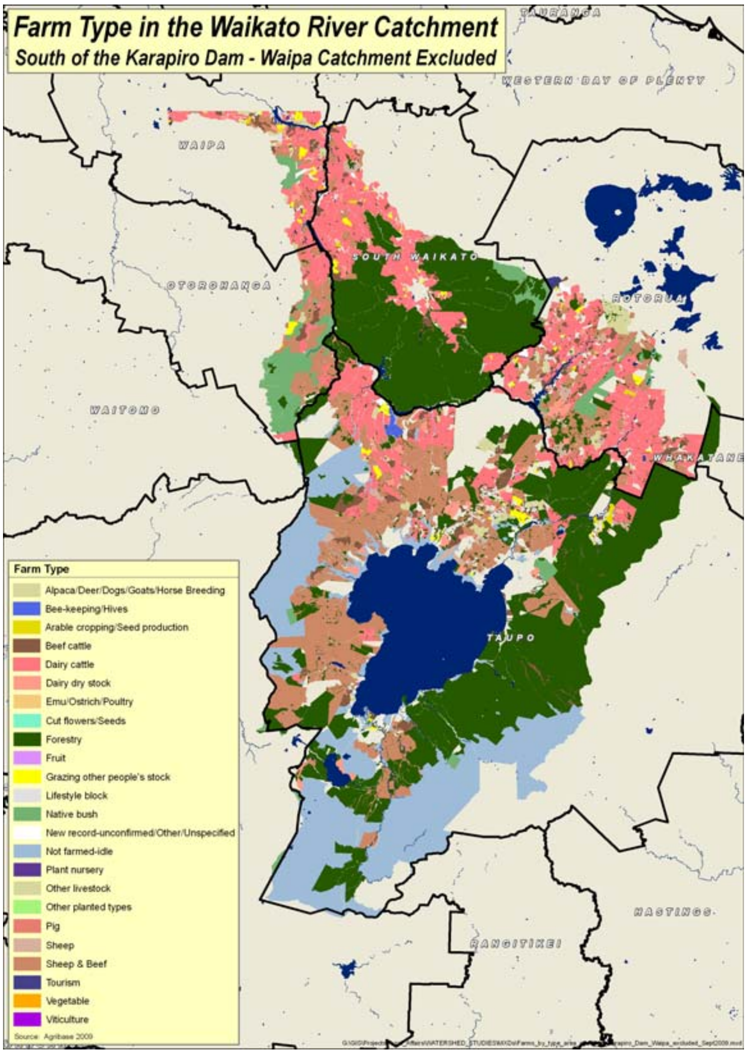
[1] The figure of 30 kgN/ha derived here differs from the 26 kgN/ha derived from the Integrated Catchment Management pilot work carried out by Environment Waikato (EW), and the Upper Waikato Nutrient Efficiency Study (UWNES, AgFrist, 2009). These studies derived the 26 kgN figure on the assumption that all 70 000 hectares of forestry were converted to dairying.

The basis of this economic analysis therefore is to look at the cost effectiveness within two scenarios of allowing the dairy farms to intensify, while reducing nitrogen leaching down by 42 percent over assumed 2030 levels[2].

The area of land affected is that part of the Waikato River south of the Karapiro Dam, excluding the Waipa River catchment as shown in Figure 1.

Figure 1: Farm type 2009 (Source: Agribase)



[2] The figure of 1.5 percent per year intensification of dairying within the hyrdro lake catchment is another key assumption by Vant (2006) based on information provided by Fonterra. Analysis of the dairy statistics for the Taupo, Rotorua, and South Waikato Districts (as a proxy for the catchment area) shows that: cow numbers have increased by 5.9 percent per year from 1994/95 through to 2008/09; stocking rates increased by 0.7 percent per year; production per hectare increased by 2.6 percent per year for the period 1994/95 through to 2008/09 (14 years), by 3.6 percent for the period 1998/99-2008/09 (10 years), and 1.0 percent for the period 2004/05–2008/09 (5 years). Ledgard (pers com) advises that a good indicator of nitrogen leaching is the amount of feed consumed by cows, and a good proxy of this is production levels. For the purposes of this study, it is assumed that the 1.5 percent intensification per year continues, in the sense of increased production per hectare, and this is directly reflected in nitrogen leaching.

Table 6: Land use in Waikato catchment south of Karapiro, excluding Waipa

Farm Type	No. of Farms	Area in Ha
Beef cattle	255	46 816
Dairy cattle	724	130 505
Deer	58	7 987
Sheep	39	5 269
Sheep & Beef	222	114 058
Forestry	70	209 897
Other	1 753	142 492
Total	3 121	657 025

Source: Agribase Sept 2009, LUM-MfE 2008

As can be seen from Figure 1, the main districts affected are Taupo, Rotorua and South Waikato, with some eastern parts of Otorohanga and Waipa.

5 Assumptions

Within this study there are a range of assumptions – given the complexity and variability of farm management or the various issues discussed, assumptions were needed in order to derive relevant figures. In a number of instances arbitrary figures – best guesses based on available research – have been used in the absence of any direct information. In addition, proxy values are also used around a number of the environmental benefits. These are discussed in the relevant text.

In this respect therefore, the answers derived should be regarded as indicative or illustrative rather than absolute.

Three key assumptions underlying this study are:

- That the hydro lakes would remain as is. Removing the dams would result in a significant increase in water flow, "flushing" the river on a regular basis. While this may solve the problem of water quality in the upper section of the river, it would merely shift the problem to the lower section, and coastal waters off Franklin District.
- That other farming systems in the catchment remain in a status quo situation; that is, sheep and beef farm nutrient output remains as is (subject to the assumptions outlined in Section 4), and no further land use intensification takes place.
- A number of the technologies and management practices described in scenario 1 result in increased pasture grown, which could potentially result in an increase in stocking rate, and hence increased nitrogen outflows. Within the study it is assumed that stocking rates are held as is, with any increase in pasture grown resulting in increased per cow production. This in itself would increase nitrogen outputs at the margin, but these are ignored. Similarly some strategies reduce pasture grown, which reduces per cow production – again this would reduce nitrogen output at the margin, and again this is ignored.

6 Viewpoint

The study will consider the costs and benefits from a national viewpoint, although most of the costs and benefits will fall within the Waikato region. This is important mostly for scenario 2 discussed in this report, where multipliers are included.

The approach will be from a "with" and "without" viewpoint. The "with" viewpoint will be calculated using two scenarios (discussed later) relating to changes to reduce nitrogen input. Currently dairying within the catchment is a complying activity, and the "without" viewpoint assumes no intervention to improve water quality, which implies a static land use situation, including no further impacts from land use intensification. This may not hold true into the future, as land use change is likely to occur (for example, more dairying, more urban and peri-urban, more horticulture, etc) but this is difficult to predict and therefore is ignored. There is also an issue in valuing the "without" situation (that is, the cost of allowing the river to continue to deteriorate). Within this study, as discussed in the section on environmental benefits, non-market values determined by willingness to pay/choice modelling approaches will be used as a proxy for this. In essence, the "without" viewpoint involves continued economic gain, but at an environmental cost. If, for whatever reason, dairying becomes non-complying then the "with" situation would hold.

It should also be noted that the situation on individual farms will invariably differ, such that costs and benefits may be greater or lesser than depicted in this study. Allowing for such variability would greatly add to the complexity of this study, and therefore the costs and benefits are based on the "average" farm situation.

7 Cultural aspects

Maori cultural values are a significant component around the recent signing of the Waikato Tainui/Waikato river settlement. Within a traditional cost benefit analysis, the objective is to endeavour to monetarise all costs and benefits in order to develop a final net present value. However, there are no studies available as to the money value of such direct use values such as Manakitanga (provision of food from the river re hospitality for guests/visitors), or indirect values such as Kaitiakitanga (environmental guardianship).

While these factors are likely to result in positive impacts with respect to improving water quality, developing such monetary values is well outside the scope of this project, and therefore are not included.

8 Scenarios

The reduction in nutrient was modelled by two scenarios. While there are many other possible scenarios, and permutations within these as well as the two modelled, trying to include these adds greatly to the complexity, and therefore the two scenarios were kept as straight forward as possible.

- Technology transfer/Best management practices scenario

This scenario involves achieving the nitrogen reductions mostly via changes in management and a range of on-farm actions.

A number of recent studies (Environment Waikato, 2008; Environment Waikato, 2009; AgFirst Waikato, 2009; Environment Bay of Plenty, 2007) have indicated that an intensive technology transfer/extension programme and on-farm action can be effective in reducing nutrient outflows from dairy farms. This involves a range of factors, such as: reducing nitrogen fertiliser input, efficient effluent management, off-farm winter grazing, the use of nitrification inhibitors, use of wintering pads, and possible reduction in stocking rates. Measured on-farm results have indicated reductions of up to 10 percent, while modelled scenarios have indicated up to 30 percent reductions.

The costs for this scenario would involve an intensive technology transfer programme throughout the catchment on an ongoing basis. The intent of the scenario is to look at known technologies, and consider their adoption, both with respect to costs and benefits.

- Land use change scenario

The intent in this scenario is to look at a straight forward swap of dairying into a low-nitrogen output land use. Within this scenario there is no restriction on dairying – it continues to intensify as usual, with the reduction in nitrogen leaching necessary achieved via taking land out of dairying. This could possibly be considered the worst case scenario. As discussed later in this report, the area involved would be in the order of 66 400 hectares.

Two possible low-nutrient output land uses are considered under this scenario:

Production Forestry: this scenario would involve planting up the required area of dairy farm land to give a net 42 percent reduction in nitrogen outflows. While there are a range of possible forestry options to achieve this, the one modelled in this study is planting Radiata Pine for timber production, with carbon credits also claimed.

Energy Farming: much of the land in question is easy rolling to flat, and hence can be covered by machinery; this scenario will look at the use of the land for energy farming, for example, planting it in salix spp that would be machine harvested every four years, to be converted into biofuel and other products.

These scenarios would look at the impact on the national economy of removing such an area in dairying and the subsequent investment into the forestry/energy farming regimes. Given the scale involved, it is assumed that these forestry/energy farming ventures will be corporate investments rather than farm forestry/woodlots.

9 Discount rates

Discount rates are a critical component of cost benefit analysis, in that a high discount rate discounts future cash flows to a much greater extent than a low discount rate.

Two discount rates are used in this analysis:

- Treasury Guideline Rate, based on the "government opportunity cost of capital" (Treasury, 2008), is used as the "risk based rate". This gives a default discount rate of 8.0 percent real (deflated for inflation and tax).

  This is calculated as follows:

  WACC(real) = [(1+WACCn)/(1+i)]-1

  Where: WACCn = [RFR x (1-Tc) + (Ep x βa)] / (1-Te)

  Tc (corporate tax rate) = 30%

  Te (effective tax rate) = 20%

  Ep (equity risk premium) = 7%

  RFR (risk free rate) = 6.4%

  i (inflation rate) = 3%

  βa (asset beta) = 0.67
- The second discount rate would be considered as the "risk-free alternative", or social time preference rate, which is taken as the ten-year average of the ten-year government bonds. This equals 6.2 percent (nominal) (BNZ, 2009). If this is adjusted for inflation, allowing a 3 percent inflation rate as used in the Treasury calculation, the real discount rate becomes 3.1 percent. The decimal point (0.1) is ignored (the PV differences between 3.1 and 3.0 percent were minimal), so the real risk-free rate used in this analysis is 3.0 percent.

10 Farm statistics

From Table 5, it can be seen that there are 724 dairy farms within the catchment, covering a total area of 130 505 hectares. This gives an average farm size of 180 hectares. An analysis of the LIC/DairyNZ statistics for the districts covering the catchment indicates an average stocking rate of 2.74 cows/effective hectare, and production of 320 KgMS/cow. The assumptions used in this report therefore are shown in Table 7.

Table 7: Average catchment dairy farm parameters

Number of farms	724
Average farm: total area (ha)	180
Average farm: effective area (ha)	175
Number of cows wintered	480
Number of cows milked 15 December	468
Production (kgMS)	150 000
Economic farm surplus ($/ha)*	1 164
Average real payout ($/KgMS)*	5.50

* EFS and the average real payout were calculated as the 2010 value calculated over a 10 year period (2000–2010) – that is,, the values over this period were inflated through to 2010 using the CPI index.

11 Scenario 1: Best management practices

The intent behind this scenario was to look at a range of known technologies or approaches that could be used by farmers to reduce nutrient inputs into water bodies. By implementing these practices, farmers would be able to meet the required reduction in nutrient output. A major premise behind this scenario is that an intensive technology transfer programme is carried out to achieve this – the literature (for example, Journeaux 2009) shows the value of extension efforts, and the mixing of farm business and environmental goals as part of this, in achieving improved environmental outcomes.

The technologies assumed adopted, and costed, in this report are:

- storage of dairy effluent to allow for better application to land when soil moisture levels are not saturated;
- no application of nitrogen fertiliser over the winter months (May/June/July);
- fencing off of streams and development of riparian margins;
- construction of a wintering pad/off-paddock facility;
- use of nitrification inhibitors; and
- reduced stocking rate.

As noted earlier in the section on scenarios, modelling work has shown that the first four activities can achieve around a 30 percent reduction in nitrogen output. Nitrification inhibitors are a relatively new technology, but have the potential to be a significant contributor in achieving the desired 42 percent reduction. An analysis and discussion around reduced stocking is also included. While this is perhaps more around farming efficiency, it would also contribute to reduced nitrogen leaching.

Technology transfer programme

Rate of Adoption

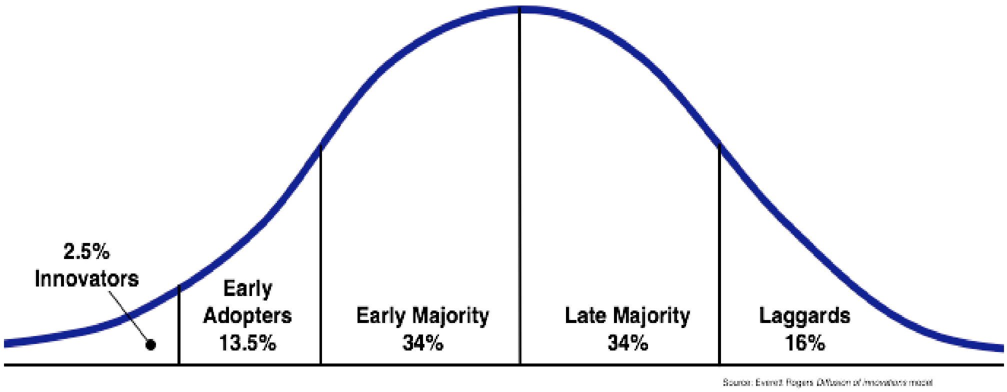
Technology transfer programmes, or extension, are a critical aspect of enabling farmers to adopt new innovations or systems. There has been significant research (as discussed in Journeaux, 2009) to show the value of farm extension in assisting farmers to adopt these innovations or new systems.

There are a number of factors that influence the uptake on innovations, including the characteristics of the innovation such as relative advantage, complexity, trialability and observability, the characteristics of the individual such as time availability, and their personal and family circumstances. The use of extension agents can significantly influence these aspects.

