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On Farm Nutrient Management Practice – Research and Applicability to Upper Waikato

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Nutrient management is an evolving field of study and as new research arises, further feedback is welcome.

Please direct enquiries to Justine Young or Ross Abercrombie at Environment Waikato.

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Executive summary

This study presents a review of research into options for on-farm nutrient management, identifying their relevance to the Upper Waikato and any gaps in existing information to guide policy development for this part of the region. On-farm practices were reviewed with a dual focus on their effectiveness in reducing nutrient losses from the farm system, and possible impacts (economic and practical) on the existing farm business operation. An additional focus was to identify factors that lead to differences in the range of environmental and on-farm economic impacts presented in the literature.

A review of literature and discussion with key specialists in this field has shown that:

1. A sound scientific research platform exists and principles have been identified for managing nutrient issues that can be transferred to this catchment.
2. Local climatic, soil and farm management variables will influence the magnitude of environmental gain from implementing different practices.
3. Nitrogen pathways and practices to reduce loss are well understood and there is a broad scientific consensus on their effectiveness. A possible exception is how much reduction in leaching and what pasture response will occur from using nitrification inhibitors in this area under different farm systems. There is also limited data on nitrogen losses under grazed winter crops in this region, and on the extent of land area under cropping in this catchment.
4. Phosphorus pathways are well understood, but the importance of particular sources and hotspots, and consequently the most effective ways to avoid losses, has to be assessed on a farm-by-farm basis. Excessive Olsen P levels can be identified from soil tests, and much overland runoff is observable by the farmer. Key sources can be seen by walking the farm in the rain to observe runoff or by checking for discharges to waterways following effluent irrigation.
5. The economic impacts of practices vary according to the details of each property, but a range of modelling has been done for Taupo, Toenepi, Rotorua and Hamilton farm systems that will have some relevance.
6. Beyond the scientific principles, the local issue needs to be clearly communicated. Of critical importance is assembling clear evidence showing that:
   - nutrient flows into the hydrolakes are increasing/ are likely to increase further - *What* is happening
   - this will have a substantive effect - *So what*
   - land use change and intensification are linked to this effect - *How this happens*
   - within this, the greatest factors at play in this area/ where nutrient contributions come from/ relative importance of N and P losses - *What influences it the most*

From this, the land use practices that have been identified through the literature can be applied to the Upper Waikato in a strategic way, focusing on *what will make the most difference, where*.

Applying this at a farm-scale level to some 'typical' farms of the area will help farmers to make the assessment of *what will work for me*.

The processes for engaging people in learning and action around these issues are reasonably well understood. However local information about different farmers' practices and how individual farm context affects farmers' choice of nutrient management practices may be a current knowledge gap.

A range of nutrient management practices are currently available. But there are only a few that are easily adopted into the farm system while having a positive impact on farm income and the environment. However, some practical options do exist within the current set of possibilities that can be promoted to farmers of the Upper Waikato catchment. The summary tables in this document outline what those practices are.

1 Introduction

1.1 Purpose and scope of this review

Nutrient management is a focus for Environment Waikato in managing water quality. The Upper Waikato catchment (up-stream of the Karapiro dam) has been highlighted recently as farming intensifies and land use changes.

Nutrients can affect water quality by promoting the growth of algae and water weeds. Algal growth can cause a change in river water colour and clarity (with consequences for amenity and recreation). Some forms of algae can be toxic if present in stock drinking water. Excessive plant material breaking down in waterways can also reduce dissolved oxygen and affect aquatic life. Larger slimes or filamentous algae and water weeds can cause physical obstructions in streams and interfere with pumps. Impacts on the physical and biological aspects of a waterway can also have cultural implications, both in terms of the mauri of the waterway and its capacity to support traditional cultural activities.

Work is underway to investigate nutrient status and trends in waterways of the Upper Waikato. However, there are clear links between land use intensification and rising nutrient levels in waterways in the region as a whole (Environment Waikato, In prep). In addition, as water extraction increases, the capacity for nutrient dilution is reduced. Therefore, land use change and intensification against a backdrop of demand for water extraction represent potential issues for the Upper Waikato.

The purpose of this study is to present a review of research into options for on-farm nutrient management, identifying relevance to the Upper Waikato and any gaps in existing information to guide policy development for this part of the region. On-farm practices were reviewed with a dual focus on their effectiveness in reducing nutrient losses from the farm system, and the impacts (economic and practical) on the existing farm business operation. An additional focus was to identify factors that lead to differences in the range of environmental and on-farm economic impacts presented in the literature.

The intention is that policy-makers could use this information to inform plans for further research, and to assist in choosing practical and effective policy options. The research collated in this report may also be of use to those in advisory roles regarding on-farm nutrient management practice. However, detailed farm-by-farm analysis and modelling is recommended, as economic and management factors result in varying impacts of these practices between farms.

The principal focus of this review is on-farm nutrient management practice. Other factors such as nutrient pathways and hydrological effects between farm and river, and nutrient harvest, removal or capping within waterways are outside the scope of this study. However, interception/nutrient removal methods that can be incorporated into farmland management, such as wetlands or riparian barriers, are considered. Other issues (beyond nutrients/ water quality) are briefly canvassed in Table 7 in the Appendix to the report.

The two plant nutrients that are the focus of this review are nitrogen and phosphorus. Algae will generally respond to increasing nutrient levels if the water has not yet reached saturation for those nutrients. However, the relative impact of nitrogen and phosphorus depends on which of these two nutrients is the limiting factor in that waterway. Nutrient enrichment can particularly promote algae in the Waikato River due to the retention of water in the hydrolakes giving algae the opportunity to grow. Algal growths on rocks (e.g. in streams) is also affected by other factors apart from nutrients (Welch et al.1992):

1. Current velocity, which controls nutrient transport to the algae
2. Frequency of scouring floods
3. Suspended sediment (which obscures the light)
4. Shading
5. Substrate type
6. Grazing.

2 Definitions

RED – Resource Efficient Dairying.
EBIT – Earnings Before Interest and Tax.
SUBS – Soils Underpinning Business Success.
Allophanic soils – soils with high P retention. They occur mainly in volcanic parent materials such as ash.
Pumice soils – soils with generally more than 25 cm or more of Taupo pumice.

3 Intensification drivers and farmer responses

Background information to the Resource Efficient Dairying (RED) trials notes that pressures to intensify exist because dairying has expanded onto most of the suitable land, so farmers now have to grow more feed from existing dairying land or bring in feed from cropping areas (or amalgamate/ expand their farms). Farmers will move to higher input systems if the marginal returns for milk exceed the marginal cost of feed plus operating costs. High input systems may also be attractive if feed allows more profitable use of existing land, cows, plant and/or labour. In this particular area, suitable dairying land can also be found currently under forestry cover, so that there are dual sources of intensification – from forestry conversion and from intensification on existing dairy farms.

There are many factors that influence farm-level decision making. There is a need to offer a wide range of management options because farmers make decisions based on different criteria:

- economic/ production
- labour considerations
- skills and knowledge
- enjoyment/ lifestyle (often a desire for simplicity and fewer worries)
- stock health and welfare
- attitude to debt and capacity to raise capital
- resilience of the system and attitude to risk
- sustainability, aesthetic or environmental concerns
- a desire to increase land values long-term.

Different farmers are at different points in their development which influences their preferences. Parminter (2002) suggests that if communications are not segmented and organised around different farmers' decision-making orientation, then communication is more likely to be focussed on the agency's need than the farmers'.

Criteria and priorities may change according to the policy context. Capping of nitrogen emissions, as in Taupo, creates different economic variables as land values can be affected. This impacts on debt ratios, and may change people's interest rates and ability to raise capital if they are forced to refinance. In this scenario, profit per kg N leached becomes an important criterion for management practice choices.

4 Promoting nutrient management options

Where nutrient management has been a focus in Taupo and Rotorua, farmers have consistently called for proven options that are economically viable. Bewsell, Kaine and Higson (2005) recommend providing practical solutions that link strongly with farm context. (Farm context is defined as the mix of practices and techniques used on the farm, and the biophysical and financial resources available to the farm business (Kaine and Johnson 2004)). Rotorua experience shows that where there are win-win options, farmers can move quite quickly from their current practice to their on-farm economic optimum, but where these changes are insufficient to meet water quality targets, the situation becomes more challenging. Rotorua farmers have expressed concern at the lack of practical options to further reduce nutrient losses to meet targets, and at the dual burden of new rules and a targeted rates rise.

In order for people to engage in the issue, it is important to establish the value of managing nutrients. This is easier where there is an iconic water body, especially one that supports the local economy such as Taupo or Waitomo. It may be harder with the Waikato River, with its large catchment and diverse and spread-out communities.

Taupo and Rotorua experience has shown that farmers demand a high standard of proof and need answers to the questions ‘Why is this a problem?’ and ‘What are the solutions?’ This creates pressure to reach consensus around the evidence, some of which has considerable uncertainty around it. Trying to answer these questions through more research can create long delays in the participatory policy-making process.

Parminter (2002) suggests that poor communication can create mistrust of officials and divert energy into ‘spoiling’ and dysfunctional behaviour. In order to promote better nutrient management practices agencies need to communicate well with farmers. Taupo experience suggests that where regulation is the policy response, useful approaches focus on dialogue, practical science to identify ways to increase profit within the N cap, and a ‘compliance assistance’ or capacity-building approach to regulation.

Parminter points out that different communication approaches have different strengths:

- mass media – low cost way to reach people but low engagement
- written arguments – good for complex information
- video – can show contextual factors visually
- field days – demonstrations of results gives confidence – can give good arguments if focused presentations occur, also has the strength of group discussion
- groups – can have both a normative and a cognitive influence on people. Group discussion can help people remember and process information where enough information is available and reasoned discussion is facilitated. But groups can be biased towards prevailing attitudes of dominant members and there can be group-induced polarisation.

Face-to-face social pressure (norming) works best in small communities where people know and meet with each other, where there is seen to be a common benefit in cooperating on an issue, and with issues where there is visible evidence of people’s practices so they can be ‘monitored’ by their peers (Uphoff 1992; Ostrom 1990).

Nutrient management issues are often invisible and difficult to monitor. However farmers will often have a ‘fair idea’ of what each other is doing.

Farm plans have a long history in New Zealand, and nutrient management planning can be seen as another form of farm plan. The OECD uses Environmental Farm Plans as one of its agricultural indicators, but does not specify what one entails. In the past, there has generally not been a strong focus on integrating economic and environmental planning in New Zealand but this has changed with farm plan models like SUBS (Soils Underpinning Business Success). Also there has been a shift since the 1990s towards more interactive ways of developing plans, rather than purely an expert- (agency) prepared plan based on land classification (Manderson et al. 2007).

Nutrient management plans can help to look beyond nutrient budgets, which do not cover all of the options for mitigating nutrient losses. Over-reliance on nutrient budgeting alone can overlook some farm-specific mitigation practices with potential to significantly reduce farm nutrient losses to waterways (such as targeted riparian/wetland practices, drain management or track design). Therefore on-farm observation and planning to identify nutrient loss sources and address them are a valuable addition to nutrient budgets.

A farm plan is only as good as its implementation, which is greatly aided by appropriate follow-up. Manderson et al. (2007) also point out that farm plans rely on transferring research results regarding proven practices to a new context. This is less reliable when:

- the practice has yet to be fully proven (possible example could be N inhibitors for dry-stock systems)
- the practice is implemented but modified (e.g. width of riparian strip)
- it is not tailored to the unique management and environmental conditions of the site (e.g. the influence of soil type and contour on the benefits of wintering pads).

This applies not only to farm plans, but to all transfer of research results into new contexts. The tables that follow in this report summarise research regarding practices currently being advocated to farmers and whether the findings are likely to apply to the Upper Waikato. An indication is also given of how proven each practice is. Key factors that determine both environmental effectiveness and on-farm economic impacts are also identified, along with the local features relevant to these factors.

5 Existing research knowledge and gaps

A substantial body of literature and research exists on nutrient management in New Zealand, and more is underway, especially in focus catchments like Rotorua. The table below summarises key findings of existing studies that are relevant to the Upper Waikato catchment. See the Source Data for the Analysis in the Appendix for detail and sources.

Table 1: Summary of research and relevance to Upper Waikato

Farm practice to reduce nutrient losses	Likely effectiveness in reducing nutrient loss	Range of economic impacts	Factors influencing impact in Upper Waikato
Nutrient budget and nutrient management plan	Could be large for small number of farms, mostly small-moderate (5-10%)	Positive, proportionate to the reduction in fertiliser	Current fertiliser, effluent, supplement and wintering practice
Wintering practices - wintering on pads - 'cut and carry' feed	For dairy, large potential reduction in N loss e.g. 30-60% from wintering on a pad. Level of gain depends on current wintering practice and what other changes are made as a result which may increase overall nutrient cycling	Large range of impacts from wintering pads but generally negative on Earnings Before Interest and Tax (EBIT) (4-15% drop).	Nutrient reduction depends on length of time/ season on pad. Economic impact depends on cost of pad, feed and labour, and cost of other wintering options. Benefit relies on feeding cows well/ utilising extra pasture grown.

Wintering practices - wintering off the farm	Effective but transfers the issue to another location	Often profitable with other system changes	System changes (e.g. calving earlier, milking longer, increasing stocking)
Wintering practices - winter forage crops	A high N-loss land use (less if on-off grazing)	Often incorporated into re-grassing sequence	Extent of crop area, fertiliser used and on-off grazing practices.
Effluent management - switching from ponds to land treatment	Can give a large reduction in P loss for those farms (60%).	If existing ponds are used for storage, a switch is possible for a minor drop in EBIT (1%) as nutrient 'credit' of land application offsets some of the cost	Number of dairy farms currently using pond systems.
Effluent management - better land application	Smaller reductions in overall N and P loss (0-10%)	Small economic benefit due to better use of nutrients	Extent of poor practice with current systems
Riparian management	Riparian strips prevent direct inputs and filter out particulate P (50-80%) but have less effect on dissolved P, so moderate gains overall for P (20-50%). Effectiveness can drop over time (e.g. after 20 years). Minor for N unless soils in riparian area are wet and act like wetlands (denitrification occurs).	Capital and maintenance costs (weeds, floods) but savings on stock losses and stock management time. Grants may assist e.g Clean Streams (35%) Overall impact can be positive if subdivision/ pasture utilisation improves.	Current stage of farm fencing/ subdivision; current stock access/ impacts to streams. Riparian strip width (5+ metres required for effective filtering). Eventual fate of stored P in the filter strip area. Extent of wet soils for N removal.
Nitrification inhibitors	Moderate to substantial reductions in N loss for dairy (15-30%) are possible, enhanced if stocking rates remain constant and other inputs drop	Increase in pasture growth (5-10%) may cover costs or give economic benefits if well utilised – EBIT gain of 1-15% under modelling	Depends on response in local conditions both for N leaching and pasture growth; and any other changes made to the farm system
Hotspots e.g. tracks and races, yards	Farm-specific but can be significant for P and N; can also be significant for faecal contamination	A cost to re-shape areas/ redirect effluent. Can save on ongoing costs e.g. track maintenance	Contour, runoff pathways, cut-offs/ diversion in place, time stock spend on the area, stock type
Wetlands	Effective if sufficiently large to retain water (e.g. 2-5% of catchment area can remove 50% of the N in the runoff)	Easy to fence existing wetlands on dairy farms. More costly to construct a wetland, but ongoing cost low.	Catchment water flows/ extent of wetlands, time water is retained in wetland
Feed manipulation - low-N/high sugar or high tannin feed, salt supplements	A range of alternatives still being researched	Different alternative feeds will have different effects on production	Depends on supplement reducing overall nutrients in the system.

There are also many opportunities to adjust current systems for more efficient N-use, with neutral or positive economic impacts. These include fine-tuning grazing practices, getting better animal performance for each unit of N used, and more strategic fertiliser use (especially avoiding winter use of N fertiliser).

5.1 Research gaps identified by scientists

In a review for the Dairy Environment Review Group, de Klein (2005) identified several areas for further research in this field, (see following table).

Table 2: Research gaps identified by de Klein (2005)

Contaminant	Knowledge gaps	Solutions gaps
Nitrate and nitrous oxide	• Importance of dissolved organic N • How to increase N retention in animals • How to manipulate animal urination patterns • Relative contribution of laneways to losses • Trade-off effects of one N loss versus another • Effect of buffer strips/ wetlands/ walls on N_2O • Systems optimisation/ impact of current technologies and nutrient practices	• High N retention animals • Animals that deposit urine more evenly • Animals or forage systems which increase N partitioning in dung rather than urine
Phosphorus/ sediment	• Relative importance of different sources (including laneways) • Long-term effects of buffer strips on P	• Forage legumes with low P requirements • Practices that target the main sources

The following research gaps were identified from Taupo research (Thorrold 2006):

- Nitrification inhibitor optimisation and effects in sheep and beef systems e.g. on which paddocks should it be used?
- Which crops are best suited for different sites, and fertiliser regimes for cropping in local situations
- N leaching below deep rooting crops e.g. lucerne

Leaching loss under cropping was also seen by Ledgard et al. (2003a) as a gap: 'Forage estimates have large uncertainty because of the lack of data for validating model estimates'.

Little work has been done to quantify what tracks and races contribute to nutrient yields, although a trial is now underway in Southland (J. Quinn; R. Monaghan, pers.comm., August 2007).

6 A 'rough guide' to the range of nutrient management practices

The economic and environmental impacts of various nutrient management practices are influenced by a large range of contextual on-farm factors. Therefore, the following 'rough guide' should be treated as indicative only and used as a basis for discussion and debate. See also the 'sensitivity factors' listed in Table 3, for an indication of the contextual factors which can influence a practice's environmental and on-farm economic impacts. These lists were compiled in consultation with farm systems and nutrient management researchers. Information for the effectiveness of the different practices is sourced from the research presented in the Appendix.

6.1 Spectrum of research and testing

The following gives an indication of how well understood different practices are in terms of their effectiveness and application to a range of contexts.

Well tested, understood and researched

As an indication, practices that are currently included in the OVERSEER model have been well tested and researched:

- Effluent management practice
- Changing land uses/ stock types
- Fertiliser inputs (rates, form and timing), feed inputs
- Wintering practices

Tested, understood but still gaps in understanding of different contexts for application

As an indication, practices that are soon to be incorporated into OVERSEER fall into this category:

- Nitrification inhibitors
- Wetlands and riparian management – stock exclusion, filter strips, crossings
- Cropping practices

Proven but context-specific factors dominate and many systems or specific situations are not well understood

- Controlling erosion/ sediment sources e.g. gullies, stream banks
- Tracks and races
- Hotspots e.g. yards
- Grazing management of sensitive areas
- Drain management

Proven as a concept with potential but practicality still not fully established

- Alternative feeds, forage and supplements

6.2 Spectrum of effectiveness at reducing nutrient losses

Due to situational factors and farm-specific contexts, it is impossible to be definitive about which nutrient management practices will be most effective across all farms. However, it is also true that not all practices have equal scope to reduce nutrient losses. In addition to the indicative lists below, a nutrient budget can help to assess each farm's context. Separate lists are given for nitrogen and phosphorus, as their pathways to water are different, and therefore practices to prevent their loss from the farm also differ.

Nitrogen

Practices ordered from most through to least potential to reduce nitrogen loss[*]

- Changing land uses/ stock types (e.g. forestry vs cattle vs sheep)
- Wintering practices (e.g. pads)
- Low input systems/ N efficient systems (e.g. better production for less N input)
- Nitrification inhibitors
- Wetlands and drain management (e.g. creating wetland conditions in drains)
- Effluent management (e.g. switching to land application/ increasing area irrigated/ deferred irrigation/ low rate systems)
- Fertiliser management (e.g. no winter N applications)
- Feed manipulation (e.g. low N or high sugar feed)
- Riparian management (e.g. stock exclusion, filter strips, crossings)
- Tracks and races and hotspots (e.g. yards)

Note, a nutrient budget could assist with planning several of these practices including fertiliser and feed inputs and effluent management.