The rate of adoption of innovations follows a normal distribution curve, as shown in Figure 2:

Figure 2: Adoption Curve

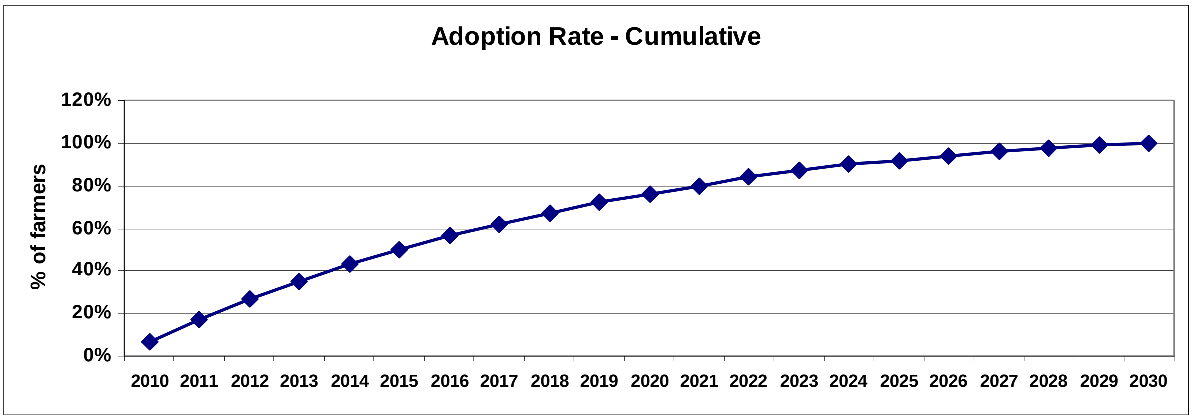
(an illustrative diagram from Rogers and Shoemaker (1971))



The intent behind this study was to ensure that all farmers had adopted the technologies by 2030, as per the problem definition discussed earlier. Given we are currently in 2010, this gives a 20-year window to achieve this, which is a relatively short period. As the literature indicates (discussed in Journeaux, 2009) the time horizon on adoption of complex farm management systems (which most environmental issues fall into) is of the order of 25–30 years. A key assumption therefore is that all (that is, 100 percent) of farmers will adopt these technologies/management practices over the 20-year period. This is problematic, and expanded on further in the discussion section of this scenario.

A further key assumption behind this study therefore is the rate of adoption over the 20-year period. An adoption curve was constructed to determine this, as illustrated in Figure 3.

Figure 3: Assumed adoption rate (refer Appendix 1)



As the curve illustrates, approximately 50 percent of farmers have adopted over a 5-year period, with the remainder somewhat more slowly over the remaining 15 years. This represents a quite fast (but not impossible) rate of adoption, and an intensive extension effort would be required to achieve this.

The significance behind this curve is that the rate of adoption of all the technologies discussed in this report follow this curve, as do the costs and benefits calculated.

Technology transfer programme costing

While there could be various ways to achieve the extension programme, the following key assumptions were made for this programme, so as enable some costings around it:

- 8 day "setup" per farm – advisor visits farm, desktop modelling of farm to develop farm plan, follow up visits to gain acceptance of the plan. This would in effect take about 2 years.
- The equivalent of 4 by 1 day visits by the advisor per year for the next 5 years.
- The equivalent of 2 by 1 day visits per year for the remainder of the programme.
- A mix of field days and seminars/workshops also held.

To achieve this, at a ratio of 50 farms per advisor, 14 advisors and 2 support staff would be needed for the first seven years, with 8 advisors and 1 support staff for the remainder of the programme. The Present Value (PV) cost of this is:

$PV_{8.0\%}$ = $17.2 million

$PV_{3.0\%}$ = $24.6 million

[Details are shown in Appendix 2]

Such an intensive advisory effort would also have direct spin-offs on-farm profitability. A number of studies (discussed in Journeaux, 2009) have shown financial returns of between +20 percent through to greater than +100 percent from farm extension programmes. For this study it is assumed that farm net profit before tax improves by 0.6 percent per year as a result of the intensive advice on management issues. The direct benefit of the extension programme therefore is calculated as:

$PV_{8.0\%}$ = $19.9 million

$PV_{3.0\%}$ = $39.5 million

[Details are shown in Appendix 2]

It should be noted that this benefit is additional to any benefit gained via the various strategies discussed in this scenario – the intensive advice would have additional impacts on farm and financial management beyond implementing the strategies discussed.

Farm management strategies

While the grazing of cows outside of the catchment over winter would be a legitimate approach to reducing nitrogen leaching during this period, it would, however, simply transfer the problem from one catchment to another, albeit possibly less sensitive. The intent of this study was to look at possible permanent solutions, and for this reason grazing of cows outside the catchment was not considered.

1. Reduction of winter nitrogen

The main period of nitrogen leaching occurs over the high risk months of May, June, and July. The management strategy here is to apply nitrogen fertilisers in the autumn and spring, but missing out the winter period. So instead of five applications, this is reduced to four; one in April, and three over August/September/October. A reduction in N fertiliser application over winter (omitting one application in total) has two effects:

- It will avoid direct leaching of the applied fertiliser N, which can be up to 30 percent of the N applied, depending on the N rate, rainfall, and any specific conditions within that year (Ledgard *et al.,*1988); and

- An indirect affect of less N fertiliser applied overall, resulting in less increase in pasture nitrogen percent, which reduces urine N excreted, but also less pasture growth. (Ledgard *et al.,* 1999).

On the model farm used for this study, this action resulted in a 9 percent reduction in N leaching as modelled by the Overseer nutrient balance model.

Average nitrogen application in the Waikato is equivalent to 95 kgN/ha measured over the whole farm (MAF 2009a). Assuming 15 percent of the farm area is for effluent disposal, this gives a figure of 112 kgN/ha of the remainder of the farm. Assuming five dressings, this would give the equivalent of 22 kgN/ha, or 49 kg urea/ha, per dressing.

Removing the one winter dressings brings the application rate down to 90 kgN/ha over the farm excluding the effluent area.

Again there are both positive and negative economic impacts to this strategy.

The positive is the cost saving from reduced nitrogen fertiliser application. The PV value of this is:

$PV_{8.0\%}$ = \$18.4 million

$PV_{3.0\%}$ = \$32.3 million

The negative side is the loss of pasture grown over this period, which is costed as the value it would have had if it was used to produce milksolids (assumes lower milksolids per cow). This is calculated assuming a response rate of 8 kgDM per Kg N (Average response to nitrogen in the winter-early spring is 10–15 kgDM/kgN, whereas the response later in spring is around 20 kgDM/kgN (DairyNZ, 2006a), and costed at the marginal value of milk solids less direct costs. The PV value of this is:

$PV_{8.0\%}$ = \$29.5 million

$PV_{3.0\%}$ = \$51.8 million

[Details are shown in Appendix 3]

An implicit assumption in this strategy is that the farmers essentially all-grass winter. If the reduction in nitrogen is substituted by bought in supplementary feed, the reduction in nitrate leaching would be negligible.

Anecdotal evidence (Abercrombie, pers com) would indicate that nitrogen usage within the catchment is higher than the Waikato average, with useage on some farms up to 250KgN/ha. If this figure is used, the PV values are:

Saved N costs:

$PV_{8.0\%}$ = \$41.0 million

$PV_{3.0\%}$ = \$72.0 million

Loss of pasture:

$PV_{8.0\%}$ = \$65.9 million

$PV_{3.0\%}$ = \$115.7 million

2.. Improved effluent systems

Virtually all dairy farms within the catchment operate spray irrigation systems (Abercrombie pers com), with the exception of a few farms who operate a two-pond system due to topographical restraints on irrigation systems.

The main requirement is to improve effluent storage so as to prevent run-off of effluent when soil moisture levels are high. The amount of nitrogen leaching saved by doing this varies significantly with soil type, with the greatest gain coming from deferred irrigation on poorly draining soils. For the freer draining pumice and ash soils in the upper catchment, the reduction in nitrate leaching may be quite small, with greater gains coming from reductions in microbial and phosphate leaching/run-off (Houlbrooke and Monaghan 2010; Silva *et al.,* 2000).

The assumption here was to construct a storage pond suitable for 90 day storage for the average 480 cow herd. Given the variability of soil types within the catchment, 90-day storage may not be necessary on every property, but that is what is modelled here. In discussion with local contractors the prices quoted ranged from $12 000 to $18 000 for earthworks, plus $22 000–$25 000 to line the pond. Mid-point costings were used, such that the cost to the average farm was $38 000. Lining was considered desirable given the free-draining nature of many of the soils in the catchment. There were also some wide variations in estimates of lining costs, of up to $100 000 depending on the size of the herd.

For the farms operating a 2-pond system, the assumption was that they would have to move to an advanced pond system. Estimates on the construction cost of these varied considerably, from $80 000 to $200 000. An average cost of $150 000 was used in this study. Overall, the PV cost of this programme was:

$PV_{8.0\%}$ = $19.1 million

$PV_{3.0\%}$ = $25.2 million

[Details are shown in Appendix 4]

The benefits of such a system means that the effluent can be sprayed onto pastures later into the spring when soil moisture levels are not as high as typically experienced in late winter/early spring. So, for example, the effluent is stored over July, August, September, and then irrigated over October and November.

The gains to this are a reduction in run-off of nutrients and a greater response in pasture growth by applying the nutrient (especially nitrogen) later in the spring. As noted earlier, average response to nitrogen in the winter-early spring is 10–15 kgDM/kgN, whereas the response later in spring is around 20 kgDM/kgN (DairyNZ, 2006). Assumptions therefore are; that the effluent is stored and applied in October/November, achieving an extra growth of 7.5 kgDM/KgN, the amount stored is equivalent to 0.03 kgN/cow/day (DairyNZ, 2010), and that the extra pasture grown at that time is made into silage. The PV value of this is:

$PV_{8.0\%}$ = $5.5 million

$PV_{3.0\%}$ = $9.6 million

[Details are shown in Appendix 5]

3. Fencing off streams/riparian margins

Fencing off of streams to prevent livestock access, and the planting of riparian margins would give some reduction in nitrogen in run-off, albeit minor on ash/pumice soils, plus could give a small reduction in underground N flows to streams. Overall this may be around a 5 percent reduction. It is however a significant means of preventing both sediment and phosphate run-off, as well as microbial run-off (MAF 2006; MCKergrow *et al.,* 2007; Taranaki Regional Council, 2010).

GIS analysis of the catchment indicated a total stream length of 2039 km on dairy farms, and 2073 km on sheep and beef farms. These were streams with permanently running water. The assumption was that all streams on dairy farms needed to be fenced and planted, and 20 percent of the sheep and beef farms, on the assumption they would be running dairy heifer grazers.

This gave a total length of fencing required (given that both sides of the stream would need to be fenced) of 4908 km.

A recent Environment Waikato survey (Reece, pers com) has shown that 35 percent of dairy farms in the region had fenced both sides of their streams to achieve total stock exclusion. In addition to this it was assumed that 10 percent of the remaining length did not need to be fenced due to natural barriers.

The type of fencing assumed was a three-wire electric fence, costing $3500/km. The PV cost of fencing streams off was:

$PV_{8.0\%}$ = $6.4 million

$PV_{3.0\%}$ = $8.7 million

[Details are shown in Appendix 6]

The next step was consideration of planting of a riparian margin, and the width of that margin. In many respects farmers could well just fence 2–3 metres back from the stream, which would reduce the amount of land lost for productive purposes, but also reduce the effectiveness of the riparian margin.

The width of riparian strips, to be effective, depends very much on soil type and slope (Quinn, pers com), with the greater the slope the greater the width needs to be. For the purposes of this study, it was assumed that dairy farmers fenced off the stream 5 metres back from the stream, sheep and beef farmers planted 10 metres back (on the assumption that they are on steeper country and water run-off velocity is greater) and planted up the margin in a variety of (mostly) native plants. The design of riparian buffers can be complex, depending on what they are required to do. If stream bank stability and biodiversity are prime goals, then planting the strips up is required. To control nutrient run-off, grass strips are often more effective. With a 5 metre margin, the amount of light entering the strip would be high, and a reasonable level of grass growth could be expected. As noted therefore, the assumption is that the riparian strips would be planted up.

These widths could also be considered the minimum required to achieve some degree of effectiveness, without taking up significant areas of productive land. For riparian strips to be self sustaining, they need to be in the order of 10–20 metres wide (Quinn, pers com) However, at this width they would start to take up significant areas of productive land, and the opportunity cost of this could be significant. For example, assuming a 20 metre strip of which 70 percent was productive land, the opportunity cost would be: PV8.0% = $27.8 million.

Assuming the margin widths noted above, the area taken out within the catchment would equate to 1951 hectares. Given these relatively narrow widths, for the purposes of this study it was assumed that 50 percent of this was productive land. At the given EFS per hectare the PV losses were:

$PV_{8.0\%}$ = $6.3 million

$PV_{3.0\%}$ = $11.1 million

[If the productive area lost was 20 percent, the PV8.0% = $2.5 million]

The cost of planting the riparian margins could vary significantly. A costing from Environment Waikato (EW), based on planting a plant every square metre, and using contracted labour, along with follow-up weed control, was $92 000 per hectare. A costing from Taranaki Regional Council (TRC), based on provision of plants at cost, a much lower planting density, and farmers using their own labour, worked out at approximately $6.20 per linear metre, assuming a 5 metre margin width (refer Appendix 7).

On the assumption that farmers would not plant every square metre, the Environment Waikato costing was halved down to $45 000/hectare. The PV values of these two options were:

Environment Waikato:

$PV_{8.0\%}$ = $53.6 million

$PV_{3.0\%}$ = $72.5 million

[If the full EW riparian planting costs was used, the PV values double, that is, PV8.0% = $107.2 million]

Taranaki Regional Council:

$PV_{8.0\%}$ = $11.3 million

$PV_{3.0\%}$ = $15.4 million

Farmers would be attracted by the much cheaper TRC approach, but this approach does contain some implicit subsidies, in that TRC buys and sells the plants at cost, and the cost of planting and post planting release and weed control is carried by the farmer, whereas the EW approach is fully costed, including follow-up work. For this reason, the EW costings have been used in this study.

[Details are shown in Appendix 8.]

The planting up of such an area in native plants also opens up the possibility of claiming carbon credits via the Permanent Forestry Sink Initiative (PFSI). This scheme allows landowners to claim carbon credits for permanent forests that are planted on previously unplanted areas (MAF, 2010a). This could also apply to riparian margins, provided the riparian strip consists of tree species capable of reaching 5 metres in height and which form at least 30 percent of the canopy, the riparian strip on either side of the stream is at least 15 metres wide, and the waterway is less than 15 metres on average (Pitcher-Campbell, pers com).

Given that the riparian strips were 5 metres on dairy farms and 10 metres on sheep and beef farms, they would not qualify as such. Nevertheless, this option is available for riparian strips which do meet these criteria.

The planting of the riparian margins would, as noted above, result in an area of 1951 hectares planted in (mostly) native plants. This is a significant area within the catchment, and would represent ideal corridors for native birds. In this respect therefore a positive biodiversity benefit is likely, which is discussed further in the environmental section.

4. Wintering facilities

The approach here is for each farm to construct a wintering facility of some sort to enable the cows to be taken off the pasture during winter when the soil is very wet. This both reduces nitrogen leaching, and helps prevent soil pugging, resulting in improved pasture growth. Trials at DairyNZ using on-off grazing for 4–6 hours per day over winter achieved an average 20 percent reduction in nitrogen leaching. (Ledgard *et al.,* 2006).

Some recent research (Christensen *et al.*, 2010) at Massey University with duration-controlled grazing practices, in conjunction with the use of an off-paddock wintering facility, resulted in a 41 percent (5.2 kgN/ha) reduction in nitrate leaching.

On the cost side of this scenario, the assumptions were:

Thirty percent of farmers already had some structure (based on discussion with a number of consultants), the cost of this being "sunk" and not included in this study.

The average cost of the structure, was assumed at $1000 per cow. This recognises that some structures (for example, using sawdust/bark) could be constructed more cheaply, whereas a herdhome would cost in the order of $1200 per cow. It also recognises that many of these structures are feedpads, requiring some effluent management system, rather than just stand off pads. An allowance for maintenance costs has also been included. The PV costs of this were:

$PV_{8.0\%}$ = $192.3 million

$PV_{3.0\%}$ = $279.3 million

Pugging and compaction can result in damage to pasture reducing utilisation by 20–40 percent, and a reduction in future pasture yield to between 20–80 percent for 4–8 months, depending on soil type, as well as greater fertiliser requirements and sediment run-off (DairyNZ, 2006b). It is difficult to accurately determine an "average" benefit for wintering facilities given the variations between farms and between years. This is particularly so for the catchment, given that many of the soils tend to be lighter (that is, pumice), and consequently less susceptible to pugging. For this study it was assumed that the reduction in soil pugging meant on average an extra 500 kilograms of dry matter per hectare was grown. This was costed as the value it would have had if it was used to produce milksolids. The PV value of this is:

$PV_{8.0\%}$ = $90.4 million

$PV_{3.0\%}$ = $158.8 million

[Details are shown in Appendix 9]

[These figures change linearly with respect to the amount of "saved" pasture – if 250 kgDM/ha they halve, if 1000 kgDM/ha they double]

5. Use of nitrification inhibitors

Nitrification inhibitors are a relatively recent technology that has been introduced to New Zealand farming. It involves the use of *dicyanimides* that are applied to paddocks just prior to winter and just after, and act on soil microbes such that the ammonia excreted in the urine by cows is more slowly converted to nitrates (NO_3 – which leach through the soil profile) or to nitrous oxide (N_2O) which is a greenhouse gas.

The main issue with nitrification inhibitors is that being a new technology, and with little research carried out in the North Island, farmers are reluctant to use them until more research proves their efficacy, both with respect to nitrogen leaching, and increased pasture growth. There is also something of a catch-22 situation in that because of the limited use, there is a shortage of contractors able to apply the product.

Never the less, nitrification inhibitors represent a potential management strategy available to farmers. It was included in this study in that the management strategies discussed earlier generally will only result in a 30 percent reduction in nitrogen leaching, well short of the required 42 percent to maintain the status quo.

Most of the research on nitrification inhibitors has been done in the South Island. An indication of the efficacy in the North Island is a reduction in nitrogen leaching of 10–30 percent, and increased pasture growth of 5–10 percent (A Roberts, personal communication).

Assuming an applied cost of $200 per hectare (that is, two dressings at $100 each), the PV cost of this was:

$PV_{8.0\%}$ = $14.3 million

$PV_{3.0\%}$ = $19.4 million

Assuming a mid-point response (of 7.5 percent) in pasture growth, and costing this as the value it would have had if it was used to produce milksolids, the PV benefit was:

$PV_{8.0\%}$ = $18.9 million

$PV_{3.0\%}$ = $25.6 million

[Details are shown in Appendix 10]

One recent research trial on a Rotorua dairy farm on pumice soils and 1500 mm rainfall showed a 20 percent decrease in N leaching, and a 5 percent increase in pasture production (Ledgard *et al.,* 2008).

The profitability of this strategy depends very much on the increase in pasture production. A sensitivity analysis around this is shown in Table 8.

Table 8: Sensitivity analysis of pasture growth response

Pasture Response (%)	Value of Pasture ($PV_{8.0\%}$) $ million	Net Value (Cost less Return) $ million
0	0	–$14.3
5	12.6	–$1.7
7.5	18.9	$4.6
10	25.2	$13.9

The issue with this strategy is that farmers are currently cautious about its use in the face of limited research, and the probability around capturing the extra pasture growth.

Another issue is that the use of wintering pads would reduce the efficacy of inhibitors given the amount of N from animals being deposited on pastures over winter.

6. Reduced stocking rate

Recent modelling by MAF (and other agencies, for example, Ridler *et al.,* 2010) has indicated that many farms could reduce their stocking rate by 10 percent, reduce their level of bought-in supplementary feed by around 50 percent, but maintain their current level of production, provided they can lift their grazing management to ensure that pasture quality is maintained.

This latter assumption is quite critical, and the ability of farmers to achieve this would be quite variable, although within this study the assumption of intensive consultancy input would assist. The maintenance of production would also be assisted given the increasing genetic worth of dairy cows in New Zealand.

The reduction in nitrogen leaching is not necessarily significant, as the cows are essentially substituting pasture for the bought-in feed, in order to maintain production. The model farm used in this study (480 cows on 175 hectares, producing 150 000 kgMS) was run through Overseer, with the amount of bought in feed (Palm Kernel Expeller) reduced by 45 percent. This resulted in a 7 percent reduction in nitrogen leaching.

The major benefit to this option is the savings in bought-in feed, with the only cost being a reduction in income from having a lesser number of livestock to sell. As noted above, the critical assumption here is that grazing management lifts to ensure no drop in pasture quality due to the lower stocking rate. A secondary saving is made in reduced variable costs due to the lower numbers of cows. The PV of the savings was:

$PV_{8.0\%}$ = $225.2 million

$PV_{3.0\%}$ = $395.6 million

Whereas the PV of the reduced income was:

$PV_{8.0\%}$ = $21.5 million

$PV_{3.0\%}$ = $37.7 million

[Details are shown in Appendix 11.]

If pasture quality did drop such that a 10 percent reduction in stocking rate resulted in a 10 percent reduction in production, the PV cost of this would be:

$PV_{8.0\%}$ = $106.8 million

$PV_{3.0\%}$ = $187.6 million

[Note: This costing is not included in the summary of costings.]

The extent to which farmers can reduce their stocking rate, while maintaining production, would vary. The main benefit is around economic gain, and while the reduction in nitrogen leaching can be limited, it remains a possible option.

Another aspect, in a similar vein, is diet manipulation. It is possible to reduce nitrogen leaching if cows are fed a low protein/high carbohydrate diet (for example, maize silage). Generally, New Zealand pasture levels are high in protein, with the limiting factor being energy (for example, sugars or carbohydrates). By feeding a diet of (say) 60 percent pasture and 40 percent maize silage, the result is a much lower ammonia level in the cow’s urine, and consequent lower nitrogen leaching.

However, such a management system has its difficulties. There is the issue of the 40 percent of pasture “not eaten”, which means it must be either conserved as supplementary feed and/or the stocking rate lifted to accommodate it, with an accompanying lift in nitrogen leaching due to the greater number of cows.

In addition, the growing of the maize often results in the same amount of nitrogen leaching as the original system. While the maize could be grown outside of the catchment, and there are management techniques to reduce nitrogen leaching from maize, this system of diet manipulation is very complex, and was not analysed within this study.

SUMMARY OF SCENARIO 1

Results

A summary of the results of the above analysis is shown in table 9 and 10.

Table 9: Scenario 1 – Summary of results excluding stocking rate reduction*

	$ million	
	8.0%	3.0%
PV of Costs		
PV of Economic benefits		
Nett	–138.3	–143.8

* Discounted period was 20 years.

Table 10: Scenario 1 – Summary of results including stocking rate reduction*

	$ million	
	8.0%	3.0%
PV of Costs	312.8	447.2
PV of Economic benefits	378.3	661.3
Nett	65.4	214.1

* Discounted period was 20 years.

A more disaggregated breakdown of costs and benefits is shown in the Table 11.

Table 11: Cost and benefits disaggregated

	PV $ million	
	8.0%	3.0%
Cost detail		
Technology transfer	17.2	24.6
Winter nitrogen	29.5	51.8
Effluent storage	19.1	25.2
Fencing streams/riparian margins	66.3	92.3
Wintering facilities	144.9	196.1
Nitrification inhibitors	14.3	19.4
Reduced stocking rate	21.5	37.7
	312.8	447.2
Economic benefit		
Technology transfer	19.9	39.5
Winter nitrogen	18.4	32.3
Effluent storage	5.5	9.6
Fencing streams/riparian margins	0.0	0.0
Wintering facilities	90.4	158.8
Nitrification inhibitors	18.9	25.6
Reduced stocking rate	225.2	395.6
Net	378.3	661.3

* Note: some totals may not add up due to rounding.

For the individual strategies the figures (at the 8 percent discount rate) are:

	Cost $ million	Economic benefit $ million	Net $ million
Technology transfer	17.2	19.9	2.7
Winter nitrogen	29.5	18.4	–11.1
Effluent storage	19.1	5.5	–13.6
Fencing streams/Riparian margins	66.3	0.0	–66.3
Wintering facilities	144.9	90.4	–54.5
Nitrification inhibitors	14.3	18.9	4.6
Reducing stocking rate	21.5	225.2	203.7

Discussion

Overall, it would appear that technically the 42 percent required reduction in nutrient input could be achieved via the implementation of a range of best management practices, but, as can be seen from Table 8, the economic cost of the five strategies (excluding reduced stocking rate) is greater than the benefits.

Within this though, there are a range of issues.

a) As can be seen from Tables 10 and 11, the system with the greatest economic benefit, and which could ensure the whole approach has a positive economic impact, was the reduction in stocking rate. It could be argued that this is more of a management issue that revolves around the efficiency of farming, particularly regarding the amount of supplementary feed farmers purchase in, rather than an environmental issue, especially as the reduction in nitrogen leaching can be relatively small. The issue therefore is around optimizing profitability rather than maximising production. As noted earlier, the reduction in stocking rate was restricted to 10 percent, based on the MAF modelling, as this resulted in the greatest net gain. If a greater reduction in stocking rates had to be made, then the costs, particularly decreases in milksolids production, would mount rapidly.

b) As noted, the crucial issue around this strategy is whether farmers can improve grazing management so as to ensure no loss in milk production, and there's no guarantee that this would happen, although having such an intensive extension system in place as part of this strategy would certainly assist. The purchase of supplementary feed is also a risk management strategy, so while a reduction in this can result in improved profitability, it also results in a riskier production system. In addition, assuming that there is some inefficiency in the system, farmers could improve their management, at the same feed inputs, to lift production further. The reason it was included in this study was to capture the nitrogen leaching savings.

c) What this indicates is that in many respects farmers would need to look to improve the efficiency and profitability of their farming systems, of which stocking rate is one issue, in order to pay for the costs of the environmental improvements. It could be argued that there is some scope for this; in 2009/10 the top 10 percent of farmers had an EFS/Ha of $4200, compared to the average EFS/ha of $2400, and the bottom 10 percent had an EFS/ha of $800/ha (MAF, 2010b).

d) In addition to the comment around the improvement in grazing management required to achieve the benefits of reduced stocking rate, this also applies across the other practices – the assumption is that farmers' grazing management is sufficient to take advantage of any extra pasture grown.

e) The highest net cost strategy was the provision of wintering facilities. For the average farm, the assumed cost was $480 000. If a "herd home" type structure was built, the cost would be around $576 000. Most farmers would need to borrow this amount of money, and the likelihood therefore is that this strategy is likely to be one of the last to be considered/implemented.

f) Never the less, in areas with heavy soils that pug more easily, the pay-back on a wintering facility could well be much higher, and as noted by the recent Massey research, the potential reduction in nitrate leaching could be significant.

g) The second highest net cost strategy was fencing off streams and planting riparian margins. It is quite probable that farmers would prefer to fence their streams at a minimal distance; (say) 3 metres from the edge, with limited riparian plantings. This would significantly reduce costs, particularly from the opportunity cost of lost productive land, but would also reduce the efficacy of the riparian margin, particularly with respect to sedimentation, phosphate, and microbial run-off, and certainly significantly reduce any biodiversity benefit.

h) While questions could be raised as to the likelihood of farmers implementing strategies with an apparent economic cost, such as riparian margins and wintering facilities, never the less many farmers are implementing such strategies, for a variety of reasons, of which economics is only part.

i) It also needs to be reiterated that to achieve the required reduction in nitrogen leaching, all the strategies outlined need to be implemented – it is not a question of a "pick and mix" approach.

j) What the study does illustrate is the value of an intensive technology transfer programme. Without this input, the probability of the strategies being fully implemented over a 20-year time span is remote, and obviously both the economic and environmental benefits would be significantly reduced.

k) Another issue implicit within this study is the motivation by farmers to adopt the various strategies described – in essence the assumption is that all farmers would adopt the strategies over the given time period. While some of the systems described are financially viable on their own, others are not. Possibly part of the motivation would be around industry responsibilities, for example, *The Dairying and Clean Streams Accord*, and possibly some of the costs could be regarded as the cost of farming.

   - A question that arises is whether a regulatory framework would provide additional motivation, for example if Waikato Regional Council introduced a nutrient capping/nitrogen discharge allowance type regime as in the Taupo catchment. If this approach was used it would bring in another series of costs (that is, the cost of introducing the regulatory regime), which is not included in this study. Such an approach may well provide further motivation, but it would also mean a delay as the RMA process of consultation, submissions, hearings and court cases are worked through.

   - But it could also be argued that a regulatory framework would be required to ensure uptake by the last 5–10 percent of farmers.

l) For the farmers, the cost is all "real" in the sense of having to pay for the various approaches, or suffer the opportunity cost of income forgone. Similarly the economic benefits are also real, with the farmers being the direct beneficiaries of these.

m) For environmental benefits, discussed in later section, there are two significant issues:

   - Environmental benefits are essentially in ephemeral dollars – while the impact on the environment may well be real, the assessment of this is not received in cold hard cash.

   - The benefits also accrue to the wider community rather than just the individual farmers. In other words they are public goods.

n) A public good is one for which consumption by one individual does not prevent consumption by another. The improvement in the environmental and biodiversity values represent a public good, which would suggest there is a place for central and/or regional/local government to be involved in this process and possibly provide some resources towards it.

12 Scenario 2: Land use change – dairying to forestry

The intent behind this scenario was to look at a land use change approach to the issue by removing an area currently in dairying and replacing it with forestry. There are no direct restrictions on dairying within this scenario – the reduction in nitrogen is achieved via the land use change, that is, taking land out of dairying. Within this scenario, two sub-scenarios were considered:

- a production forestry regime involving planting the area in pines; and
- an energy farming regime involving planting the area in *salix* spp (willows) and using them to produce wood pellets.

It should be noted that this scenario, because of the use of multipliers (discussed later), cannot be compared to scenario one.

Scenario 2a: Production forestry

Under this scenario the assumption was to progressively plant the area in pines (*pinus radiata*). The intent is to have a conventional Central North Island intensive regime, with a rotation period of 28 years. Obviously this period is longer than in scenario one, as it fits in more with an optimal rotation for forestry. The total area required to be converted over the 28 years is 66 400 hectares, which equates to 51 percent of the area in dairying. This area is greater than the nominal 42 percent because forestry also leaches some nitrogen (assumed at 3 kgN/ha/year in this study). The total area was calculated such that the amount of nitrogen leached for the combined forestry and dairying area at the end of the 28th year equated to 30 kgN/ha leached in 2006 (as per the target in Scenario 1), allowing for the 1.5 percent increase in discharge from the dairying area. The 66 400 hectares were converted at a rate of 2371 hectares/year. (Refer Appendix 12.)