[*] These lists have been put together using the source material in the Appendix with input from key researchers

Phosphorus

Practices ordered from most through to least potential to reduce phosphorus loss[*]
Effective practices for reducing phosphorus loss are highly context-specific and the difference between practices may not be great. However, the following is an indication:

- Changing land uses (e.g. forestry vs grazing)
- Changing effluent treatment system (e.g. switching from ponds to land treatment)
- Controlling erosion/ sediment sources (e.g. gullies, stream banks)
- Adjusting P fertiliser inputs for optimum soil P status (e.g. with a nutrient budget)
- Riparian and drain management (e.g. stock exclusion, filter strips, crossings)
- Tracks and races (e.g. cut-offs to direct water into rough grass or wet areas)
- Changing stock types (e.g. running lighter stock)
- Grazing management of sensitive areas (e.g. no heavy stock near waterways)
- Better effluent irrigation management (e.g. deferred irrigation/ lower rates)
- Wintering practices (e.g. pads)
- Hotspots (e.g. yards)

6.3 Spectrum of potential change to the farm system/ business

The ease of fitting a new practice into the existing farm system is an important consideration when adopting an innovation. The following list gives an indication of which practices will require minimum adjustment to an existing farm practice and which will mean more extensive change. Again, this is obviously highly farm-specific.

Practices ordered from most through to least potential for change to the farm system

- Changing land uses/ stock types
- Feed manipulation – new forage species, salt or other supplements
- Wintering practices – feed pads
- Tracks and races
- Controlling erosion/ sediment sources e.g. gullies, stream banks
- Wetland, drain and riparian management
- Effluent management – switching to land application/ increasing area irrigated/ deferred irrigation/ low rate
- Winter grazing management and simple stand-off pads
- Low input systems/ N efficient systems
- Managing hotspots e.g. yards
- Feed manipulation – different grass species
- Nitrification inhibitors
- Nutrient budget and nutrient management plan

6.4 'Sensitivity factors'

In the following table, the influences that determine the environmental effectiveness of a practice and its on-farm economic impact are set out. They are listed roughly in order of greatest to lowest potential to influence these impacts. However, it is still important to note that on-farm economic and environmental effects will differ from farm to farm. For example, wintering pads may have economic benefits on difficult farms but negative economic impact on an easier type of country.

Table 3: Factors influencing environmental and economic impacts of practices

(Factors listed in rough order from most through to least influence)[*]

Nutrient management practices	Factors influencing environmental effectiveness	Factors influencing on-farm economic impacts
Nutrient budget and nutrient management plan	Current nutrient status (Olsen P) Action taken as a result of the budget and changes to: - Current wintering practice - Current fertiliser practice - Current effluent practice - Current supplement rates	Cost of fertiliser/ feed inputs Action taken as a result and changes to: - Current wintering practice - Current fertiliser practice - Current effluent practice - Current supplement rates Impact of change on production
Wintering practices – pads	Stock type Length of time/ season spent on pad – how closely it matches the 'drainage season' in paddocks Effluent collection and re-distribution to land Amount of extra feed brought in and increases in stocking rate (Note there are other impacts in places where the feed is grown.) Reduction in pugging and therefore runoff (varies depending on soil and contour)	Cost of pad + effluent system and cost of debt servicing How much extra pasture can be grown (pugging avoided) and how well it can be utilised Pad design to avoid lameness Cost of feed Reduction in feed wastage Labour required to operate pad Cost of other wintering options (on-farm and off-farm) Milk payout Ability to keep cows well fed and extend lactation Reduction in fertiliser inputs with extra effluent spread.
Effluent management – switching to land application/ increasing area irrigated/ deferred irrigation/ low rate	Potential to switch from pond to land irrigation Management of the systems (current and new) and of any additional fertiliser inputs Soil type and contour Presence of subsurface drains.	Whether existing ponds can be used for storage Choice of irrigation system – capital and running/labour costs Reductions made in fertiliser inputs on effluent blocks Utilisation of pasture grown
Riparian management – stock exclusion, filter strips, crossings	Stock type and current stock access to and impact on water Slope of surrounding areas Width of riparian strip Free-draining soils / mole or tile drains that bypass riparian zone Bank instability and P status of eroding soils Grazing and cropping practices next to waterways or filter strips Vegetation in the filter strip – does it slow the water flow? Channelisation of runoff flow in the strip vs 'sheet' flow Long-term fate of phosphorus trapped in the filter areas.	Capital cost (fence type, terrain, planting) Lameness avoided and time saved in crossing rivers Maintenance cost (weeds, floods) Maintenance savings (drain and culvert clearing) Savings on stock losses and mustering time Grant availability (can be 35%) Subdivision/ pasture utilisation gains Enhanced capital value.
Hotspots e.g. yards	Location of the area in relation to waterways/ aquifers Size of area and concentration of nutrients deposited on it	Cost of collecting/ redirecting effluent draining or seeping from the area
Tracks and races	Track drainage to stream/ drain Contour Stock type and time on track Cut-offs and shaping to divert runoff and how cut-offs/ diverted runoff is managed –	New race or retro-fitting? Redesign work needed e.g. reshaping, cut-offs, surfacing Maintenance saved (grading, resurfacing, culvert and drain maintenance)

[*] These lists have been put together using the source material in the Appendix with input from key researchers

	effectiveness of filtration areas	Any reduction in lameness
Nitrification inhibitors	Current wintering practice Climate/soil – may be more effective in drier, colder soils Whether N-fertiliser use drops Whether there is an increase in nitrogen cycling (e.g. stocking rate or feed intake) in response to pasture increase Number and timing of applications (two recommended – autumn and winter) Some uncertainty over ongoing effects with longer-term use	Cost of product Pasture response Ability to utilise extra pasture
Wetlands	Are there existing wetlands? What percentage of the farm's drainage is captured by them? How long is water retained? (Size, vegetation, flow pattern) Carbon source available (vegetation)	Cost to create new wetlands and/or fence existing wetland Savings in stock losses prevented Opportunity cost of not grazing Cost of any planting and weed control
Low nitrogen input systems (lower N fertiliser and supplement inputs, possibly with better animal genetics or grazing practice used to make more efficient use of N inputs)	Effectiveness of animal performance to capture N in product Consider impacts of inputs where they are produced e.g. cropping areas	Cost of fertiliser/ inputs Prices for outputs/ products Production response to inputs (genetics, pasture utilisation) More gain likely if current N use is high (e.g. 200kgN/ha/yr), as cost of N use is high relative to the marginal production gained
Fertiliser management	How closely current practice matches recommended practice - avoiding high risk period i.e. winter N application - using slow release P fertiliser in high risk areas	Amount of nutrient retained Cost of fertiliser Relative product prices pH - slow release P fertiliser (e.g. RPR) can affect production in high pH (above 6) as it is very slow-release
Grazing management of sensitive areas	Whether areas are currently critical source areas for nutrients, reduction in run-off	Alternative grazing areas available, reduction in pugging achieved
Changing land uses/ stock types	Whole farm or part of farm? How intensive is the land use e.g. lowland sheep can be intensive For crops, crop type and harvest e.g. perennial vs annual; grazed in situ vs cut and carry	Relative profitability of the alternative land uses Cash flow (e.g. forestry)
Drain management	Residence time of water in drain Ultimate fate of vegetation in drain – is it removed? Management of clearing	Drain maintenance costs reduced from stock exclusion Any stock loss avoided or reduction in labour for stock management/ mustering
Feed manipulation	Are low-N supplements used to replace N fertiliser and high N feed or are they used in addition? Impacts of growing the crops	Costs, yields, production (profitability).
Controlling erosion/ sediment sources e.g. gullies, stream banks	Slope/ soil and current erosion rates or potential risk P status of eroding areas.	Risk to assets and grazing land from erosion Cost of erosion protection Impact on production (e.g. shading from trees)

7 Conclusions: analysis of knowledge 'gaps' for managing nutrients in Upper Waikato

A review of literature and discussion with key specialists in this field has shown that:

1. A sound scientific research platform exists and principles have been identified for managing nutrient issues that can be transferred to this catchment.
2. Local climatic, soil and farm management variables will influence the magnitude of environmental gain from implementing different practices, but these are mostly reasonably predictable from work done in Taupo, Bay of Plenty and Waikato trials.
3. Nitrogen pathways and practices to reduce loss are well understood and there is a broad scientific consensus on their effectiveness. A possible exception is how much reduction in leaching and what pasture response will occur from using nitrification inhibitors in this area under different farm systems. There is also limited data on nitrogen losses under grazed winter crops in this region, and on the extent of land area under cropping in this catchment.
4. Phosphorus pathways are well understood, but the importance of particular sources and hotspots, and consequently the most effective ways to avoid losses, has to be assessed on a farm-by-farm basis. This does not require expensive research, as excessive Olsen P levels can be identified from soil tests, and much overland runoff is observable by the farmer. Key sources can be seen by walking the farm in the rain to observe runoff flows or by checking for discharges to waterways following effluent irrigation.
5. The economic impacts of practices vary according to the details of each property, but a range of modelling has been done for Taupo, Toenepi, Rotorua and Hamilton farm systems that will have some relevance. The economic impacts predicted by these studies depend on the assumptions used in the modelling. Therefore where there is less localised scientific research (e.g. for nitrification inhibitor response rates) or variability due to farm management (e.g. capturing the production gains from standing cows off wet soils) the economic predictions vary more widely. Given this, further 'monitor farm' type modelling and on-farm measurement of pasture responses and production effects of practices such as nitrification inhibitors could be usefully integrated into the Upper Waikato process for engaging farmers.
6. Beyond the scientific principles, the local issue needs to be clearly communicated. Of critical importance is assembling clear evidence showing that:
   - nutrient flows into the hydrolakes are increasing/ are likely to increase further - *What* is happening
   - this will have a substantive effect - *So what*
   - land use change and intensification are linked to this effect - *How this happens*
   - within this, the greatest factors at play in this area/ where nutrient contributions come from/ relative importance of N and P losses - *What influences it the most*

From this, the land use practices that have been identified through the literature can be applied to this area in a strategic way, focusing on *what will make the most difference, where*.

Applying this at a farm-scale level to some 'typical' farms of the area will help farmers to make the assessment of *what will work for me*. However, it is recommended that this be done as part of the engagement process or as a result of it, rather than prior to it. In this way, farmers' valuable local knowledge can help to target practices that have most potential for the area and are of most interest to those communities.

Achieving number 6 above requires expertise and data that is mostly available within Environment Waikato such as:

- monitoring trends for Upper Waikato sites (streams and main stem of the river)

- interpretation of the impacts of nutrient trends (N and P) on lake qualities and on ecological systems
- evidence of the basic relationships between intensification and water quality change - as in the recent report ‘The condition of rural water and soil in the Waikato region. Risks and opportunities’ (Environment Waikato, In prep)
- information on hydrology and soil properties for this part of the catchment
- land use cover and potential area subject to conversion out of forestry to more intensive land use
- effluent systems currently in use
- riparian work already in place under Environment Waikato schemes or grants

Other data on farming intensity and nutrient use is held in industry or government data bases, for example the Meat and Wool Economic Service and MAF agricultural census.

However, a thorough analysis of what is and is not available from these sources was not within the scope of this project, which focused on a review of the scientific literature regarding practices to reduce nutrient losses from farms.

The processes for engaging people in learning and action around these issues are reasonably well understood. However local information about different farmers’ practices and how individual farm context affects farmers’ choice of nutrient management practices may be a current knowledge gap.

A range of nutrient management practices are currently available. But there are only a few that are easily adopted into the farm system while having positive impact on farm income and the environment. More options and innovations are needed from the scientific and farming communities to expand the suite of possibilities that could suit farmers in different circumstances. However, practical options do exist within the current set of possibilities that can be promoted to farmers of the Upper Waikato catchment.

Further local study could identify the most critical source areas for nutrient loss at a farm and catchment scale, to enable the most cost-effective responses to be identified.

Appendix: Source data for the analysis

Table 4: Factors affecting nutrient losses and knowledge of Upper Waikato context

Factor	How it influences nutrient loss or practice adoption	What we know about this factor for Upper Waikato
Geographic factors		
Soil and fertility	- Leaching and potential effectiveness of wetlands - Pugging risk and therefore benefits of standing off and amount of overland runoff - Erosion rates (e.g. pumice highly erodable). - Amount of P lost attached to sediment and dung (affected by P status of soil, and infiltration vs runoff) - Effectiveness of filter strips	Soils in this area are mainly of volcanic origin, pumice and allophanic (ash) soils. Allophanic soils have a stronger structure and finer texture than pumice soils, so erode less, but have more P attached to them if they do erode. Allophanic soils produce less Dissolved Reactive Phosphate (DRP) in runoff than a sedimentary soil with the same Olsen P status, because the soil holds the P, pumice soils have moderate to poor capacity to sorb P. Pumice has high infiltration but high dissolved P
Slope	- Amount of runoff, effectiveness of riparian strips - Sources of sediment (gully soils vs fines)	Range of slopes. Many gullies retired under soil conservation schemes
Wetlands - do they exist? How much water runs into them?	- Potential to intercept and treat drainage water - Amount of denitrification for N removal - Effectiveness of filtering of P	Soils generally free-draining so may be limited run-off to surface wetlands. More information required about extent and location of wetland areas
Rainfall and seasonality	- High summer rainfall influences effectiveness of focus on wintering strategies for N loss; but duration of drainage period over winter is even more critical - Runoff of P e.g. direct loss of P fertiliser if heavy summer rainfall follows application (within 60 days) - Climate may affect nitrification inhibitors – may be best in cold, dry climate	Would be useful to know what is the drainage season in different parts of the catchment to help with risk profiling for leaching. Can be some summer rain storms e.g. in Reporoa Climate reasonably cold in winter but wet
Management factors		
Land use	- Forestry leaches < sheep < beef < dairy; crops vary.	Have some information on catchment area under each land use
Cropping practices	- Amount of cultivation and timing, fallow ground in winter, fertiliser amount and timing, whether crop grazed in situ all affect N loss - summer cultivation + cover crop over winter can give 80% less N loss - Climate variables impact on what types of crops are profitable and how much bare ground is exposed	Winter cropping of brassicas is common practice as part of regrassing. These crops are grazed in the paddock Summer maize cropping also occurring in large areas on conversion blocks More detailed information on cropping practices and extent of land area would be useful

Drainage – subsurface vs open	- Subsurface drains reduce runoff and pugging but can transport nutrients and bugs to waterways, especially when very wet or very dry (as soil above them cracks) - With subsurface drains leaching and preferential drainage flows are important – so effluent irrigation practice and careful grazing management are critical - Open vegetated drains can act like wetlands to remove nutrients	Artificial subsurface drainage uncommon in this area as soils are generally free-draining.
Effluent systems	- Ponds can be a primary source of P loss to waterways - Low-rate/ low-depth systems have least impact but require capital and some need more labour	Environment Waikato's Resource Use Group will have some information about systems currently being used in this area
Wintering practices	- Wintering on crops is a very high N loss activity - Wintering on pasture can also be high N loss	What information do we have about wintering/wintering off? Assume mostly wintering on grass here – some winter brassica crops as part of regrassing
Stock type	- Sheep leach < cows, male cows < female cows - Heavier stock create more soil compaction/ pugging	Agricultural databases have some stock type and density information
Fertiliser practices	- N – how/ when it is used affects direct loss but urine patch leaching is more critical – rises exponentially with N input. - P use – affects P lost attached to soil or dung - Type of P fertiliser has little impact as direct losses usually low (~2%), though RPR is less susceptible to direct loss if heavy rainfall does occur after spreading - Less chance of drift if P flown on is in a granulated form	Direct losses of N fertiliser can be significant at higher rates of application e.g. 400 kg/ha/yr (Ledgard et al. 1999) – will be a range of rates used in this catchment but unlikely to be many this high. Average N use in NZ dairy is 100 kg N/ha/yr (Menneer et al. 2004). However, if N fertiliser is being applied May-June-July there is potential for up to a third to be lost
Feed inputs	- Influences concentration of N and P in excreta	Will be range of feeds used – pasture and maize silage, enriched feed
Economic factors		
Pricing	- Influences choice between buying land, N fertiliser, feed, and returns in terms of milk, lamb, beef	Prices fluctuate for lamb, beef. High dairy payouts. N fertiliser is still a relatively cheap source of feed. Palm kernel now widely available
Interest rates	- Influences attractiveness of high vs low capital options	
Farmer factors		
Risk averseness	- Attitude to high input systems and capital outlay	In this area there is likely to be a range of farmers and stages of the business cycle from well-established to still developing. Will also be a range of ownership structures and some multiply owned Maori land
Degree of production focus, lifestyle and labour issues, stage of life or business cycle, ownership structure, debt ratio/ servicing capacity	- Attitude to low input systems vs intensive systems e.g. feed pads - Attitude to different effluent systems - Prioritising/ valuing of environmental benefits - Prioritising of shareholder/owner dividends vs reinvestment - Ability to lend capital	

Complexity/ new knowledge	- Extent of need for practice to fit existing system with minimal learning/change (e.g. nitrogen inhibitors vs a feed pad)	
Regulation averseness	- Some farmers may prefer options that don't involve a consent/ keep the regulators off my back	
Attitude to EW	- Whether ready to work with EW or not	May have been affected by helicopter fly-overs, history of soil conservation schemes, Project Watershed. Will be aware of Taupo and Rotorua processes.

Table 5: Available research about practices recommended to Upper Waikato farmers in January 2007

Source of research	Key findings about environmental and/or economic benefits	Likely to be applicable here? Why/why not?	Other benefits to farmers, or barriers with these practices (identified from literature and through discussion with researchers)
Nutrient budgets and nutrient management plans (including timing and rate of fertiliser)			
For P loss: Monaghan et al., In prep.	Reducing Olsen P to optimum levels estimated to create annual savings of $15-22 per cow for 10 years, and then $10-18 per cow thereafter. In Toenepi (soil P levels are high) predicted to reduce farm P loss by 30% Other modelling puts reduction closer to 11% for Toenepi – depending on what changes are made as a result of the nutrient budget.	Yes, likely to apply here but: Depends on what changes farmers make as a result of doing a nutrient budget. Also current Olsen P levels e.g. in Bog Burn where Olsen P levels were closer to optimum, only predicted to reduce P losses by 7-14%. Can isolate different parts of the farm needing less P e.g. dry hill country slopes. But while production on flats may justify more P, risk of loss is higher near waterway. Olsen P can influence P lost as dissolved form, as particulate form, and in the dung so it is important for all soil types.	Preparation of budgets is being encouraged through regulation; also supported by dairy and fertiliser industries through Accord and Strategy. Bewsell et al. (2005) found many farmers responded to advice from fertiliser reps to reduce soil P levels. OVERSEER gives flexibility, but farmers may take issue with its use for regulation (see submissions on Taupo variation). If used as a regulatory tool to cap N, the allocation process may be seen as unfair, and hard on those yet to intensify or in the process of developing during the benchmarking phase (e.g. improving genetics) and now not able to profit from it. Taupo farmers have been reluctant to do benchmarking. EBOP work shows farmers appreciated one-on-one advice from advisors who understand farm businesses. Almost all the Rotorua farmers interviewed said they would welcome a visit from a land management officer to identify options. OVERSEER needs more mitigation (e.g. wintering systems, wetlands, inhibitors), more time sensitivity e.g. when stock are carried and more data on imported feeds.
Wilcock et al. 2006b	Reducing Olsen P to optimum levels was estimated to reduce maintenance P fertiliser costs in Toenepi by $50-60/ha/yr.		
For N loss: Edmeades; Taupo benchmarking experience; Wilcock et a l. 2006b	Nutrient budget can help identify excessive N in system and whether effluent blocks are the right size, and may encourage farmers to reduce inputs of fertiliser accordingly, creating dollar savings also. Nutrient management plan needs to look at overall throughput and wintering (loss from urine patches), since direct loss of fertiliser is not usually as significant. Single input analysis e.g. of fertiliser input only, has limited value for explaining catchment responses e.g. in Toenepi N fertiliser use went up 51% over 9 years while total N in the water declined 40%.	Yes – decrease in inputs from nutrient budget/ management plan depends on how well current N use matches production demand and changes made. Economic benefit depends on price of N. Need to use a profit-assessment tool like Stockpol/ Farmax or UDDER to assess economic implications of different OVERSEER scenarios.	
Ledgard et al. 1988 and Ledgard et al. 2007	Seasonal application effects of N fertiliser - direct losses measured of around 30% of N fertiliser applied in winter at Ruakura. Modelling no winter N fertiliser in Rotorua lakes showed a small drop in leaching since direct losses are small relative to total leaching from urine patches.	Yes, relevant here due to free-draining soils. Magnitude of gain will depend on how much N fertiliser is currently applied in winter and rainfall patterns.	Has economic gain for farmers and an easy practice to adopt. Also reduces wastage from gaseous losses on wet soils.