There would also be an issue of legacy nitrogen – once the area was planted in trees, nitrogen levels in the soil would take some years to drop back to a status quo level compatible with trees. Again there is nothing that can be done to mitigate this.

Because the rotation length assumed for this scenario is 28 years, the discount period is in fact 56 years – the forest is planted up over 28 years, and then one full rotation of 28 years is allowed for.

The cost of this scenario is the cumulative loss of dairying over this period, and into the future. This was costed assuming an Economic Farm Surplus – in effect the free cash flow of $1164 per hectare, as in scenario one (being the 10 year average of the EFS from the MAF Waikato/Bay of Plenty Dairy Farm Monitoring model, expressed in 2010 dollars). Given that production is assumed to be increasing at 1.5 percent per year, it could be assumed that the EFS is also increasing. However this is not necessarily so, and the EFS was kept at the same value for this analysis.

The PV of the dairy loss is:

$PV_{8.0\%}$= $403.5 million

$PV_{3.0\%}$ = $1.689 billion

[Details are shown in Appendix 13]

If the EFS is increased at 0.5 percent per year, the PV values are:

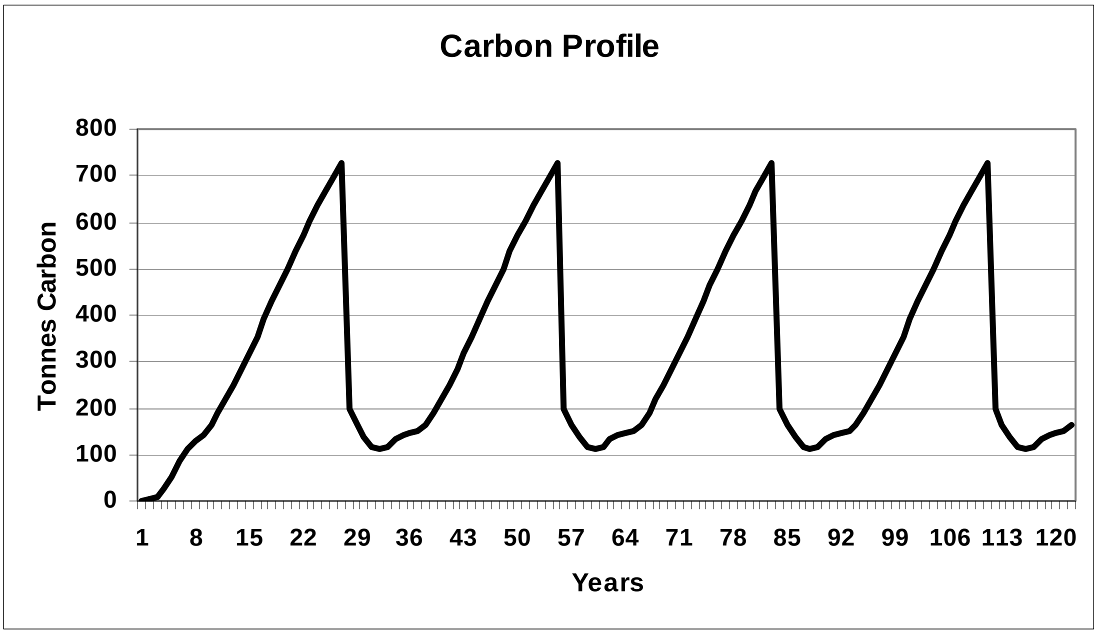
$PV_{8.0\%}$ = $632 million

$PV_{3.0\%}$ = $3.253 billion

This represents the loss of dairying returns at the farm gate. The loss of milksolids from this catchment is also likely to have an impact on processing factories; the average annual loss of production over the period is 2.6 million kilograms of milksolids. The closure of factories would result in some salvage value, but the assumption is that, given the conversion happens over the 28-year period, sufficient time is given for the dairy companies to run plant down and rationalise processing plants. While some salvage value may be received it was felt to be minor, and was ignored.

The gain is the returns from forestry over this period and into the future. In addition to the returns from the timber, the value of carbon credits at $25 per tonne of CO_2 was also included. The CO_2 sequestration rates used were based on the MAF look-up tables for the Waikato region (MAF, 2009b), with an assumed decay rate for the slash at harvest. The resultant carbon profile is illustrated in Figure 4.

Figure 4: Carbon profile (tonnes carbon/hectare)



The PV of the forestry is:

$PV_{8.0\%}$ = $120.3 million

$PV_{3.0\%}$ = $1.28 billion

[Details are shown in Appendices 14, 15 and 16]

With a Carbon Value of $0/t:

$PV_{8.0\%}$ = -$8.8 million

$PV_{3.0\%}$ = $798 million

With a Carbon Value of $50/t:

$PV_{8.0\%}$ = $249 million

$PV_{3.0\%}$ = $1.759 billion

The planting of the forest would have an environmental impact as well, both with respect to ecosystem services, and biodiversity.

[Note: while carbon has been included within the forestry scenario – given that forestry is already operating within the ETS, it has not been included in the dairying one. There are two main reasons for this: (a) while calculations have been made on the impact on-farm for an average dairy farm for 2015, there is no data available on the impact beyond this, and (b) the uncertainty around the introduction of agriculture into the ETS. Nevertheless, the ETS would reduce dairy profitability beyond 2015, assuming it is introduced. The impact in 2015 would reduce the EFS/ha in of the order of $60, and hence not including a carbon charge for dairying in this study does advantage it.]

Multiplier effect

Given the significant area involved in land use change in this scenario, the impacts would be much wider than just at the farm/forest gate. In this respect therefore the multiplier effect has been calculated in order to gauge the wider implications of such a change.

The multiplier effect is where spending in one area of the economy stimulates spending in other areas. For example, farmers spend money on buying in inputs such as fertiliser, which in turns means the fertiliser company spends money on inputs and wages, with the workers in turn spending money on further services they need, and so on.

In economic jargon, this is explained as: if there is an increase in final demand for a particular product, we can assume that there will be an increase in the output of that product, as producers react to meet the increased demand: this is the "direct effect". As these producers increase their output, there will also be an increase in demand on their suppliers and so on down the supply chain: this is the "indirect effect" (that is, Type I multipliers). As a result of the direct and indirect effects the level of household income throughout the economy will increase as a result of increased employment. A proportion of this increased income will be re-spent on final goods and services: this is the "induced effect" that is, Type II multipliers) (Butcher, 1985).

Value-add multipliers provide estimates of value added to products resulting from the sale of a good or service to another sector. This Value Add includes the cost of employee compensation, indirect business taxes, and proprietary and other property income.

In this study, value-add multipliers were applied across both the dairy and forestry cash flows where labour cost had been excluded. This gives an indication of the impact on GDP of the land use change.

The multipliers used were the Type II multipliers for dairy farming and forestry and logging respectively, derived at the national level, (G MacDonald, 2009, pers com). These were applied across the final cash flows for each land use type. For the forestry cash flow this also included the value of the carbon credits, and it could be argued that this inflates the final forestry figure, as carbon credits would mostly only impact significantly at the final consumption/induced effect end.

In addition, both forward and backward linkages were used: backward relate to the services each industry buys in to provide their goods, while forward linkages relate to the processing/manufacturing process through to the wharf.

Multipliers used were:

Table 12: National multipliers

	Backward	Forward	Total
Dairy farming:			
Type II Value Add	2.70	2.35	5.05
Type II Employment	2.72	2.58	5.30

Forestry and logging:			
Type II Value Add	2.95	3.72	6.67
Type II Employment	4.23	5.93	10.16

The results of the analysis were:

Table 13: Multiplier results

	Value Add: $ million
Dairy:	
$NPV_{8.0\%}$	3 214
$NPV_{3.0\%}$	13 451
Forestry:	
$NPV_{8.0\%}$	1 193
$NPV_{3.0\%}$	9 350

Varying the price of carbon, and assuming carbon had the same multipliers as forestry, the forestry results were:

Table 14: Carbon price sensitivity

Forestry	Value Add: $ million
$0/Tonne CO_2:	
$NPV_{8.0\%}$	332
$NPV_{3.0\%}$	6 146
$50/Tonne CO_2:	
$NPV_{8.0\%}$	2 053
$NPV_{3.0\%}$	12 554

Employment Effects

The reduction in dairying and increase in forestry would also have effects on employment nationally. This can again be calculated using multipliers outlined in Table 12. For every $1 million increase or decrease in income for that sector, employment increases or decreases accordingly.

From the figures derived above the impact would be:

Loss of dairying: –2142 jobs

Gain from forestry: 1222 jobs

Net effect is a loss of 920 jobs

This impact covers jobs both on the farm/in the forest, and in the processing sector. Within the Waikato region there would be varying impacts. For dairying, basically all the milk produced in the catchment would be processed within the region. For forestry the situation is slightly more problematic, as not all the logs produced would necessarily be processed within the Waikato region – logs would be exported via Auckland, Tauranga, and Napier, and some would be processed in mills in the Bay of Plenty, or even possibly Hawke's Bay.

Scenario 2b: Energy farming

In this scenario the land use change would involve planting the dairy land in willows (*salix* spp) that would be harvested every three - four years and the wood chips then used to produce wood pellets for heating. The costs and returns for this enterprise is based on the best available information, but given that such an industry is not yet established in New Zealand, the results are again included in this study as illustrative, and should not be regarded as absolute. Similarly, multipliers were not used in this scenario (refer Appendix 17).

Given the uncertainty with the data, the assumption behind this scenario is that the land would be converted over a period of 22 years. This means the land is converted over 7 rotations – first harvest would occur in year 4, and then every 3 years thereafter. Again the area required to be converted was calculated on the basis that the area in trees plus the area in dairying at the end of the 22 years leached the equivalent nitrogen as the area in dairying in 2006. On this basis the total area converted to energy farming was 60 000 hectares, giving an area of 2727 hectares converted per year. [This area is less than that for the forestry regime in that with a longer rotation more land is required due to the compounding effect of the 1.5 percent dairying increase assumed in this report].

The cost of this system is the loss of dairying, and the benefit is the gain from the energy farming and any environmental gains.

The NPV of the dairy loss (at the farm gate) is:

$PV_{8.0\%}$ = $426 million

$PV_{3.0\%}$ = $1.643 billion

[Details are shown in Appendix 18]

The NPV of the energy farming benefit is:

$PV_{8.0\%}$ = $91.5 million

$PV_{3.0\%}$ = $244.5 million

[Details are shown in Appendix 19]

SUMMARY OF SCENARIO 2

Results

Table 15: Forestry scenario (farm gate)

		$ million
	8.0%	3.0%
PV of Costs	403	1 689
PV of Economic benefits	120	1 300
Net	–283	–389

Table 16: Forestry scenario (using multipliers)

		$ million
	8.0%	3.0%
PV of Costs	3 214	13 451
PV of Economic benefits	1 193	9 350
Net	–2 021	–4 101

Table 17: Energy farming scenario

		$ million
	8.0%	3.0%
PV of Costs	426	1 643
PV of Economic benefits	92	245
Net	–334	–1 398

Discussion

As can be seen from Table 15, at the farm/forest gate, the change in land use to forestry provides a lesser economic return compared to the loss from dairying.[3]

If the wider impacts of the land use change are taken into account, as illustrated by Table 16, this differential widens significantly. As noted, the forestry multiplier is overstating the effect due to the inclusion of carbon. If carbon is excluded, the net effect is a significantly greater negative.

The overall profitability of the forestry regime is very reliant on carbon. Without carbon, profitability is relatively low.

Such a conversion would also have a negative impact on employment within the region.

For the energy farming scenario (Table 17), the overall effect is a significant negative impact. Within this scenario no multipliers have been applied, as they don't currently exist for the energy farming/processing sector.

[3] The issue is the relative profitability between forestry and dairying, with dairying generally more profitable than forestry (Scion, 2011).

13 Environmental benefits

The purpose of this section was to illustrate a methodology of working through what the environmental benefits could be. As discussed below, much of the data has been extrapolated from studies not directly related to the issue in hand, and a range of assumptions made. The figures derived therefore are illustrative only.

In addition, the lag effect of improving water quality has a significant impact in reducing the value of some of the environmental benefits. This is an issue that needs further investigation, as discounting over such a period of time would automatically reduce these values relative to any immediate economic costs.

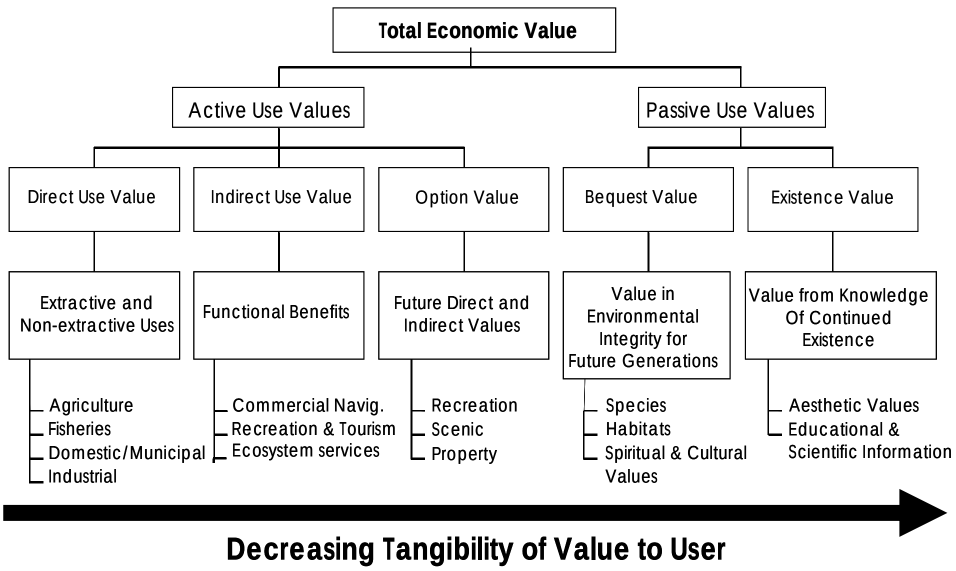
Social benefits of improved water quality

The interaction of demand and supply dynamics in the marketplace reveals an individual's market value for some goods and services. However, for some goods and services a tradable market does not exist and can thus be categorised as non-market goods and services. These may include, but are not limited to, such things as air quality, ecosystem services and outdoor recreation.

Benefits from non-market goods and services can be divided into three categories, direct use values, indirect use values, and passive values. Direct use values are those associated with tangible uses or environmental resources, such as recreational use or environmental quality that impacts on human health. Indirect use values are those associated with ecosystem services while passive values are the more intangible values of environmental resources such as aesthetics. This is illustrated in Figure 5.

Figure 5: Constituents of total economic value

Source: EVRI (www.evri.ca)



They can be further categorised as follows:

Existence value	Preservation of a resource without any current or potential active use of the resource.
Bequest value	Desire to make current sacrifices to raise the well-being of future descendants.
Altruistic value	Occurs from individual's valuing the opportunity for other people to enjoy high environmental quality.
Option value	Desire to preserve the option to use a resource in the future.
Ecological services	Include nutrient cycling, atmospheric processes, carbon cycling, clean air, clean water and biodiversity.

Values are not mutually exclusive in the sense that an individual may have multiple values.

The economic value of an environmental resource incorporates all of the environmental, financial and social benefits associated with the use of that resource. These values reflect the well-being of society in relation to that resource and techniques have been developed to understand and measure individuals' preferences for the use of environmental resources. The two categories of techniques are revealed preference techniques and stated preference techniques.

Revealed preference techniques such as the travel-cost method (TCM) collect data on number of trips taken and the financial outlay. An example of this is the amount a fisherman may spend to travel to, and stay near, a favoured fishing spot. The TCM tends to be restricted to site specific studies such as the use of recreation parks and it fails to capture indirect use values.

The stated preference techniques of contingent valuation (CV) and choice modelling (CM) on the other hand are able to elicit these indirect use values along with the direct use values. The contingent valuation method (CV) presents hypothetical situations to respondents who reveal economic values of environmental resources through a bid vehicle. The bid vehicles ask respondents their willingness-to-pay (WTP) or willingness-to-accept (WTA) in dollar terms the hypothetical situation.

Choice modelling involves respondents being shown cards with scenarios describing different combinations of economic, environmental and social factors. Respondents are asked to rank, and/or state their preferences for the scenario they prefer, which in turn reflects the tradeoffs made between attributes. An advantage of CM over CV is respondents are not being asked to trade-off directly between environmental quality and money.

The WTP is used to measure the economic value (also known as social benefits or consumer surplus) obtained from environmental improvements associated with a policy option, for example, improved air quality from the closure of a coal fuelled power plant. If an individual values an environmental improvement more than everyday consumables, such as a box of beer, then they ought to be willing to sacrifice those consumables for an improved environmental outcome. Thus the WTP scenario is about understanding societies' preference for environmental goods and services.

The WTA is the conceptually correct measure of social losses in order to compensate the reduction of benefits obtained from environmental resources. Losses matter more to people than do commensurate gains, and reductions in losses are worth more than foregone gains. The WTA has typically exceeded the WTP for environmental resources, possibly due to the constraint of income on WTP. This has resulted in the WTA measure of environmental losses to be seldom employed by economists because of the apparent disparity

Limitations

There are three potential problems that create bias in the application of stated preference techniques: strategic bias, embedding effects and hypothetical bias. These biases are commonly referred to as potential bias for the CV, however they are applicable to a lesser extent for CM as well.

- Strategic bias poses a problem when respondents provide misleading information to wrongfully influence public policy decisions in order to maximise the benefits they are likely to receive.
- Embedding effects occur when there is no difference in the economic value of different quality and quantity levels of an environmental resource.
- Hypothetical bias arises when respondents do not correctly interpret the hypothetical situation they are being asked to value leading to misrepresentations of economic value. (Carson 2000)

Aggregation issues for cost benefit

The use of WTP figures for cost benefit analysis, in aggregating the figures derived up to a full population level, also involves a number of issues, as discussed by Morrison (2000), and Bateman et al (2006). These include:

- The response rate to the survey – the greater the response rate the lower any aggregation bias, and vice-versa;
- The similarity of respondents and non-respondents. If non-respondents are randomly distributed, the simple extrapolation of estimates across the population will be valid. However, this is difficult to determine with non-use values; and
- The correlation between preferences and socio-demographic characteristics. This relates to both their socio-economic status – individual wealth often influences the "willingness to pay", and distance from the issue. While often the amount people are willing to pay decays with distance from a particular issue, this is not always the case. Morrison (2000) cites the case of people throughout Australia being more willing to pay to preserve the Kakadu Conservation Zone from mining than people in the Northern Territory. Bell (pers com) noted that while they had found differences in WTP in their study (Bell et al, 2009) decayed with distance, this was not statistically significant. Often distance decay can be high for active values, and low for passive values.

Adjusting for some of these factors, Morrison (2000) noted that mean WTP could be 40–50 percent less than stated in the original survey.

In the absence of data to accurately calculate these aggregation bias's, that is, it could be anywhere between 0 and 50 percent, an arbitrary figure of 25 percent (as a mid-point) was used to reduce the WTP figures (that is, the WTP figures were reduced by 25 percent).

While the viewpoint for this study is at a national level, this then creates some difficulties when it comes to aggregating up the WTP figures, due to distance issues – people in other areas may not be as willing to pay as much, or anything, for more local issues, although they can do so for existence type issues. The environmental WTP case cited below was carried out within the catchment. The biodiversity WTP case used was carried out throughout New Zealand, but it could be assumed that (for example) the good people of (say) Otago would be more interested in riparian development in Otago than in the Waikato.

For this reason, within this study the WTP figures are aggregated up by the number of households in the Waikato region (141,747 based on the 2006 census), rather than the number of national households (1.17 million). It is acknowledged that this probably under-estimates the resultant gross WTP, but using the national figures would equally result in an over-estimation.

Groundwater lag effects

A key component that has to be considered is the lag effect of nitrogen already in groundwater. The period of these lags are variable, and means that any reduction in groundwater flows into the Waikato River due to reductions in nitrate leaching on-farm, will take some time. In this respect, while this study looks at reducing nitrogen (and other nutrients) into the river, it will not significantly impact on the river itself until the "legacy nitrogen" has moved through the ground water aquifers. A parallel can be drawn with the situation of Lake Taupo; the programme, already started, is to reduce nitrogen leaching within the catchment by 20 percent from manageable sources over a 15-year period. However, the legacy of groundwater nitrogen means that it could well be 50 years or more before an improvement is apparent. This issue becomes important within this study when considering the environmental benefits, in that while the economic costs and benefits are relatively immediate, significant environmental benefits may not be apparent for some years, which needs to be taken into account when discounting these future benefits.

Within the catchment, ground water lags are currently not well understood (J Hadfield, pers com), although work is underway to study this. These lag periods also vary spatially – depending on how close farms are to water bodies. For example, a farm alongside the Waikato River may have a lag of only 1–3 years, whereas a farm at the top of the catchment may have a lag period of 50–60 years, and the overall mean lag period for the catchment may be (say) 30 years.

The spatial effect is also important in that any reduction in N leaching on farms close to the river would have a more immediate effect in N reductions within the river, and it could be assumed that the dairy farms within the catchment are generally located on the easier contour land closer to waterways. Given this, the assumption made for this study was a mean lag period for nitrogen leached from dairy farms of 15 years.

Any reduction in N leaching would also have an impact, albeit minor, on the N flows within the groundwater, as opposed to nothing happening for 15 years before an effect is apparent (K Rutherford, pers com). For example, a reduction of 1 unit of N via leaching may see a reduction of 0.001 unit in groundwater flows into the river in year one, 0.002 in year 2, etc.

For the purposes of this study, a minor, curvilinear reduction in groundwater N flows was assumed through to year 14, with a significant drop assumed in year 15. This affected the benefits as calculated for the "social benefit" and the "ecosystems services".

New Zealanders' WTP for water quality improvements

A small number of non-market valuation studies on water quality have been conducted in New Zealand. Research in this field began with Harris (1984) who estimated Waikato residents' WTP for water quality improvements at $16 per person in 1982 dollars. This paper remains the only New Zealand water quality valuation study to be published in an international journal. Other studies include Bell *et al.,* (2004), Kerr *et al.,* (2004, 2003) and Williamson (1998) who all estimated the nominal value for water quality improvements to be under $50 per household. Sheppard *et al.,* (1993) estimated nominal values of between $102 and $124 per household, while Takatsuka *et al.*, (2007) estimated a nominal value closer to $200 per household. Most of these studies related to drinking water quality.

Within this study, three areas of environmental benefit were considered:

- Social benefit/existence value.
- Improvement in biodiversity.
- Eco-system services.

Scenario 1 – Environmental benefits

1. Social benefit/environmental value

This approach is based on a Choice Modelling exercise carried out by Marsh (2010) who investigated the community's willingness to pay for improvements in the water quality of the Karapiro and Arapuni hydro lakes. Respondents were asked a series of questions around their WTP with respect to suitability for swimming, water clarity, the ecological health of the lakes, and potential job losses in dairying.

A summary of the results is shown in table 18.

Table 18: WTP for environmental factors for Karapiro and Arapuni Lakes

Compensating surplus: welfare gain for change from status quo to improved outcome (NZ$ per household per year over 10 years)				
Attribute	Status Quo	Policy 1	Policy 2	Policy 3
Swim (Chance of algal bloom)	50%	20%	10%	2%
Clarity (metres)	1m	1.5m	2m	4m
Ecology (% excellent)	40	50	60	80
Median welfare gain (assuming no job losses)		$26/yr	$51/yr	$86/yr

As can be seen from table 18, the lowest level of improvement gave a WTP of $26 per household for 10 years. It is quite possible that respondents would have indicated a WTP of zero if asked about the amount they were willing to pay just to maintain the river in its current state. However, for this study the $26 figure was used. Again caution is noted, in that a WTP figure should directly relate to a specified water quality level.

For the study, a Present Value of the WTP figure was calculated at the two discount rates, adjusted for aggregation bias as discussed above, applied across the number of households in the Waikato, the lag effect allowed for, and then applied in the same pattern as the rate of adoption discussed earlier, which would equate with the rate of improvement.

The PV of this was:

$PV_{8.0\%}$ = $1.1 million

$PV_{3.0\%}$ = $7.8 million

[Details are shown in Appendix 20]

Table 19: Sensitivity Analysis around social benefits

	8% Discount (PV in $m)		3% Discount (PV in $m)	
	Lag	No Lag	Lag	No Lag
Standard	1.1	11.0	7.8	19.0
No aggregation bias adjustment	1.5	14.7	10.4	25.3
Using national household numbers	9.0	90.9	64.3	156.0

Using upper end WTP of $86 per household	3.6	36.5	25.9	62.9

2. Biodiversity values

As noted earlier, the planting of riparian margins would result in a significant area (1951ha) being planted in native plants. This would result in a significant network of native plant "corridors" throughout the catchment, which is very likely to attract native birds. In this respect therefore the plantings would result in a biodiversity benefit, which is a measure of the health of an ecosystem. Again the approach is to use choice modelling in order to gain an appreciation of the preferences and values of the community with respect to the biodiversity issue in question.

In addition to the probability of attracting native birds, the planting or riparian strips would also have an impact on in-stream biodiversity, where the shading and cooling of the stream by the trees, and the addition of leaves etc, would result in an increase in invertebrates and fish species.

The choice modelling approach needs to deal with the unique issue in question, but unfortunately no such study exists for the upper Waikato catchment. To illustrate the point though, proxy values have been used based on two studies with respect to the planting of shrubs and trees within the riparian margins. Unfortunately no such studies are readily available around in-stream biodiversity, so this aspect is excluded in this study.

The first of these is a study by Yao and Kaval (2009), who considered the willingness to pay for councils to encourage plantings of native plants in order to enhance native biodiversity. The sample for this study was drawn from various regions, including in the Waikato. The study showed a median WTP of $42 per ratepayer (that is, they were willing to pay an extra $42 per year on their rates towards such projects). Normally in such studies the WTP is for a set period, but in this case the respondents weren't asked to consider a time period, so the inference is that the WTP on the extra rates is in perpetuity. The $42 was converted to a present value, and extrapolated over the 20 year period relative to the adoption rate, again adjusted for aggregation bias as discussed above.

Given that the riparian margins would represent a relatively narrow corridor (being 5 metres wide on either side of the stream), they would suffer from strong edge effect gradients, and in all probability they would be of use for only a minority of generalist species. In this respect therefore the biodiversity effect would be greatly diminished relative to if the 1951 hectare was in one contiguous block, and consequently the value calculated has been reduced by 50 percent.

The PV values of this were:

$PV_{8.0\%}$ = $16.6 million

$PV_{3.0\%}$ = $56.9 million

[Details are shown in Appendix 21]

In the absence of any adjustment for aggregation bias or edge effects, the figures were:

$PV_{8.0\%}$ = $44.3 million

$PV_{3.0\%}$ = $151.7 million

The second study was by Kerr and Sharp (2008). This study looked at the willingness to pay to control wasps in the Nelson Lakes forests, in order to maintain and enhance the native bird life. In the Nelson study the choice was to go from some birds to many birds, whereas the Waikato situation is somewhat different, in that it is going from no/few birds to some birds.

It is acknowledged that this is "stretching" the values derived in the Nelson study, but it does serve to illustrate the use of such values in a cost benefit analysis.

The WTP in the Kerr study to improve the number/survivability of native birds was $120 per household for 5 years. Again this was converted to a present value, adjusted as noted above, and extrapolated over the 20-year period relative to the adoption rate. The PV values of this were:

$PV_{8.0\%}$ = $15.2 million

$PV_{3.0\%}$ = $23.5 million

[Details are shown in Appendix 22]

The figures from the Yao *et al.,* study are the ones used in the summary of this study.

3. Ecosystems services

Ecosystem services refer to the many goods and services emanating from the functioning of local ecosystems. The community benefits from many different ecological functions, from water purification services within water bodies, to wild pollination (Coleman, 2009). Ecosystems are natural assets and provide services that, if not vital to human existence, at least contribute to our welfare (van den Belt *et al.,* 2009).

Within this study, the adoption of best management practices within the upper Waikato catchment would result in an improvement in ecosystems services, in that the reduction of nutrients into the water system would improve its capacity to assimilate nutrients.

The value of this has been extrapolated from a study done in the Manawatu (van den Belt *et al.,* 2009), looking at the value of ecosystem services across that region. The values used in this study have, in turn, been extrapolated from overseas published literature, so again caution is needed in interpreting the results.

The Manawatu report notes that the total ecosystems value for dairy farming, incorporating both direct and indirect values, is $1796 per hectare. The direct benefits have already been incorporated within this study via the economic analysis, and therefore the main values of interest are the indirect values. The indirect ecosystem value for dairying is $404 per hectare. This is a 2006 value, which when updated to 2010 by the CPI (11.5 percent over the period) equals $450/ha. Of this "waste treatment" – the assimilation of nutrients by the environment - provides 7.6 percent. Given that the reduction in nutrient outflows as a result of the introduction of the best management practices is 42 percent, the value of this was calculated as:

$450 x 7.6% x 42% = $14.33/hectare

This was then applied to the effective area of dairying in the catchment, following the rate of adoption curve, and allowing for the lag effect in groundwater. The PV value of this was:

$PV_{8.0\%}$ = $1.0 million

$PV_{3.0\%}$ = $7.3 million

[Details are shown in Appendix 23]

If the lag effect is ignored, the values are:

$PV_{8.0\%}$ = $10.1 million

$PV_{3.0\%}$ = $17.7 million

Scenario 2: Environmental benefits

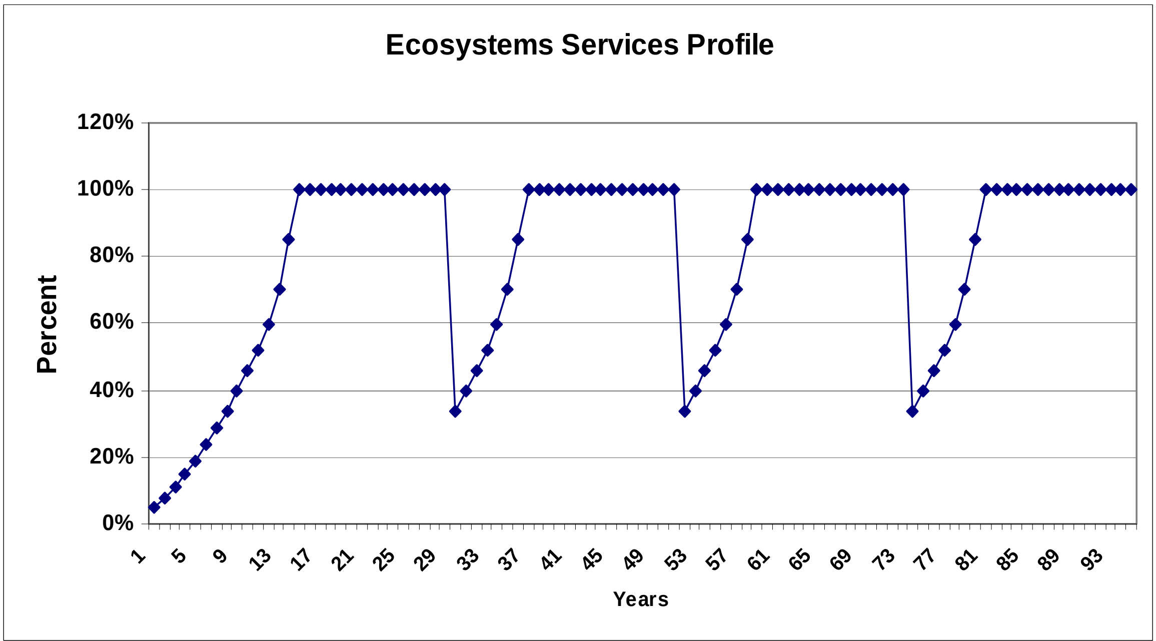
Production Forestry Scenario

Ecosystem services

For ecosystem services, the value of an exotic forest is estimated at $2280 per hectare (van den Belt et al, 2009), incorporating both direct and indirect values. Given the direct (economic) values are covered already in this study, it is the difference in indirect values which is of interest. The indirect values for an exotic forest are given as $1791 per hectare whereas the indirect value of a dairying ecosystem services is estimated at $404 per hectare, giving a difference of $1387 per hectare. These are 2006 values, so inflating them forward to 2010 gives a difference of $1545 per hectare per year. It should be noted that this figure is well in excess of any WTP figures.