Wintering practices – pads			
Smeaton and Ledgard (handout to Puketapu field day 2004); Thorrold 2006; Menneer et al. 2004	Activities to reduce return of excreta N during winter could have 50-60% impact on N leaching rates Economic evaluation of winter feed-pad systems for beef cattle with range of capital costs $200-$500 per animal – in all cases feed pad systems were less profitable than standard winter grazing. Combining more N fertiliser and on-off grazing gave a similar Gross Margin but less N leaching than N fertilised all-year grazing, as long as a low-cost pad could be used. Pads gave higher Gross Margin per kg N leached than winter grazing.	Yes, but magnitude of environmental benefit depends on: - how long stock spend on the pad per day and over winter and how closely this matches the drainage season (N) - how long cows spend in transit depositing excreta on tracks (P) - how much extra feed is brought in and if stocking rate goes up to keep on top of the spring pasture growth or if lactation is extended – i.e. more nutrients cycling (N and P) – also what are the impacts on the site where feed is grown? - effluent collection system and practice when reapplying the effluent to land - alternative N treatment in landscape e.g. wetlands/ wet soil denitrification - how much pugging is avoided and how much runoff is reduced – factor of soil type, rain and slope (P) – note this area has mainly free draining soils - percentage of cows/cattle in the system or catchment - high input systems may still have high leaching as more N cycling occurs Economic impact depends on: - capital cost of pad, debt servicing cost - price of feed, operating cost and labour - milk payout - pasture response from less pugging and farmer ability to make the most of any extra spring pasture growth – may mean increasing stocking rate (negating some environmental benefits) - production benefits – depends on feeding well (access to supplement, management), extending lactation - next best wintering alternative e.g. in Southland wintering off on a crop is costly - avoiding lameness on pad or from moving cows to and from the pad – though pad may reduce foot problems caused by standing in muddy paddocks	Wintering pads with no grazing require supplement, either bought in or else grown on farm – if grown on farm, need some flat land. Flat land also gives more options for effluent application. Cheapest supplement currently palm kernel – not much price variation with location. Also need to consider the impacts in the site of origin of palm kernel production. Labour requirements for operating the pad (feeding, managing extra effluent), as well as skills, enjoyment/ lifestyle, and attitude to risk are all relevant to major system change. A stand-off option can give the confidence to increase stocking rates so that pasture surplus can be controlled without the risk of pasture/ soil damage if conditions are wet for a while i.e. installing a pad could improve pasture utilisation overall. Restricted grazing of pasture (on-off) with a stand-off pad can give some N loss reduction without the feeding of supplements required. But in RED trials it was difficult to get the cows to eat enough in a limited time to maintain production. Benefits of wintering with pads include keeping your stock at home (as opposed to wintering off). A pad gives farmers more options at all times of the year - very valuable to those with difficult farms (steep, wet). Also may be long term soil health benefits.
Monaghan et al., In prep.	Modelling of wintering pad delivered 28% N loss reduction with around 10% reduction in EBIT in Toenepi c.f. no EBIT reduction in Bog Burn (assumes a nutrient credit, 85% of effluent captured from pad and spread with a value of $26/cow/yr).		
De Klein and Monaghan 2005	Modelling showed a wintering pad decreased nitrate leaching by 44% and decreased EBIT by 14% in Toenepi due to the cost of feed, and the capital and operational cost of the pad. (No allowance was made for an increase in income by avoiding soil and pasture damage.)		
Ledgard et al. 2007 Rotorua lakes	Measured leaching with no winter grazing (i.e. equivalent to wintering off-farm or on a pad), N leaching was 34-42% lower than standard winter grazing. Note – a relatively high-input system was in place (150kgN/ha/yr in effluent, + 180 kg N fertiliser + maize supplement) – may account for lower leaching reduction than reported in other studies.		

Environment Bay of Plenty work	Use of a Herd Home full time in winter reduced N leaching 46% compared to pasture wintering; Herd Home gave similar GM/ha as wintering on if production gains offset capital costs. Stand-off or wintering pads had reduced GM/ha but no allowance was made for any pasture increase due to standing off wet soils.	- being able to store and make good use of the effluent e.g. irrigating in dry periods, applying no more than pasture can take up	
Clark et al. (no date)	RED trials – stand-off pad had lower leaching than control (31 kg N/ha c.f. control 42). There was a pasture response to standing off but per ha and per cow production were lower than control (winter grazing) i.e. it was difficult to turn the extra pasture produced into milk.		
Wintering practices – grazing off			
Ledgard et al. 2003b Taupo	Initially calculated grazing off would reduce N leaching by 35% but because farmers would then raise stocking rate to eat pasture surplus, adjusted reduction was only 18%	Benefits of wintering off depend on stocking rates (for the environment) and pasture utilisation (for the farmer). Exporting the problem could be encouraged if the cows go to catchments where nutrient loss is less of a focus (for surface or groundwater). Unsure how many cows wintered off in this area. Some cows from outside the catchment will be wintered in it.	Wintering off the farm, farmer loses some control of stock health and condition etc.
Ledgard et al. 2007 Rotorua lakes	Measured leaching with no winter grazing (i.e. equivalent to wintering off-farm or on a pad), N leaching was 34-42% lower. Relatively high-input system in place (150kgN/ha/yr in effluent, + 180 kg N fertiliser + maize supplement) – may account for lower leaching reduction than reported in other studies.		
Thorrold 2006	No grazing from April-Sept in Taupo reduced N leaching to 6 kg N/ha compared to all-year grazing N losses of 14 kg. No winter grazing reduced pasture production by 12% compared to continual grazing		
Effluent management – storage and deferred irrigation			
Monaghan et al. 2006 Bog Burn	Estimated that storage and deferred irrigation costs $45/cow up-front, but can eliminate direct effluent drainage (mole/tile drains).	Yes Degree of environmental benefit depends on: - current effluent practice e.g. ponds vs land treatment, type of land irrigation, current scheduling - soil type - how wet the soil gets, for how long (N leaching and P runoff)	Ponds are a non-labour intensive option but do require consent and so higher compliance cost. Some soils in this area will be developing out of forestry so there may be additional advantages to irrigating the effluent to build organic matter.
Wilcock et al. 2006a and 2006b	Reduction in ammonium in Toenepi over 9 years was attributed to more land application of effluent as opposed to pond treatment.		

	OVERSEER modelling indicated pond emissions contributed almost two thirds of total farm P losses from average dairy farm. Changing from direct pond discharges to either Advanced Pond System or storage and deferred irrigation, and reducing soil P to optimum levels was estimated to reduce P losses by up to 70%.	- how much area is mole/tile drained – not likely to be much in this area - if opting to defer irrigation, how effectively farmers manage the scheduling of the deferred irrigation - open drain management – what happens to effluent reaching drains Economic benefit depends on whether the application technology allows for all the nutrients to be used, and the cost of the technology/ storage ponds (e.g. if existing two-pond systems can be used for storage)	
Houlbrooke et al. 2004 (review article)	Effluent can represent a 10-12% saving on fertiliser. Pasture growth increased 7% when effluent applied at 75kg N/ha/yr in Waikato (measured by Roach et al. 2001) – response similar to applying urea at same N loading. When soil is at or close to saturation, 30% of applied effluent can get into mole-tile drains, but if application is deferred until soil is dry, there can be zero nutrient loss.		
Monaghan et al., In prep	Changing from pond to deferred irrigation in Toenepi was predicted to deliver a small reduction in EBIT (less than 1%) but large reduction in P loss (58%)		
Effluent management – increasing effluent area irrigated			
Monaghan et al., In prep. Longhurst et al 1999 cited in Houlbrooke et al. 2004 Horotiu silt loam	If best management practice is followed for total annual application (sufficient area) as well as split applications, only 2-20% of nutrients in the effluent reach waterways. N in effluent applied over several passes up to 75 kg N/ha/yr was 85% recovered by plants, but at 375 kg N/ha/yr recovery was only 40% and 2.1 kg N leached. This was with no cattle grazing, showing direct loss of N from effluent is minor compared to that from urine e.g. Taranaki trial by Roach et al. N leaching was 18, 20 and 50 kg/ha/yr below <u>grazed</u> pasture treated with effluent equivalent to 100, 200 and 400 kg N/ha/yr	Yes, environmental benefit depends on: - nutrient concentration of effluent - how long cows spend in shed/yards i.e. how much effluent is collected - what type of irrigation system is used and how well the system is managed e.g. travelling irrigator may still exceed recommended rates of N in one pass Economic benefit depends on whether the application technology allows for all the nutrients to be used and fertiliser is reduced accordingly on those blocks	Increasing effluent area has an up-front capital cost to put in pipe work etc but can benefit farmers in terms of lower K levels, better nutrient recovery, less soil ‘sealing’, and more options to fit effluent application in with the grazing rotation.