The ecosystem services derived from the forest would build up once an area was planted to a plateau, and then drop back when the forest was harvested, before building up again. This pattern is illustrated in Figure 6:

Figure 6: Ecosystems services profile per hectare



Again there would be a lag period before nitrogen already within the groundwater aquifers has been depleted, as discussed earlier, and hence a delay before the ecosystem services within the river improved. Given this, the profile outlined above, ands extrapolate this out over the period of the conversion, and into the future, the cumulative value of these ecosystem services, allowing for the groundwater lag period, is:

$PV_{8.0\%}$ = $26 million

$PV_{3.0\%}$ = $455 million

[Details are shown in Appendix 24]

If the lag is ignored, the values are:

$PV_{8.0\ \%}$ = $261 million

$PV_{3.0\%}$ = $1.0 billion

Extreme care needs to be taken in interpreting these values, as (a) they are further extrapolations based on extrapolations by van den Belt of northern Hemisphere values, and (b) in one sense they represent the opportunity cost of carrying out an economic activity. Assuming the indirect ecosystem services value of an exotic forest is around $1545 per hectare per year as calculated in this study and was taken as a real cost, then few forests would be felled. Similarly, if humans did not exist, the value of ecosystems services would be zero.

In this respect perhaps the better approach, given the uncertainty around the figures, is to look at the quantum of the figure, and note that there would be a significant ecosystem benefit, but more research is required to derive valid base data.

Biodiversity Value

The biodiversity value of an exotic forest is also somewhat hard to establish. While it does not support the same degree of native wildlife as an indigenous forest, never the less there is abundant evidence that plantation forests can provide valuable habitat for native species and may contribute to the conservation of biodiversity by various mechanisms (Brockerhoff *et al.,* 2008).

No studies are readily available to establish the biodiversity values of exotic forests. One approach could be to assume the biodiversity value established for riparian plantings in scenario one, and extrapolated this over the area converted into forestry. This was done by dividing the WTP figure by the number of hectares planted to give a per hectare figure, which was then multiplied up over the 28-year period of the conversion. The aggregation bias adjustment used in scenario 1 was included, but the “edge” adjustment was removed, given that these forests would largely be contiguous areas.

Brockerhoff (pers com) noted that with respect to conservation values, exotic forestry would rate between 50-70 percent of the level of biodiversity compared to a native forest. For the purposes of this study a mid-point of 60 percent was used. Given the assumptions above, the PV8.0% value = $277 million. (refer Appendix 25)

However, this figure is very sensitive to the area assumed covered by the riparian margins. For example, if the riparian margins were 20 metres, the area involved would be 6145 hectare, and given the assumptions note above, the PV8.0 value for biodiversity would be $69 million.

In this respect therefore, the figures derived indicate that the biodiversity value could be anywhere between $69 and $277 million, are just too uncertain to be considered valid, and perhaps again the best that could be said is that there would be significant biodiversity values involved, but the raw data available is not sufficient to calculate this.

Energy Forestry Scenario

It could also be expected that the energy farming land use would also result in greater ecosystems services, similar to the forestry scenario. Assuming a similar ecosystem value as for exotic forestry, the difference with dairying is $1545 per hectare in 2010 dollars. Applying this across the area converted, and allowing for the lag period as discussed earlier, the values derived are:

$PV_{8.0\%}$ = $27 million

$PV_{3.0\%}$ = $387 million

[Details are shown in Appendix 26]

If the lag is ignored, the values are:

$PV_{8.0\%}$ = $268 million

$PV_{3.0\%}$ = $939 million

There would also be a biodiversity effect from the energy farming, although, given the trees were harvested every four years, the fauna would most likely be of exotic species rather than native birds. Within the resources of this study it is not possible to value these, although it could be envisaged that people's willingness to pay for more sparrows, starlings, and blackbirds could be relatively limited. Because of this difficulty, the biodiversity value for this land use scenario was ignored.

14 Acknowledgements

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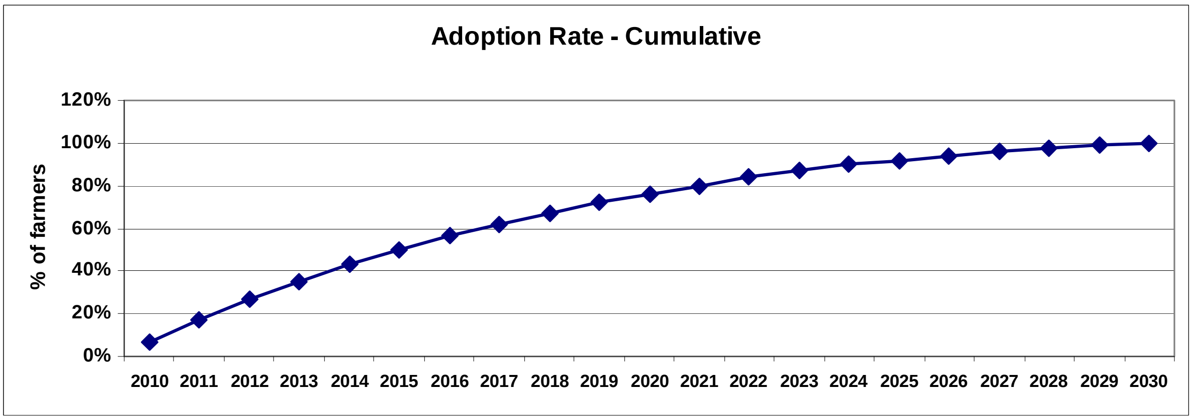
16 Appendices

APPENDIX 1: ASSUMED ADOPTION RATE

	Cumulative % of farmers	% change by year
2010	7%	7%
2011	17%	10%
2012	27%	10%
2013	35%	8%
2014	43%	8%
2015	50%	7%
2016	57%	7%
2017	62%	5%
2018	67%	5%
2019	72%	5%
2020	76%	4%
2021	80%	4%
2022	84%	4%
2023	87%	3%
2024	90%	3%
2025	92%	2%
2026	94%	2%
2027	96%	2%
2028	98%	2%
2029	99%	1%
2030	100%	1%



APPENDIX 2: ASSUMPTIONS UNDERLYING THE TECHNOLOGY TRANSFER PROGRAMME

Assume 8-day "setup" per farm - farm visit, desktop modelling to derive farm plan, revisit to farm to gain acceptance of the plan.

Assume equivalent of 4x1 day visits per farm for next 5 years.

Assume equivalent of 2x1 day visits per farm thereafter.

Also assumes a mix of field days, seminars, etc.

Benefit of advisory effort = 0.6% increase in farm profit before tax per year.

Number of farms = 724

Average fpb4t (09/10) = $115,858 per farm

Number of farms per advisor = 50

Number of advisors in first 7 years = 14 Plus 2 support staff

Number of advisors next 13 years = 8 Plus 1 support staff

Annual cost per advisor (FTE) = $140,000

Annual cost per Support Staff = $80,000

	PV cost = $17,159,892		PV benefit = $19,864,327
2010	2,187,200	2010	35,230
2011	2,187,200	2011	120,789
2012	2,187,200	2012	256,676
2013	2,187,200	2013	432,827
2014	2,187,200	2014	649,240
2015	2,187,200	2015	900,884
2016	2,187,200	2016	1,187,758
2017	1,200,000	2017	1,499,796
2018	1,200,000	2018	1,836,998
2019	1,200,000	2019	2,199,365
2020	1,200,000	2020	2,581,863
2021	1,200,000	2021	2,984,493
2022	1,200,000	2022	3,407,254
2023	1,200,000	2023	3,845,114
2024	1,200,000	2024	4,298,072
2025	1,200,000	2025	4,761,096
2026	1,200,000	2026	5,234,186
2027	1,200,000	2027	5,717,342
2028	1,200,000	2028	6,210,563
2029	1,200,000	2029	6,708,818
2030	1,200,000	2030	7,212,105

APPENDIX 3: ASSUMPTIONS UNDERLYING REDUCTION IN WINTER NITROGEN

Strategy is to reduce nitrogen fertiliser application over the critical months (May/Jun/July)

Instead of 5 applications, apply 4 applications in autumn/spring (Apr, Aug/Sep/Oct)

Normal application of N = 112 kgN/ha excluding the effluent area

New application of N = 90 kgN/Ha excluding the effluent area

Saving equivalent to 49 kg/ha of urea.

Number of farms = 724

Average area = 149 ha

Cost of Urea = 630/tonne

Loss of pasture production:

Assume 8 kgDM/Kg N = 179 kgDM/ha

Assume 75% utlilisation

Assume 15 kgDM/KgMS

	PV Benefit = $18,368,038		PV Cost = $29,505,484
2010	231,273	2010	371,505
2011	561,662	2011	902,226
2012	892,052	2012	1,432,947
2013	1,156,363	2013	1,857,523
2014	1,420,675	2014	2,282,100
2015	1,651,948	2015	2,653,605
2016	1,883,220	2016	3,025,109
2017	2,048,415	2017	3,290,470
2018	2,213,610	2018	3,555,830
2019	2,378,805	2019	3,821,191
2020	2,510,960	2020	4,033,479
2021	2,643,116	2021	4,245,768
2022	2,775,272	2022	4,458,056
2023	2,874,389	2023	4,617,272
2024	2,973,506	2024	4,776,489
2025	3,039,584	2025	4,882,633
2026	3,105,662	2026	4,988,777
2027	3,171,739	2027	5,094,921
2028	3,237,817	2028	5,201,065
2029	3,270,856	2029	5,254,138
2030	3,303,895	2030	5,307,210

APPENDIX 4: ASSUMPTIONS UNDERLYING IMPROVED EFFLUENT MANAGEMENT – COSTS

1. Upgrade of effluent storage

Number of farms = 695

	mid point
Earthworks: $12-18k	15,000
Lining: $22-25k	23,000
Cost of storage facility for 480 cow herd for 3 months	$38,000

	PV = $15,733,917
2010	1,848,700
2011	2,641,000
2012	2,641,000
2013	2,112,800
2014	2,112,800
2015	1,848,700
2016	1,848,700
2017	1,320,500
2018	1,320,500
2019	1,320,500
2020	1,056,400
2021	1,056,400
2022	1,056,400
2023	792,300
2024	792,300
2025	528,200
2026	528,200
2027	528,200
2028	528,200
2029	264,100
2030	264,100

2. Upgrade of pond systems

Number of farms = 29, Cost of upgrade to APS = $150,000

	PV = $3,351,588
2010	$725,000
2011	$725,000
2012	$725,000
2013	$725,000
2014	$725,000
2015	$725,000

APPENDIX 5: ASSUMPTIONS UNDERLYING IMPROVED EFFLUENT MANAGEMENT – BENEFITS

Volume of effluent	50 litres/cow/day
Nitrogen content	0.03 kg/cow
Winter/early spring response	10-15 kgDM/KgN
Mid spring	20 kgDM/kgN
Assume difference	7.5 kgDM/KgN
Stored Effluent (90 days)	1264 kg/N
Pasture grown	9477 kgDM
Made into silage at	15 c/kgDm
Wastage	20%
At 15 kgDm/kgMS	505 kgMS/farm
Value	$983,460

	PV = $5,467,555
2010	$68,842
2011	$167,188
2012	$265,534
2013	$344,211
2014	$422,888
2015	$491,730
2016	$560,572
2017	$609,745
2018	$658,918
2019	$708,091
2020	$747,430
2021	$786,768
2022	$826,106
2023	$855,610
2024	$885,114
2025	$904,783
2026	$924,452
2027	$944,121
2028	$963,791
2029	$973,625
2030	$983,460

APPENDIX 6: ASSUMPTIONS UNDERLYING FENCING OFF STREAMS

Length of streams on dairy/dairy drystock farms (km)	2039
Length of streams on sheep & beef farms (km)	2073
Dairy km to be fenced	4079
S&B km to be fenced (assuming 20% of farms are running dairy grazers)	829
Length of streams already fenced on dairy farms in 1998	28%
Length of streams already fenced on dairy farms in 2008	35%
Length not requiring fencing due to natural barriers	10%
Fence used is 3 wire electric @ 3500 per km	

NPV = $6,406,334

	Dairy	S&B	Total
2010	549,597	203,133	752,730
2011	785,139	290,190	1,075,328
2012	785,139	290,190	1,075,328
2013	628,111	232,152	860,263
2014	628,111	232,152	860,263
2015	549,597	203,133	752,730
2016	549,597	203,133	752,730
2017	392,569	145,095	537,664
2018	392,569	145,095	537,664
2019	392,569	145,095	537,664
2020	314,055	116,076	430,131
2021	314,055	116,076	430,131
2022	314,055	116,076	430,131
2023	235,542	87,057	322,599
2024	235,542	87,057	322,599
2025	157,028	58,038	215,066
2026	157,028	58,038	215,066
2027	157,028	58,038	215,066
2028	157,028	58,038	215,066
2029	78,514	29,019	107,533
2030	78,514	29,019	107,533

APPENDIX 7: RIPARIAN PLANTING COSTS

Environment Waikato Riparian Planting Costs

Description	Units	Cost	Total
Pre-plant spot spray	10,000	$0.75	$7,500
Plants (pb3)	10,000	$3.50	$35,000
Planting Labour	10,000	$2.00	$20,000
Release 1 (spring following planting)	10,000	$1.50	$15,000
Release 2 (summer following planting)	10,000	$1.50	$15,000
		Total/ha	$92,500

Taranaki Regional Council. Riparian Planting Costs

Average cost of plants through TRC plant scheme are around $2.70 each (PB3). A contract charge of $1.85 per plant to pre-plant spray, plant, and apply a residual herbicide for weed releasing.

Minimum width (3m) margin for one side of streambank requires 2 rows of plants, averaging 1 plant per lineal metre of streambank. Cost per 100 metre for one side of streambank = $455 per 100m or $4.55 per metre. As the margin widens for every 2–3m, add another $1.65 per metre. TRC budget around $3.50–$4.00 per metre for a 3 wire electric fence for dairy. Overall typical average cost per metre of $8–9 rather than per hectare.

APPENDIX 8: ASSUMPTIONS UNDERLYING PLANTING RIPARIAN MARGINS

Assume fencing is 5 metres back from stream edge for dairy farms, 10 metres for sheep & beef

Area Planted (ha) = 1951

Cost of planting/weed control

Environment Waikato $46,125 ha	$89,977,889
Taranaki Regional Council $20 metre	$19,048,674
Percent area productive	70%

Riparian Costs

PVew	$53,064,872
PVtrc	$11,348,362

PV lost revenue = 8,836,636

		Riparian Costs		Nett	
	Lost Revenue	EW	TRC	EW	TRC
2010	111,262	$6,298,452	$1,333,407	6,409,715	1,444,670
2011	270,209	$8,997,789	$1,904,867	9,267,998	2,175,076
2012	429,155	$8,997,789	$1,904,867	9,426,944	2,334,022
2013	556,312	$7,198,231	$1,523,894	7,754,543	2,080,206
2014	683,469	$7,198,231	$1,523,894	7,881,700	2,207,363
2015	794,732	$6,298,452	$1,333,407	7,093,184	2,128,139
2016	905,994	$6,298,452	$1,333,407	7,204,446	2,239,401
2017	985,467	$4,498,894	$952,434	5,484,362	1,937,901
2018	1,064,940	$4,498,894	$952,434	5,563,835	2,017,374
2019	1,144,413	$4,498,894	$952,434	5,643,308	2,096,847
2020	1,207,992	$3,599,116	$761,947	4,807,108	1,969,939
2021	1,271,570	$3,599,116	$761,947	4,870,686	2,033,517
2022	1,335,149	$3,599,116	$761,947	4,934,265	2,097,096
2023	1,382,833	$2,699,337	$571,460	4,082,170	1,954,293
2024	1,430,517	$2,699,337	$571,460	4,129,853	2,001,977
2025	1,462,306	$1,799,558	$380,973	3,261,864	1,843,279
2026	1,494,095	$1,799,558	$380,973	3,293,653	1,875,069
2027	1,525,885	$1,799,558	$380,973	3,325,442	1,906,858
2028	1,557,674	$1,799,558	$380,973	3,357,232	1,938,647
2029	1,573,568	$899,779	$190,487	2,473,347	1,764,055
2030	1,589,463	$899,779	$190,487	2,489,242	1,779,950

APPENDIX 9: ASSUMPTIONS UNDERLYING WINTERING FACILITIES

Provision of a physical structure to use as on-off grazing over the winter months

Average cost	$1000 per cow
Average farm cost (480 cows)	$480,000
Average maintenance cost	$35/cow
Number of farms	724
Proportion of farms constructing wintering facilities	70%
Assume benefit of reduced pugging over winter (increased pasture growth)	500 kgDm/ha
Average farm area	175 ha
Utilisation of pasture	75%

Incr Production = 15 kgDM/kgMS = 33 kgMS/ha

	PV Cost = $192,261,000		PV Benefit = $90,396,703
2010	17,624,477	2010	1,138,188
2011	25,773,821	2011	2,764,172
2012	26,625,245	2012	4,390,155
2013	22,441,104	2013	5,690,942
2014	23,122,243	2014	6,991,728
2015	21,285,600	2015	8,129,917
2016	21,881,597	2016	9,268,105
2017	17,442,029	2017	10,081,097
2018	17,867,741	2018	10,894,088
2019	18,293,453	2019	11,707,080
2020	16,201,382	2020	12,357,473
2021	16,541,952	2021	13,007,867
2022	16,882,522	2022	13,658,260
2023	14,705,309	2023	14,146,055
2024	14,960,736	2024	14,633,850
2025	12,698,381	2025	14,959,047
2026	12,868,666	2026	15,284,243
2027	13,038,950	2027	15,609,440
2028	13,209,235	2028	15,934,637
2029	10,861,738	2029	16,097,235
2030	10,946,880	2030	16,259,833

APPENDIX 10: ASSUMPTIONS UNDERLYING USE OF NITRIFICATION INHIBITORS

Use of DCD inhibitors to reduce nitrate leaching	
Cost	$200 per hectare
Average farm is 175 ha	$35,000 per year
Number of dairy effective hectares in catchment	126,700
Proportion of hectares treated	95%
Proportion utilised	75%
Assuming pasture response of	7.5%
Current pasture grown	12,800 kgDM/ha
Incr DM grown	960

Value at 15 kgDM/kgMS = $264 per year

	PV Cost = $14,341,635		PV Benefit = $18,930,959
2010	1,685,110	2010	$2,224,345
2011	2,407,300	2011	$3,177,636
2012	2,407,300	2012	$3,177,636
2013	1,925,840	2013	$2,542,109
2014	1,925,840	2014	$2,542,109
2015	1,685,110	2015	$2,224,345
2016	1,685,110	2016	$2,224,345
2017	1,203,650	2017	$1,588,818
2018	1,203,650	2018	$1,588,818
2019	1,203,650	2019	$1,588,818
2020	962,920	2020	$1,271,054
2021	962,920	2021	$1,271,054
2022	962,920	2022	$1,271,054
2023	722,190	2023	$953,291
2024	722,190	2024	$953,291
2025	481,460	2025	$635,527
2026	481,460	2026	$635,527
2027	481,460	2027	$635,527
2028	481,460	2028	$635,527
2029	240,730	2029	$317,764
2030	240,730	2030	$317,764

APPENDIX 11: ASSUMPTIONS UNDERLYING REDUCTION IN STOCKING RATE

Intent is to reduce stocking rate by 10%

Reduce bought-in feed by 45%

Maintain milk production at current levels.

Benefit is in saved feed costs plus saved variable costs.

Reduction is reduced bought in feed (PKE) by 100 tonnes/farm

Number of farms	724
Price for PKE (landed)	$250
Number of cows reduced/farm	48
Saved cost per farm	$26,880
Cost incurred is lesser number of stock to sell	
Reduction in cattle sales per farm	$5334

Marginal FWE:	$/cow
An Health	70
Breeding	42
Dairy Shed exp	18
Electricity	34
Fertiliser	184
Feed	297
	645

	PV Benefit = $225,243,762		PV Cost = 21,469,804
2010	$2,836,053	2010	$270,327
2011	$6,887,557	2011	$656,509
2012	$10,939,061	2012	$1,042,690
2013	$14,180,264	2013	$1,351,636
2014	$17,421,467	2014	$1,660,581
2015	$20,257,520	2015	$1,930,908
2016	$23,093,573	2016	$2,201,235
2017	$25,119,352	2017	$2,394,326
2018	$27,145,077	2018	$2,587,417
2019	$28,170,829	2019	$2,780,508
2020	$30,791,430	2020	$2,934,980
2021	$32,412,032	2021	$3,089,453
2022	$34,032,634	2022	$3,243,925
2023	$35,248,085	2023	$3,359,780
2024	$36,463,536	2024	$3,475,634
2025	$37,273,837	2025	$3,552,871
2026	$38,084,138	2026	$3,630,107
2027	$38,894,438	2027	$3,707,343
2028	$39,704,739	2028	$3,784,580
2029	$40,109,890	2029	$3,823,198
2030	$40,515,040	2030	$3,861,816

APPENDIX 12: ASSUMPTIONS FOR FORESTRY PLANTINGS

Tree Planting

Total area planted (ha): 66,400

Residual area (ha)	Annual area planted (ha)	Residual time (yrs)
66400	2371	28
64029	2371	27
61657	2371	26
59286	2371	25
56914	2371	24
54543	2371	23
52171	2371	22
49800	2371	21
47429	2371	20
45057	2371	19
42686	2371	18
40314	2371	17
37943	2371	16
35571	2371	15
33200	2371	14
30829	2371	13
28457	2371	12
26086	2371	11
23714	2371	10
21343	2371	9
18971	2371	8
16600	2371	7
14229	2371	6
11857	2371	5
9486	2371	4
7114	2371	3
4743	2371	2
2371	2371	1

APPENDIX 13: ASSUMPTIONS FOR DAIRY REMOVAL

Average kgMS/farm	150,000
Average effective ha	175
EFS from dairying ($/ha)	$1164
Average milksolids/ha	857
PV	$403.5 million

		kgMS per ha	EFS per ha	Hectares converted	Total Loss
1	2010	857	1164	2371	2,760,343
2	2011	870	1164	2371	5,520,686
3	2012	883	1164	2371	8,281,029
4	2013	896	1164	2371	11,041,371
5	2014	910	1164	2371	13,801,714
6	2015	923	1164	2371	16,562,057
7	2016	937	1164	2371	19,322,400
8	2017	951	1164	2371	22,082,743
9	2018	966	1164	2371	24,843,086
10	2019	980	1164	2371	27,603,429
11	2020	995	1164	2371	30,363,771
12	2021	1,010	1164	2371	33,124,114
13	2022	1,025	1164	2371	35,884,457
14	2023	1,040	1164	2371	38,644,800
15	2024	1,056	1164	2371	41,405,143
16	2025	1,072	1164	2371	44,165,486
17	2026	1,088	1164	2371	46,925,829
18	2027	1,104	1164	2371	49,686,171
19	2028	1,121	1164	2371	52,446,514
20	2029	1,137	1164	2371	55,206,857
21	2030	1,154	1164	2371	57,967,200
22	2031	1,172	1164	2371	60,727,543
23	2032	1,189	1164	2371	63,487,886
24	2033	1,207	1164	2371	66,248,229
25	2034	1,225	1164	2371	69,008,571
26	2035	1,244	1164	2371	71,768,914
27	2036	1,262	1164	2371	74,529,257
28	2037	1,281	1164	2371	77,289,600
		1,056		66400	$965,680,807
					PV of future cashflows

APPENDIX 14: ASSUMPTIONS FOR FORESTRY COSTINGS

Net forest area (ha) = 1	Cost/ha	Year
Land Prep Costs	260	0
Planting	1200	0
Releasing	230	1
Pruning Costs 1st prune	825	4
Pruning Costs 2nd prune	675	6
Pruning Costs 3rd prune	640	8
Thin to waste	420	8
Annual costs	100	0 to end
Harvest costs $/m^3$	26	
Transport costs $/m^3$/km	0.19	
Transport distance km	70	

Expected Log Prices $/m^3$	
Pruned	140
Unpruned	90
Pulp	49

Pruned	
Yields m^3/ha, 28 yr rotation	568
Pruned	145
Sawlogs	316
Pulp	107

Unpruned	
Yields m^3/ha, 28 yr rotation	650
Sawlogs	450
Pulp	200

APPENDIX 15: FORESTRY CASHFLOW

Forestry PV = $120.25 million

	Year	Forestry Net Returns $m	Carbon Credits $m	Nett Cashflow $m
2010	0	-4.01	- 0.10	-4.11
2011	1	-4.24	0.02	-4.22
2012	2	-4.48	0.21	-4.27
2013	3	-4.72	1.07	-3.65
2014	4	-6.91	2.25	-4.66
2015	5	-7.15	3.87	-3.28
2016	6	-8.99	5.15	-3.84
2017	7	-9.22	6.05	-3.18
2018	8	-11.98	6.62	-5.36
2019	9	-12.21	7.61	-4.60
2020	10	-12.45	8.80	-3.65
2021	11	-12.69	10.22	-2.47
2022	12	-12.92	11.69	-1.23
2023	13	-13.16	13.30	0.14
2024	14	-13.40	14.96	1.57
2025	15	-13.64	16.67	3.04
2026	16	-13.87	18.43	4.55
2027	17	-14.11	20.18	6.07
2028	18	-14.35	21.89	7.54
2029	19	-14.58	23.60	9.01
2030	20	-14.82	25.30	10.48
2031	21	-15.06	26.92	11.86
2032	22	-15.30	28.48	13.19
2033	23	-15.53	30.05	14.51
2034	24	-15.77	31.47	15.70
2035	25	-16.01	32.89	16.88
2036	26	-16.24	34.31	18.07
2037	27	-16.48	35.69	19.21
2038	28	62.37	26.30	88.67
2039	0	62.61	24.54	87.15
2040	1	62.84	23.05	85.90
2041	2	63.08	21.15	84.24
2042	3	65.27	19.73	85.01
2043	4	65.51	18.36	83.87
2044	5	67.35	17.83	85.18
2045	6	67.59	17.45	85.04
2046	7	70.34	17.12	87.46
2047	8	70.58	16.17	86.75
2048	9	70.81	15.65	86.46
2049	10	71.05	15.41	86.46
2050	11	71.29	15.37	86.65
2051	12	71.52	15.23	86.75
2052	13	71.76	15.18	86.94
2053	14	72.00	15.13	87.13
2054	15	72.24	15.08	87.32

	Year	Forestry Net Returns $m	Carbon Credits $m	Nett Cashflow $m
2055	16	72.47	15.08	87.56
2056	17	72.71	15.13	87.84
2057	18	72.95	15.13	88.08
2058	19	73.18	15.13	88.31
2059	20	73.42	15.23	88.65
2060	21	73.66	15.27	88.93
2061	22	73.90	15.27	89.17
2062	23	74.13	15.41	89.55
2063	24	74.37	15.41	89.78
2064	25	74.61	15.41	90.02
2065	26	74.84	15.46	90.31
	PV of future cashflows	935.12	193.19	1128.31

APPENDIX 16: CARBON CASHFLOW

CO_2 equivalents

CO_2 Price: 25 $/Tonne

Residual Carbon at harvest = 200 T/ha

Harvest in Yr 28

Age (Yrs)	Waikato/Taupo Carbon stock T per ha	Annual increment	Carbon cashflow $/m	Carbon setup costs $/ha $50	Carbon admin $m (% of revenue) 20%	Net Cashflow $/m
1	0.4	0.4	0.02	$118,571	0.00	-0.10
2	3	2.6	0.18	$118,571	0.04	0.02
3	7	4	0.42	$118,571	0.08	0.21
4	25	18	1.48	$118,571	0.30	1.07
5	50	25	2.96	$118,571	0.59	2.25
6	84	34	4.98	$118,571	1.00	3.87
7	111	27	6.58	$118,571	1.32	5.15
8	130	19	7.71	$118,571	1.54	6.05
9	142	12	8.42	$118,571	1.68	6.62
10	163	21	9.66	$118,571	1.93	7.61
11	188	25	11.15	$118,571	2.23	8.80
12	218	30	12.92	$118,571	2.58	10.22
13	249	31	14.76	$118,571	2.95	11.69
14	283	34	16.78	$118,571	3.36	13.30
15	318	35	18.85	$118,571	3.77	14.96
16	354	36	20.99	$118,571	4.20	16.67
17	391	37	23.18	$118,571	4.64	18.43
18	428	37	25.37	$118,571	5.07	20.18
19	464	36	27.51	$118,571	5.50	21.89
20	500	36	29.64	$118,571	5.93	23.60
21	536	36	31.78	$118,571	6.36	25.30
22	570	34	33.79	$118,571	6.76	26.92
23	603	33	35.75	$118,571	7.15	28.48
24	636	33	37.71	$118,571	7.54	30.05
25	666	30	39.48	$118,571	7.90	31.47
26	696	30	41.26	$118,571	8.25	32.89
27	726	30	43.04	$118,571	8.61	34.31
28	755	29	44.76	$118,571	8.95	35.69
29	783	28	32.88		6.58	26.30
30	811	28	30.68		6.14	24.54
31			28.81		5.76	23.05
32			26.44		5.29	21.15
33			24.66		4.93	19.73
34			22.94		4.59	18.36
35			22.29		4.46	17.83
36			21.82		4.36	17.45