Ledgard et al. 2007 Rotorua lakes	Modelling predicted that effluent spread on a larger area plus reducing N fertiliser use could reduce leaching 0-10% and be a 'slightly profitable' option		
Hotspots – silage pits and stock yards – wilting silage and avoiding stormwater flows across these areas / covering them			
	Additional (non-nutrient) benefits for faecal bugs (yards) and for maintaining dissolved oxygen levels in waterways (silage pits) - silage known to have high BOD impact.	Depends on how severe the impacts are: - extent of area, amount of pollutants, distance to waterway and interception/ filtering opportunities in between Silage more a BOD issue than nutrient	Less wastage results from wilting silage properly
Tracks and races – siting and cut-offs			
Quinn et al. 1999 Whatawhata hill country	Cut-offs to channel runoff away from water can reduce sediment loss. Additional environmental benefit from less suspended sediment and faecal bugs in waterways. Economic benefit from less track maintenance.	Yes, magnitude depends on: - track runoff – slope, do they drain to waters, time stock are on tracks, stock type, water control (cut-offs, shaping) - effectiveness of processing cut-off water – wetlands, rough vegetation, size of area, proximity to water	
Riparian management – stock exclusion from waterways (fencing and planting) and putting in crossings			
Smith, 1989 Whatawhata hill country	Riparian pasture retirement impacts on total loads were examined by comparing the average concentrations in run-off in 22 months at grazed and retired sites (10-13m strips). Gave event-flow-weighted mean reductions at retired sites in total and volatile suspended solids of 87% and 84%, and in particulate P (80%), and particulate N (85%). There were lower reductions for dissolved P (55%), and nitrate (67%). TP and TN were predominantly in particulate forms.	Yes, magnitude depends on: - current stock impacts - how much stock currently access the waterways, how often stock cross, what type of stock are on the farm - bank instability and P status of eroding soils as well as proportion of dissolved P vs particulate P in runoff (P) - width of riparian margin for filtering (P) or denitrifying (N) if wet - flow characteristics (channelised or spread out) and retention time - how long filter strips are in place (effectiveness can diminish over time – i.e. 20 years on) - for fish, benefit of crossings will depend on whether crossings (culverts) allow for unimpeded fish passage Economic impact depends on: - type of fence required (type of stock and terrain) - getting a subsidy (e.g. Little Waipa and Waipapa have priority for Clean Streams 35% grants) - value of stock being lost in the stream and time spent mustering/ bringing them in	Benefits to farmers include fewer stock losses, less stream bank loss and less sediment in drains and culverts. Fenced and planted areas can be attractive features if they are not weedy. Bewsell, Kaine and Higson (2005) found that farmers saw positive benefits of stream fencing (stock management) but had concerns about weed control and flood management.
Parkyn 2004 and Menneer et al. 2004 and Ledgard and Power 2006	Parkyn reviewed literature on riparian effectiveness and reported that grass strips can filter 50-80% of the sediment and particulate nutrients. Most particles settle out within 5m unless suspended – these fines only settle out if infiltration occurs which may require 10 m+ of filter strip. Menneer et al. cite research by Smith of 21-55% reductions in run-off with a 25-35m pine strip comprising 20% of total area.		

	Williamson et al. around Rotorua found that although riparian retirement and planting reduced sediment loss by 85%, P loss was only reduced by 27%. Ledgard and Power modelling for Upper Waikato assumes a 20% P loss reduction from a riparian filter area. In addition to nutrient benefits, fencing will reduce faecal bugs and planting will enhance habitat for aquatic insects and for native and game fish (shading) Note Menneer et al. (2004) point out issues with riparian planting identified by other researchers where grasses are shaded out by trees and erosion increases. Channelised flow may cut through the strip and reduce filtering values. Also eventually (e.g. 20 years on) the buffering capacity of the strip is saturated and dissolved P exiting the strip to a waterway is equivalent to particulate P being trapped on the paddock side.	- whether fence improves pasture utilisation through better internal subdivision (likely to be a range of subdivision/ development stages in farms in this area)	
McDowell et al. 2003	Riparian filter strips can trap P from overland flow; these strips beside waterways should be left with no applied P fertiliser.	Yes, depends on slope and degree of overland flow and avoiding P fertiliser in these areas.	
Ledgard et al. 2007 Rotorua lakes	Found that haybales to trap P were ineffective due to decomposing hay releasing P. Also found that recontouring to avoid channelised flow removed particulate P, but dissolved P was 50% of total P in the runoff. Concluded that filter strips would not be effective in removing this – would require a range of mitigation options e.g. P-sorbing materials.	These findings would be likely to apply to pumice soils in the Upper Waikato on dairy farms with similar inputs to this example.	

Table 6: Other practices (not included in recommendations to Upper Waikato farmers in January 2007)

<table>
<tr><th>Research: where, when, and by whom</th><th>Key findings about environmental and/or economic benefits</th><th>Likely to be applicable here?
Why/ why not?</th><th>Other benefits to farmers, or barriers with these practices</th></tr>
<tr><td colspan="4">Nitrification inhibitors</td></tr>
<tr><td>Di and Cameron 2002; 2005</td><td>Measured nitrate leaching reductions of between 30 to 80% with inhibitors. Pasture yield results from the lysimeter trials confirmed by three years of field trial results, showing increases in pasture production of 10–15%.</td><td rowspan="6">Will be a reduction in N loss but magnitude is uncertain.
Likely to be profitable but:
- Large variability in the modelling predictions even for the same sites, due to differing assumptions e.g. Toenepi – Wilcock predicts 60% reduction; Monaghan predicts 30%.
- Monaghan et al. predict that inhibitors are positive for both the environment and EBIT in all 5 of the model dairying catchments.
- Little knowledge for dry stock but modelling by Thorrold suggests that broadcasting inhibitors over the whole farm was not profitable for a Taupo dry stock system.
- For modelling, it all depends on the assumptions of inhibitor effectiveness and pasture surplus produced
- Also need to account for overall N cycling increase and N losses as a result e.g. will stocking rates go up as pasture surplus is produced, or will the extra pasture produced be used to reduce fertiliser inputs while keeping stocking rates constant.

Possibly drier, colder conditions give better response so may need local trials:
- Lower reductions in Rotorua lakes (Ledgard et al.) compared to some other trials were attributed to freely draining soils increasing the leaching risk
- Limited work done on allophanic (ash) soils</td><td rowspan="6">Nitrification inhibitors are a relatively easy technology to incorporate into the farming system (no major disruptions or changes).

Scientific doubt likely to be the most discouraging factor to farmers, who want to know technologies are proven before paying for them.</td></tr>
<tr><td>Bruce Thorrold evidence on behalf of FF and Thorrold 2006</td><td>Modelling of inhibitor use on Taupo sheep and beef farms suggest reduced profitability from its use
Inhibitors was most promising option for dairy in Taupo (along with wintering off) – inhibitors may be cheaper way to reduce leaching, depends on assumptions</td></tr>
<tr><td>Wilcock et al. 2006b</td><td>Preliminary modelling evaluation predicted inhibitors could reduce N loss by 60% in Toenepi</td></tr>
<tr><td>Monaghan et al., In prep. and De Klein and Monaghan 2005</td><td>Monaghan et al - Modelling inhibitor use in Toenepi indicated 30% less N loss and 16% increase in EBIT
De Klein and Monaghan – modelled a 20% reduction in N leaching at Toenepi and 18% increase in EBIT
Cites unpublished data from C. Smith that a 20% reduction is a more probable effect of nitrification inhibitors on N leaching compared to up to 60% from lysimeter trials.</td></tr>
<tr><td>Monaghan et al. 2006</td><td>Modelled N leaching reduction in Bog Burn at 7% (if stocking rate rises to utilise pasture), with 10% increase in EBIT.</td></tr>
<tr><td>Smith et al. 2005 Southland</td><td>Formulation of inhibitor (DCD) did not change effectiveness (granular vs liquid), so could be applied with N-fertiliser.
Total pasture increase of 8-21% achieved.
But where they applied urine-N there was no pasture response to the inhibitor (if there is a lot of urine-N around and no leaching is occurring, there will not be a pasture response)</td></tr>
</table>

Ledgard et al. 2007 Rotorua lakes	Measured reduction in N loss from inhibitor use of 15% in 2005 and 25% in 2006. Measured pasture annual DM production increase of 7% Modelling showed inhibitors were cost neutral on the dairy farm but profitability was reduced on the sheep and beef farm		
Wetlands			
Nguyen et al. 1999 (cited in Parkyn 2004) - Whatawhata and Parkyn 2004	Nguyen et al. found 27% removal of phosphorus and 54% removal of nitrogen over a 6-month period in a wetland at the head of a small Whatawhata stream. Parkyn reviews literature and says many authors found upwards of 90% removal of N in water retained in wetlands. Additional environmental benefits of removing faecal bugs, flood mitigation and habitat values. Economics of draining existing wetlands still make this an attractive option but there is an economic benefit of not losing stock in existing wetland if it is protected by a fence. Wetland construction has a high one-off cost but low ongoing cost.	Residence time in the wetland (a factor of size) and a carbon source (to feed denitrifying bacteria) are critical factors for N removal. Fencing and planting or natural regeneration of wetland vegetation helps to slow water down and retain it, and wetland plants supply carbon. Carbon-rich wetlands are also less likely to emit greenhouse gases. Cost range for constructed farm-scale wetlands built by a contractor, including engineering advice/ design and planting is $12-15/m^2. Cost range depends on if a liner is needed, how much soil is shifted for a planting medium, and water level structures. For Upper Waikato free-draining soils, a liner could be required. Catchment-scale wetlands with weirs such as Okaro in Rotorua cost $22/m^2 (C.Tanner pers.comm. August 2007). Feasibility depends on extent of existing wetlands or opportunity to create them. With free-draining soils there may be few seepage zones suitable for wetland creation or enhancement.	Wetlands are sometimes perceived as 'dirty wet patches' or 'swampy gullies' and may not be seen as valuable. Those who shoot ducks or like birds may like wetlands more (or they might want to dig them out and make ponds). Planting wetlands up removes potential weed issue and makes an attractive landscape feature.
Sukias et al. 2005	To achieve 40-50% nitrate removal, constructed wetlands need to cover between 2-5% of the area of the catchment from which they are receiving water. Smaller wetlands will generally remove around 20% or less of the nitrate in drainage water.		
Lower N-use or more efficient N-use systems			
Monaghan et al., In prep.	Modelled low-N feed and nil-N fertiliser options. For Toenepi, low N feed (i.e. use of maize silage to replace some of the pasture grown using N fertiliser) reduced N loss by 28% and nil N fertiliser reduced N loss by 34%. Low N feed reduced EBIT by 4% and nil N fertiliser reduced EBIT by 8%.	Reducing N fertiliser gives more profit per kg N lost but less overall profit (at high payout) - more useful if N is capped/ payout is low. N loss benefit of low-N feed depends on the on-site impacts where it is grown, also has energy implications from cropping, transport.	Supplement input to a pasture system allows stocking rate to rise, giving better control of pasture residuals for optimum growth. Different supplement systems may require different skills, different equipment and incur different risks.

	In Waiokura (Taranaki) the nil-N fertiliser had smaller impact on EBIT.	Economic effect depends on current N use, pasture response to N, animal production response and prices of N, feed, meat, milk. - To get true picture of MS/ha need to include the land crop is grown on. - May be cheaper to grow own maize silage than buy it in. - Get most gain from supplement with animals that have good genetics.	Also farmers may have varying attitudes about whether they want to be in a low-input or high-input system for reasons of lifestyle, labour, attitude to debt and risk, production competitiveness etc. Increased nutrient losses in cropping areas may be acceptable if the cropping area is not a nutrient-sensitive site.
Monaghan et al. 2006 Bog Burn	Modelled low input farming (nil N fertiliser) and found it reduced N loss by 23% but reduced EBIT 3%		
Ledgard et al. 2007 Rotorua lakes	Modelled a no-N use scenario with reduced stocking rate and later calving, and got a 50% reduction in leaching but profitability dropped. Found that feeding maize on winter pads decreased leaching but also decreased profitability. Substituting maize silage for N fertiliser in winter gave a small reduction in N leaching but reduced profitability. Optimum scenario was to winter off for longer, apply no winter N, feed less maize and calve earlier – could achieve 15% drop in N leaching and 19% increase in profit (but wintering off was exporting the problem elsewhere).		
Clark et al. (no date) and Jensen, Clark and Macdonald (no date)	RED trials show a high correlation between N leaching and overall N inputs in modelling. OVERSEER models showed supplements had high N conversion efficiency (34-37% c.f. control 30%) but high N inputs (320-606 kg N/ha c.f. control 270) and high N leaching (48-113 kg/ha c.f. control 42) - the low-N feed was additional to 200 kg N as fertiliser. The low input farm has high N conversion efficiency (45%) and low leaching (21 kg/ha). Economics - At low feed cost and high payout, 'moderate' supplement had highest profitability (moderate supplement EFS 3374 c.f. high supplement 2472, low input 2513, control 2625).	Whether you get a reduction in leaching from use of low-N supplement depends on whether it is used to replace N fertiliser/ high N feed e.g. replacing pasture silage with maize silage. Low-N supplement can increase production without a proportionate increase in leaching that would occur with other feed or N fertiliser.	

	If feed costs rise, moderate/high supplement systems drop quickly in profitability and low input is similar to low supplement (measured as EFS – not accounting for capital costs or return). If payout drops by 1$, low input EFS drops by 934, but moderate/high supplement drop by over 2000. Therefore at low payout, high supplement system unprofitable and low input is most profitable. If return on assets calculated, low input uses assets profitably, high input systems less so. Diminishing returns occurred when stocking rate rose above 5.2/ha and 10t DM maize/ha.		
Thorrold, 2006 (Puketapu project report)	High potential for improving animal production/ per head performance without much increase in N leached e.g. raising lambing percentage, cattle growth rate due to genetics and better pasture utilisation	Depends on room to lift these factors in current systems in Upper Waikato. Would expect a range of genetic improvement and grazing practice, with most people looking to improve.	
Meat and Wool NZ (Wise N Use) -Castlepoint Station Wellington Region	Focus on using N in August on north facing slopes (that dry out early), improving feed supply to ewes over early lactation to improve lamb survival and weaning weights Also improved subdivision. Stocking rates - Control 6 sheep/ha, 60kg N 6.6 sheep/ha, 120kg N 8.3 sheep/ha, plus some cattle to control cover. Leaching measured with lysimeters. Paddock with 60 kg N leached 30% more than control, and 120 kg N leached 350% more in first year (quantities not given). Spike of ammonia shown in waterway with heavy rain 5 days after applying the urea. Pasture quality and growth were better, lambs did not grow more, but ewes did and there were more lambs due to higher stocking rate so more lamb weight/ha produced.	Overall analysis of farm system required e.g. impact of raising stocking rates for rest of year.	

	Concluded there was a small economic benefit during lactation period from N use but over whole year would be less because would have to buy in feed to support higher stock numbers. Gross Margin returns very sensitive to price of N and price for lambs.		
Different land uses or stock types			
Menneer et al. 2004 (review paper).	Reports average N losses of forestry (3), sheep and beef (21), dairy (40). One study of kiwifruit orcharding was 50 kg N/ha/yr lost. Mixed cropping with autumn ploughing and leaving fallow can lose up to 110 kgN/ha/yr. Grazing crop stubble can increase leaching. Range of P losses from forestry (0.01-0.10), hill country sheep (0.11-0.75), hill country cattle (up to 1.6), dairy (0.5-1.0) but limited research on dairy and cropping losses. Forestry low P loss because less fertile soils, no P fertiliser, less run-off due to interception – average pine P loss 24-57% that of pasture.	Higher range P losses for dairy are where soils are poorly drained so unlikely to apply here. Sheep on hills can camp and get more run-off and some leaching (2-11 kgN/ha/yr); lowland sheep are grazed more intensively and may get more leaching (10-20 kgN/ha/yr). Cropping P loss depends largely on slope and amount of erosion/ soil loss.	
Ledgard et al. 2007 Rotorua lakes	Measured lower P loss from grazing sheep vs grazing cattle, but no significant difference in phosphorus loss between no grazing and sheep grazing. Also modelled forestry on 25% of steeper areas with cattle only on rest of farm – gave small reduction in N leaching and no effect on profitability.		
Cooper and Thomsen 1998 and Quinn 2003 Purukohukohu (Central North Island pine forestry)	Total N and P yields under 10-yr pines were 11 and 6% of pasture yields respectively. TN yield from pasture was 3 times that of native forest and 9 times that of the 10-yr-old pines. Pine N yields increased after logging but were still less than pasture TN yields. Average TP yield from pasture was 14 times higher than the ten-yr old pines and 18 times higher than native bush.		

	Following logging average TP yield from the pines was 4 times that of native forest but still 4-fold lower than pasture – concluded that there was an increase in nutrient loss at logging but this was short-lived. Young forest takes up more N than mature trees.		
Thorrold 2006	Forestry can be profitable on parts of a dry stock farm, but need an annuity to make cashflow feasible; environmental gain depends on how much grazing intensifies on the remaining land		
Smeaton and Ledgard 2004 (handout to Puketapu field day); Ledgard evidence to Taupo variation	Breeding ewes with high lambing percentage were the most profitable system and were still low in N-leaching in Rangiatea trial Economics very dependent on relative values for meat, milk, etc.	If farms in this area are not set up for sheep, farmers unlikely to set up that infrastructure Lamb prices lower now than when Puketapu trials were done, but still on ten-year average high performing sheep systems are profitable for the Taupo site (B. Thorrold pers.comm. March 2007).	Shifting from mixed stock types to single stock type reduces diversity in the system – less resilient to market fluctuations; also challenge to maintain pasture quality and parasite control Labour implications of running sheep – also farmers may have personal preference for certain stock types.
Thorrold 2006 (Puketapu project report)	Best sheep and beef farms get similar profit per kg N leached as best dairy systems, but the dairy systems leach twice as much per ha		
Thorrold 2006	Measured N losses under experimental maize crop of 226 kg N/ha/yr. Perennial cut and carry forage (lucerne or pasture) with high N rates leached as much as pasture but might be improved with fertiliser management or perhaps as lucerne became more established. Crops that establish and grow well will take up N, crops that do not will leach N – perennial crops have an advantage. Lucerne had high yield, warranting more exploration.		
Genesis Research and Technology	Energy farming to protect Lake Taupo (willows for bio fuel)	Attractiveness depends on trends in oil prices	
Low-rate or low-depth effluent irrigation systems			
Monaghan et al., In prep. and Monaghan et al. 2006 and	Can reduce P and N loss in dairy catchments currently using ponds (e.g. Toenepi) or where mole drains/ heavy soils exist. (Also good for reducing faecal contamination). Low-rate technologies can reduce mole-pipe drain transfer of irrigated effluent P by 95%	Effectiveness depends on spacing, operation etc but in general these systems out-perform travelling irrigators. Magnitude of environmental benefit depends on extent of subsurface drains and soil type (e.g. heavy/ wet soils) and sloping contour – less critical in this area.	This system allows precision placement of N if you know the content of your effluent. Low-rate systems will only be attractive to farmers if they do not require substantially more labour than shifting a travelling irrigator.

Monaghan and Houlbrooke 2005	Modelling switch from ponds to low-rate application in Toenepi showed 58% drop in P (same for deferred irrigation); low-rate had no drop in EBIT c.f. deferred had 1% drop. Can use smaller pump than travelling system and lower power costs K-line set-up cost for farmer on sump and travelling irrigator (no pond) estimated at $45/cow and extra annual costs of $4.10. Assumes no extra labour involved. K-line set-up cost for farmer on 2-pond is for pump, piping and sprinklers $21/cow. Extra annual costs are $3.40/cow for labour (1hr/ week) power (2 hrs/day) and maintenance and depreciation, taking into account a nutrient credit of $2.40/cow/yr	Economics depends on whether you already have a pond that can be used to separate the solids and store effluent. Also whether you reduce fertiliser accordingly, and utilise the extra pasture grown.	This might mean purchasing more pods so they can be laid out in advance. LARALL system may require less labour, but has not been researched as intensively as the K Line.
Cropping management			
Menneer et al. 2004 (review paper).	Cropping systems – N loss is related to fertiliser N and crop residues left in the soil after harvest. Length of fallow (after harvest and after cultivation) and cultivation timing are important. Mixed cropping with autumn ploughing and leaving fallow over winter can lose up to 110 kgN/ha/yr. Grazing crop or stubble can increase leaching.	Overall magnitude of effect related to area under cropping in this catchment. N loss related to timing of crop establishment, fertiliser inputs, rainfall/ climate and plant growth and uptake, and grazing practices and re-establishment of vegetative soil cover. Cropping P loss depends largely on slope, cultivation and grazing practices affecting the amount of erosion/ soil loss, proximity to waterways and filter strips.	Winter cropping practices in Upper Waipa related to regrassing sequence. Any mitigation practice would need to work well for the regrassing process. Summer (maize) cropping occurring on conversion blocks in areas where fences have not gone up yet
Monaghan et al. 2006 Southland	Modelled N leaching - grazing a winter crop had highest rates (55 kg/ha/yr), compared with dairy milking (16), dry stock (6), forestry (1.3). Dairy wintering over 10% of catchment area produced 45% of catchment N load; or 60% of total dairy leaching even though only 15% of total dairying area. Due to large amounts of mineral N in soil in late autumn after pasture cultivation and crop establishment in preceding spring; then grazing in winter when uptake is low – vs low loss if cut and carry onto a sealed pad.		