Age (Yrs)	Waikato/Taupo Carbon stock T per ha	Annual increment	Carbon cashflow $/m	Carbon setup costs $/ha $50	Carbon admin $m (% of revenue) 20%	Net Cashflow $/m
37			21.40		4.28	17.12
38			20.22		4.04	16.17
39			19.57		3.91	15.65
40			19.27		3.85	15.41
41			19.21		3.84	15.37
42			19.03		3.81	15.23
43			18.97		3.79	15.18
44			18.91		3.78	15.13
45			18.85		3.77	15.08
46			18.85		3.77	15.08
47			18.91		3.78	15.13
48			18.91		3.78	15.13
49			18.91		3.78	15.13
50			19.03		3.81	15.23
51			19.09		3.82	15.27
52			19.09		3.82	15.27
53			19.27		3.85	15.41
54			19.27		3.85	15.41
55			19.27		3.85	15.41
56			19.33		3.87	15.46
57			32.90		6.58	26.32
58			23.10			18.48

APPENDIX 17: ENERGY FARMING ASSUMPTIONS

Input data		
Period of Analysis	years	52
General data		
Interest rate	%	8.0%
Annual Planting	ha	2727
Project life	yrs	22
Average biomass increment	odt1/ha/yr	12
Rotation length	yrs	3
Insurance	$/ha/yr	15
Internal administration costs	$/ha/yr	5
Biomass price at plant gate	$/odt	100
Stock removal	$/ha	300
Establishment		
Vegetation removal	$/ha	0
Contact herbicide	$/ha	90
Plow	$/ha	280
Disc	$/ha	0
Plant cover crop	$/ha	0
Kill cover crop	$/ha	0
Planting costs (submodel calculated)	$/ha	1,890
Install fence	$/ha	0
Remove fence	$/ha	0
Pre-emergent herbicide	$/ha	120
Mech. or chem. weeding first year	$/ha	15
Cut back	$/ha	100
Mech. or chem. weeding second year	$/ha	300
Fertilizer	$/ha	107
Total establishment	$/ha	2,902
Establishment grant	$/ha	0
Total establishment incl. grant	$/ha	2,902

Projected energy wood supply

Year	000 ODT/Yr
4	98.7
7	196.3
10	294.5
13	392.7
16	790.8
19	589.0
22	687.2

APPENDIX 18: DAIRY LOSS – ENERGY FARMING

	Area planted (ha)	EFS per ha	PV Cost = $426,090,473
2010	2727	1164	3,174,545
2011	2727	1164	6,349,091
2012	2727	1164	9,523,636
2013	2727	1164	12,698,182
2014	2727	1164	15,872,727
2015	2727	1164	19,047,273
2016	2727	1164	22,221,818
2017	2727	1164	25,396,364
2018	2727	1164	28,570,909
2019	2727	1164	31,745,455
2020	2727	1164	34,920,000
2021	2727	1164	38,094,545
2022	2727	1164	41,269,091
2023	2727	1164	44,443,636
2024	2727	1164	47,618,182
2025	2727	1164	50,792,727
2026	2727	1164	53,967,273
2027	2727	1164	57,141,818
2028	2727	1164	60,316,364
2029	2727	1164	63,490,909
2030	2727	1164	66,665,455
2031	2727	1164	69,840,000
			69,840,000
	60000		$872,603,139
			PV of future cashflow

APPENDIX 19: ENERGY FARMING CASHFLOW

PV = $91.45 million

Year	Nett cashflow
0	-1.1
1	-7.2
2	-8.1
3	-8.1
4	-0.9
5	-0.1
6	-1
7	6.3
8	6.2
9	6.2
10	13.4
11	13.4
12	13.3
13	20.6
14	20.5
15	20.4
16	27.7
17	27.6
18	27.6
19	34.8
20	34.8
21	34.7
22	41.2
23	41.2
24	85.27
	PV of future Cashflow

APPENDIX 20: ASSUMPTIONS UNDERLYING ENVIRONMENTAL BENEFITS

Lowest WTP for improvements in river quality	$26 per household for 10 years
PV	$174.46
Population of the Waikato Region	382,716
Average Household (people)	2.7
Adjustment for Aggregation Bias	75%.
PV	$131
Households in the Waikato Region	141,747
Households nationally	1,170,000

Households pay the PV of WTP in proportion to rate of adoption

	Lag PV = $3,688,980		No Lag PV = $11,049,554
2010	$0	2010	$1,298,298
2011	$1,298	2011	$1,854,711
2012	$4,451	2012	$1,854,711
2013	$9,459	2013	$1,483,769
2014	$15,951	2014	$1,483,769
2015	$23,926	2015	$1,298,298
2016	$33,199	2016	$1,298,298
2017	$43,771	2017	$ 927,356
2018	$55,270	2018	$ 927,356
2019	$67,697	2019	$ 927,356
2020	$81,051	2020	$ 741,884
2021	$95,147	2021	$ 741,884
2022	$109,984	2022	$ 741,884
2023	$125,564	2023	$ 556,413
2024	$141,700	2024	$ 556,413
2025	$1,300,894	2025	$ 370,942
2026	$1,786,829	2026	$ 370,942
2027	$1,773,289	2027	$ 370,942
2028	$1,431,837	2028	$ 370,942
2029	$1,421,265	2029	$ 185,471
2030	$1,246,180	2030	$ 185,471
2031	$1,235,979		
2032	$898,051		
2033	$891,189		
2034	$883,399		
2035	$711,467		
2036	$704,790		
2037	$697,371		
2038	$525,996		
2039	$520,061		
2040	$350,355		
2041	$346,275		
2042	$341,823		
2043	$337,001		
2044	$168,593		
2045	$165,997		

APPENDIX 21: ASSUMPTIONS UNDERLYING BIODIVERSITY BENEFITS (1) (YAO AND KAVAL)

WTP	$42 per ratepayer
Adjustment for edge effects	50%
Adjustment for aggregation bias	75%
PV	$197

	PV = $16,617,873
2010	1,952,563
2011	2,789,375
2012	2,789,375
2013	2,231,500
2014	2,231,500
2015	1,952,563
2016	1,952,563
2017	1,394,688
2018	1,394,688
2019	1,394,688
2020	1,115,750
2021	1,115,750
2022	1,115,750
2023	836,813
2024	836,813
2025	557,875
2026	557,875
2027	557,875
2028	557,875
2029	278,938
2030	278,938

APPENDIX 22: ASSUMPTIONS UNDERLYING BIODIVERSITY BENEFITS (2) (KERR AND SHARPE)

WTP	$120 per household for 5 years
Adjustment for edge effects	50%
Adjustment for aggregation bias	75%
PV	$180

	PV = $15,172,691
2010	1,782,757
2011	2,546,796
2012	2,546,796
2013	2,037,437
2014	2,037,437
2015	1,782,757
2016	1,782,757
2017	1,273,398
2018	1,273,398
2019	1,273,398
2020	1,018,718
2021	1,018,718
2022	1,018,718
2023	764,039
2024	764,039
2025	509,359
2026	509,359
2027	509,359
2028	509,359
2029	254,680
2030	254,680

APPENDIX 23: ASSUMPTIONS UNDERLYING ECOSYSTEMS SERVICES BENEFITS

Manawatu study

Dairy ecosystems value	$404 per hectare (indirect value)
Adjusted for inflation	$450
% value of ecosystems services	7.6% for waste treatment
Reduction in N leaching	42%
Gain in ecosystems services	$450 x 7.6% x 42% = $14.33/ha

	Lag PV = $3,369,456		No Lag PV = $10,092,486
2010	0	2010	127,075
2011	127	2011	308,610
2012	563	2012	490,146
2013	1,489	2013	635,374
2014	3,050	2014	780,603
2015	5,392	2015	907,678
2016	8,641	2016	1,034,753
2017	12,925	2017	1,125,520
2018	18,335	2018	1,216,288
2019	24,961	2019	1,307,056
2020	32,894	2020	1,379,670
2021	42,207	2021	1,452,284
2022	52,972	2022	1,524,899
2023	65,262	2023	1,579,359
2024	79,131	2024	1,633,820
2025	206,460	2025	1,670,127
2026	381,352	2026	1,706,434
2027	554,918	2027	1,742,741
2028	695,063	2028	1,779,048
2029	834,174	2029	1,797,202
2030	956,148	2030	1,815,355
2031	1,077,123		
2032	1,163,207		
2033	1,246,804		
2034	1,327,824		
2035	1,390,199		
2036	1,450,106		
2037	1,507,471		
2038	1,546,247		
2039	1,582,627		
2040	1,600,581		
2041	1,616,320		
2042	1,629,808		
2043	1,641,009		
2044	1,633,911		
2045	1,624,743		

APPENDIX 24: ECOSYSTEMS SERVICES – FORESTRY CONVERSION

Exotic forestry ecosystems indirect value	$1791 per ha
Difference with dairying	$1545 per ha (adjusted for inflation)
PV	$535,577,053

	Lag PV = $87,264,321		No Lag PV = $261,381,670
2010	0	2010	183,207
2011	183	2011	476,338
2012	843	2012	879,393
2013	2,382	2013	1,429,013
2014	5,350	2014	2,125,199
2015	10,443	2015	3,004,592
2016	18,541	2016	4,067,192
2017	30,705	2017	5,312,999
2018	48,183	2018	6,778,653
2019	72,440	2019	8,464,156
2020	105,161	2020	10,369,508
2021	148,251	2021	12,567,990
2022	203,909	2022	15,132,886
2023	274,700	2023	18,247,402
2024	363,739	2024	21,911,539
2025	635,911	2025	25,575,676
2026	1,027,461	2026	29,239,813
2027	1,540,110	2027	32,903,950
2028	2,207,716	2028	36,568,087
2029	3,031,194	2029	40,232,224
2030	4,043,558	2030	43,896,361
2031	5,244,846	2031	47,560,498
2032	6,634,909	2032	51,224,635
2033	8,245,664	2033	54,888,772
2034	10,076,010	2034	58,552,909
2035	12,124,629	2035	62,217,046
2036	14,454,471	2036	65,881,183
2037	17,127,092	2037	69,545,320
2038	20,299,319	2038	70,607,919
2039	23,960,854	2039	71,780,443
2040	27,617,297	2040	73,062,891
2041	31,266,264	2041	74,418,622
2042	34,905,448	2042	75,920,918
2043	38,532,687	2043	77,606,421
2044	42,146,003	2044	79,658,338
2045	45,743,782	2045	82,076,668
2046	49,324,780	2046	84,275,150
2047	52,887,530	2047	86,253,784
2048	56,430,348	2048	88,012,570
2049	59,951,327	2049	89,478,225
2050	63,448,269	2050	90,577,466
2051	66,918,610	2051	91,127,086
2052	70,359,234	2052	91,127,086
2053	71,477,126	2053	91,127,086
2054	72,696,331	2054	91,127,086
2055	74,014,028	2055	91,127,086

	Lag PV = $87,264,321		No Lag PV = $261,381,670
2056	75,395,041	2056	91,127,086
2057	76,901,404	2057	91,127,086
2058	78,561,662	2058	91,127,086
2059	80,532,601	2059	91,127,086
2060	82,806,674	2060	91,127,086
2061	84,860,057	2061	91,127,086
2062	86,693,847	2062	91,127,086
2063	88,309,365	2063	91,127,086
2064	89,643,661	2064	91,127,086
2065	90,635,176	2065	91,127,086
2066	91,127,086	2066	91,127,086
2067	91,127,086		
2068	91,035,959		
2069	90,853,705		
2070	90,580,324		
2071	90,215,816		
2072	89,760,180		
2073	89,213,418		
2074	88,575,528		
2075	87,846,511		
2076	87,026,368		
2077	86,115,097		
2078	85,112,699		
2079	84,019,174		
2080	82,834,522		
2081	81,558,742		

APPENDIX 25: BIODIVERSITY VALUES – FORESTRY CONVERSION

Biodiversity Value cf native forest	60%
WTP Value per ha	$0.351
(Derived from Scenario 1, with edge effects removed)	

	PV = $276,957,189
2010	1,415,403
2011	2,123,104
2012	3,538,506
2013	4,953,909
2014	6,369,312
2015	7,784,714
2016	9,200,117
2017	10,615,519
2018	12,738,623
2019	14,861,727
2020	16,984,831
2021	19,107,935
2022	21,938,740
2023	24,769,545
2024	27,600,350
2025	30,431,155
2026	33,261,961
2027	36,800,467
2028	39,631,272
2029	43,169,779
2030	46,000,584
2031	49,539,090
2032	53,077,597
2033	56,616,103
2034	58,031,506
2035	60,862,311
2036	63,693,116
2037	66,523,921

APPENDIX 26: ECOSYSTEMS SERVICES – ENERGY FARMING

	Lag PV = $88,506,798		No Lag PV = $268,256,192
2010	$0	2010	$210,698
2011	$211	2011	$547,815
2012	$969	2012	$1,011,350
2013	$2,739	2013	$1,643,444
2014	$6,152	2014	$2,444,096
2015	$12,010	2015	$3,455,446
2016	$21,323	2016	$4,677,494
2017	$35,313	2017	$6,110,239
2018	$55,414	2018	$7,795,823
2019	$83,310	2019	$9,734,243
2020	$120,941	2020	$11,925,502
2021	$170,497	2021	$14,453,877
2022	$234,507	2022	$17,403,647
2023	$315,920	2023	$20,985,512
2024	$418,320	2024	$25,199,470
2025	$731,332	2025	$29,413,428
2026	$1,181,636	2026	$33,627,386
2027	$1,771,211	2027	$37,841,344
2028	$2,538,994	2028	$42,055,303
2029	$3,486,039	2029	$46,269,261
2030	$4,650,314	2030	$50,483,219
2031	$6,031,860	2031	$54,697,177
2032	$7,580,026	2032	$58,700,437
2033	$9,482,754	2033	$62,577,279
2034	$11,586,994	2034	$66,327,702
2035	$13,941,249	2035	$69,909,566
2036	$16,617,281	2036	$73,322,872
2037	$19,685,084	2037	$76,525,481
2038	$23,324,006	2038	$79,517,391
2039	$27,523,974	2039	$82,298,603
2040	$31,717,831	2040	$84,826,978
2041	$35,903,893	2041	$87,102,516
2042	$40,080,220	2042	$89,125,216
2043	$44,244,622	2043	$90,810,799
2044	$48,394,571	2044	$92,074,986
2045	$52,577,598	2045	$92,707,080
2046	$56,638,674	2046	$92,707,080
2047	$60,539,620	2047	$92,707,080
2048	$64,303,274	2048	$92,707,080
2049	$67,927,657	2049	$92,707,080
2050	$71,373,832	2050	$92,707,080
2051	$74,640,746	2051	$92,707,080
2052	$77,690,429	2052	$92,707,080
2053	$80,522,841	2053	$92,707,080
2054	$83,045,443		
2055	$85,221,531		
2056	$87,052,370		
2057	$88,539,475		

	Lag PV = $88,506,798	No Lag PV = $268,256,192
2058	$89,610,453	
2059	$90,194,507	
2060	$90,111,282	
2061	$89,369,625	
2062	$88,535,261	
2063	$87,608,191	
2064	$86,588,413	
2065	$85,475,928	
2066	$84,270,736	
2067	$82,972,837	