Thorrold et al. 1998 Oteramika, Southland	Used Basin NZ (BNZ) catchment modelling. Predicted N leaching under grazed winter forage crop of 80kgN/ha/yr. Forage cropping was 7% of catchment area but contributed 22% of N load to groundwater. Edendale soils (free-draining). If pugging occurs, more N will be lost in gaseous forms through denitrification.	Noted, soil type can change leaching losses by up to 10kgN/ha/yr. Upper Waikato soils are free draining soils. Losses depend on how long soil remains bare after grazing – e.g. using a winter crop that will re-grow after grazing could reduce loss (ryecorn/ short rotation rye)	
Ledgard et al. 2003a	Modelled N leaching on cropping block (not grazed – made into maize/oats silage) at 55 kgN/ha/yr compared to dairy grazing block at 38 kgN/ha/yr.	Growing a low-protein crop decreased the N leached per tonne Milksolids by 10% due to high conversion of N in the feed. But when N leaching on the cropping site was included, there was no real advantage in efficiency.	
Drewry and Paton 2005; McDowell et al. 2003; McDowell et al. 2005 Southland	Grazing cows on winter crops with no backfence caused more soil compaction than grazing with a backfence or restricted grazing (3-4 hrs on, then off). Restricted grazing resulted in less P loss (75% less in 3 hrs/day grazing compared with 24 hrs/day grazing). E. coli in runoff from restricted grazing were also lower. Treading in a winter crop resulted in more runoff, higher suspended sediment levels and more P loss.	Soils of Upper Waipa are more free draining and less susceptible to pugging than the Pallic soils of Southland. However, the principle applies that intensive grazing of winter crops leaving bare soil and dung exposed increases the risk of runoff, sediment loss, faecal contamination and P loss.	
Careful grazing and management of sensitive areas			
Menneer et al. 2004	Avoiding areas susceptible to run-off or drainage when wet/ only grazing light stock. Not flying P fertiliser on near streams.	May be important in some sites but generally free-draining soils in this area.	
Ledgard et al. 2007 Rotorua lakes	Measured more P loss from cattle grazed plots than sheep grazed plots. Concluded grazing sheep in high-risk P source areas could be a good strategy, or if cattle-grazing is done in these areas for production reasons, need to look at more interception options.		
Drain management – vegetated drains			
Wilcock et al. 2006a	Cited as important practice for P management in dairy catchments	Depends on extent of open drains, cleaning of them and ultimate fate of P trapped i.e. is it cleaned out and spread	Some farmers prefer the tidy appearance of a clean, bare drain.

Other feed manipulation			
RED AgResearch	High-tannin feeds partition N to dung AgResearch looking at salt supplements to make cows drink and dilute their urine. High sugar grasses being researched.	More research needed – high tannin feeds not high producing. But good for lowering greenhouse gas emissions (methane).	
Controlling sediment to reduce P losses			
McDowell and Wilcock 2004	Different studies have shown that in different locations, P loss can be dominated by: - streambanks (50%) - gully erosion (62%) - tile drains (60%)	Will depend on farm specific factors, i.e. erosive power of slopes and unstable hills or gullies, whether streams are fenced, extent of subsurface drainage, compaction and overland flow, and siting and state of tracks	Important to promote farms doing their own assessment, as high level of variability between farms as to what will be contributing the most.
McColl 1977	Large storms accounted for 70% of particulate P loss from hill pasture and these comprised 55% of total P losses.	Note there may be a poor relationship between P yield and sediment yield because large sediment losses may be of relatively unfertile subsoil	
Williamson et al. 1996 Rotorua	In Rotorua, high proportion of P is lost as DRP from topsoil or fine particulate P, so controlling streambank erosion by 85% only reduced P loss by 27%		

Table 7: Non-nutrient issues and key practices

Research done where, when and by whom	Key findings about environmental and/or economic benefits	Likely to be applicable here? Why/why not?
Faecal contamination		
Wilcock et al. 2006a	Target practices: - fence waterways - change from pond to land irrigation, and use deferred irrigation - grass filter strips in riparian zones - avoid grazing wet soils to reduce runoff - stand-off pads to increase soil infiltration	Waikato river monitoring shows faecal contamination in the river currently does not exceed acceptable levels. Any future increase could be a concern in Waikato system due to recreational uses e.g. Karapiro. Localised faecal contamination could impact on food sources e.g. watercress in streams.
Monaghan et al., In prep.	Inventory analysis showed that in Toenepi, pond systems contributed about half the faecal load to the stream so an Advanced Pond System or low rate deferred irrigation system is recommended.	Faecal pathways less well understood than nutrient pathways, but critical factors include current effluent systems (pond vs land) and preferential flow through mole/tile drains and stock access as well as rates of overland flow. Interception is also important (filter strips, wetlands) – so die-off can occur
Monaghan et al. 2006 Bog Burn Southland	Faecal sources in Bog Burn identified as: - stream access and direct deposit 0.1% - subsurface drains (grazing effluent) 6% - irrigated effluent over mole and pipe drains 78%	Depends on whether there is stock access to streams, and mole and tile draining. Unlikely to be much mole and tile drainage in this catchment.
Sediment in water		
McDowell and Wilcock 2004 – Bog Burn	Suspended sediment loss was greater from sloping land, in spite of it being under forest land use compared with grazing on gentle slopes. Streambanks can be another significant source if not protected from stock. Soil damage via compaction can create more overland flow of sediment and contribute to P loss.	Sediment not generally considered major issue in Upper Waikato (compared with Waipa River) – harder geology. But have been erosion control schemes around Karapiro, Arapuni, Reporoa – due to light soils, highly erodeable. Sediment loss also an issue for P loss.
Shade/aquatic habitat		
Quinn 2000 (review chapter).	Compared to forest streams, pasture streams have higher temperatures, more bank erosion, more silt in the water and stream bed, more flow variation, higher nutrient levels, less woody debris and lower dissolved oxygen (due to excess algae or organic matter in the water). Deer and cattle grazing in or by streams have marked localised effects. Key habitat factors for fish are unimpeded passage, temperature and ammonium levels (e.g. from ponds or direct flow of effluent to streams). Trout need clean gravels to spawn. Land drainage affecting wetland areas and stream channelisation reduce aquatic habitat diversity.	Some Upper Waikato streams are trout fisheries so temperature (shade) and clean gravels are important. Some stream care activity is already underway e.g. Little Waipa. Also extensive riparian planting has been done through the soil conservation schemes around Reporoa and in the catchments of Arapuni and Karapiro lakes. Smaller streams can be more easily rehabilitated than large channels. A riparian strip restores to a pasture stream much of the habitat value of a forested stream.

Other biodiversity		
	Most important actions are controlling a range of pests, protection of under-represented habitat types (e.g. wetlands, lowland forest) and linkages.	Maungatautari nearby so providing linkages/ habitat ‘overflow’ could be considered.
Greenhouse gases (GHG) and energy		
Di and Cameron 2002	Measured nitrous oxide emission reductions of between 50 to 75% through use of ecoN inhibitor	Extent of current emissions will depend on soil type and wintering practices (heavy soils grazed in winter emit more N_2O), intensity of inputs (N fertiliser and cropping are high energy use), and extent of pumping for irrigation (energy use). Farming generally moderate in intensity in this part of the catchment. Some irrigation occurs e.g. Reporoa.
Monaghan et al., In prep.	Modelled different N mitigation strategies and found best GHG reductions occurred from using no N fertiliser (17% drop), low-N feed (5-14% drop) and inhibitors (6-11% drop) – inhibitors reduce nitrous oxide emissions dramatically but increase methane and carbon dioxide due to increase in overall farm system production. Energy use increased slightly with inhibitors and significantly (16%) with pads - due to energy for harvesting crops and feeding out. Energy use reduced under nil-N fertiliser by 45% and low N feed 7-24% due to less N fertiliser used.	
De Klein, Smith and Monaghan 2006; De Klein and Monaghan 2005	Over 80% of N_2O emissions come from deposit of excreta to pasture in winter during wet conditions. Stand-off pads were measured to reduce these emissions by 7-11% (3 hours grazing per day). Also reduced nitrate losses 41% and therefore indirect N_2O emissions from nitrate. Emissions from the pad and from the effluent applied to land doubled but these are a minor source of N_2O so not significant. HOWEVER De Klein and Monaghan modelled <u>total</u> greenhouse gases (including on-farm and on supplement blocks) and found they increased 10% with the wintering pad due to fuel use, supplement production, and fertiliser. Methane did not change significantly. (No adjustment was made for any improved soil conditions from using a pad which could reduce N_2O emissions from pasture.) De Klein and Monaghan also looked at N inhibitors to reduce GHG and found N_2O (direct + indirect) dropped 40-52% but left total GHG largely unchanged if the increased production was used to raise stocking rate – due to more methane and CO_2 An alternative could be that extra pasture from the inhibitor response is used to replace inputs of fertiliser or supplements in spring whereby stocking rate and milk production would not increase and total GHG would drop.	

Soil compaction		
		Generally not heavy soils here so this is unlikely to be a major issue.
Water availability		
Quinn 2003 Purukohukohu pine plantation Fahey and Rowe 1992	Average water yield from mature pine forest was 76% of pasture over 7 years prior to logging. Water yield increased in the first 3 years after logging to 125% of pasture yield. Lower interception and evapotranspiration losses of rainfall from pasture than forest typically result in increased flow yield, flow variability and surface runoff rates	Impact of changing land use on hydrology – less trees, more flooding potential Impact of irrigation on water availability

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