Rangitāiki Freshwater Futures Community Group

Workshop Agenda

Tuesday 3 April 2018

Co-Chairs:	**Larry Wetting / Alamoti Te Pou**
Members:	**Alan Law, Atamira Nuku, Beverly Hughes, Bill Kerrison, Councillor Bill Clark, Cathy Brown, Christina Bunny, Colin Maunder, Craig Rowe, Daryl Christie, Earl Rewi, Gareth Boyt, George Johnston, James Doherty, John Gibson, Kerry Snowdon, Kirsty Joynt, Linda Conning, Mark Ross, Matt Gow, Matt Osborne, Ngapera Rangiaho, Nick Doney, Nicholas Woodley, Robert Pouwhare, Steve Brightwell, Tom Lynch, Wetini Paul**
BOPRC Staff:	**Simon Stokes (Relationship Manager), James Dare (Science), Santiago Bermeo (Water Policy), Kerry Gosling (Facilitator), Stephanie MacDonald (Support Facilitator), Nicki Green (Water Policy), Andrew Millar (Water Policy)**
Administrator:	**Michelle Lee (Water Policy)**
Apologies:	
Venue:	**Galatea Hall**
Time:	**9.00am – 2.30pm**

8.30am	**Join us for a cup of tea catch up**
9.00am	**Welcome**
	Purpose
	National and regional updates
10.00am	**Morning Tea**
	Mitigation bundles and costings BOPRC has engaged Perrin Ag Consultants & Landcare Research to give us some advice on mitigation practices to be considered within our catchment model, building on previous feedback from the community group. Perrin Ag & Landcare will also be estimating the cost of implementing these mitigation practices. During this workshop we will be considering Perrin Ag & Landcare's recommended mitigation bundles and baseline profit estimates, against which costs will be estimated later on. A background report and workshop paper will be sent out separately, ahead of the workshop.

12.30pm	**Lunch**
1.00pm	**Plan Change 9 – Rangitāiki matters**

Plan Change 9 – Rangitāiki matters

The purpose is to outline/clarify some issues and range of submitter points that were heard at the recent Plan Change 9: Water Quantity hearing and which are particularly relevant in the Upper Rangitāiki catchment – in particular, how unauthorised dairy shed wash down is to be managed. This issue cannot be resolved by the community group, but sound understanding is important as the group moves towards considering minimum flows and allocation limits. Presentation and handouts will be provided on the day. No briefing note.

Introduction to Environmental Flow Setting for rivers

In this session we will introduce key terms and concepts for minimum flow and allocation setting, and introduce the EFSAP tool and how it will be used. The purpose is to prepare the group for considering options for flow and allocation limits at the next meeting. Presentation and handouts will be provided on the day. No briefing note.

Introduction to groundwater environmental level setting

The purpose is to discuss options for setting groundwater quantity limits in the Rangitāiki Water Management area. The groundwater modelling work to inform setting groundwater quantity limits has commenced. However, the initial results will not be available until December 2018. More robust results with a greater level of confidence will not be available until sometime after that. Options and implications for setting limits prior to the completion of the groundwater modelling work will be discussed and preferred approach identified.

Next Steps

2.30pm **Close**

WORKSHOP PAPER

To: **Rangitāiki Freshwater Futures Community Group**

From: Santiago Bermeo
Senior Planner (Water Policy)

Date: 27 March 2018

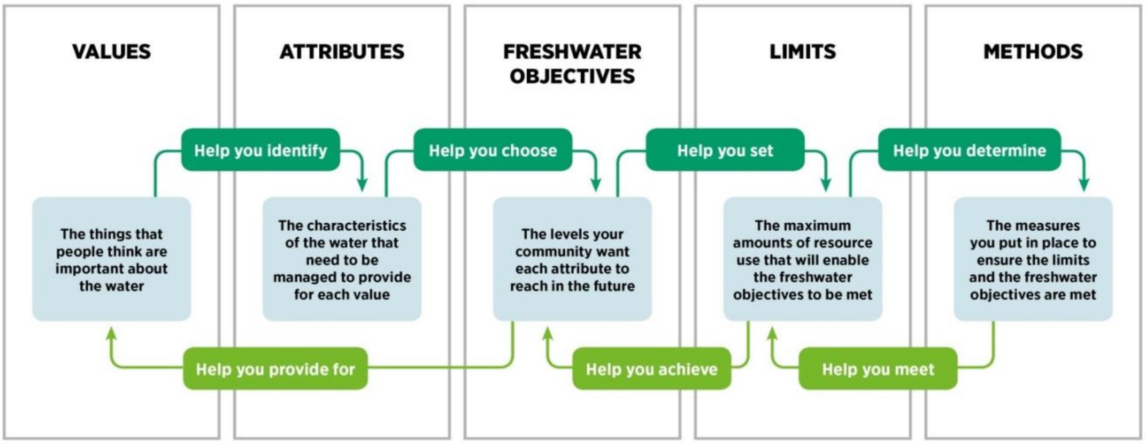
Subject: **Mitigation bundles and baseline profit estimations**

1 Purpose

The purpose of this paper is to introduce new material we will consider during Workshop 7 in relation to mitigation bundles and baseline profit estimations. It also summarises previous discussions and activities we have completed in earlier workshops in relation to this topic.

2 Mitigation practices are a method to achieve freshwater quality objectives

Mitigation practices are, in this case, farming and growing practices aimed at reducing contaminant loss from agricultural land use. Mitigation practices are some of the methods that would give effect to limits and freshwater objectives, as illustrated in the diagram below. Mitigation practices will be grouped into bundles, based on cost/ease of adoption and effectiveness. The impact of these mitigation bundles on contaminant loss and water quality outcomes will be tested through the bio-physical catchment model.



At this stage we are only exploring what mitigation practices would allow us to meet desired water quality objectives; these are not concrete options yet. Likewise, at this point we are not too worried about how these bundles of practices could eventually be implemented.[1]

[1] Eventually, it could be through regulation (e.g. Regional Plan provisions, consent conditions), industry self-regulation (e.g. supply agreements) or incentives. It may also be possible that some practices could be adopted in some parts of the catchment, or for some land uses, and not others.

Following this exploratory stage, we will revisit desired water quality objectives and the methods required to achieve them, in a solution-building stage.

3 What we have done previously

During Workshop 5 we carried out a brief brainstorming session of all methods that could reduce contaminant loss. During Workshop 6 we started narrowing down the longlist of methods identified and classifying them into “Good Management Practices” (i.e. standard expected practice from environmentally responsible water and land users) and additional mitigations (i.e. practices that go beyond standard expected practice). Because not all community group members had an opportunity to consider the full longlist of practices during Workshop 6, we also carried out an online survey at the end of 2017 to get additional feedback. Some useful feedback was gathered and we thank the members that responded. Please find attached as Appendix 1 a summary of responses to the online survey.

4 Advice on mitigation bundles, baseline profits and cost estimation

We have engaged Perrin Ag Consultants and Landcare Research to give us some advice on the make-up of mitigation bundles. Perrin Ag Consultants and Landcare Research will also be estimating the cost of implementing these bundles (in terms of reduction in farm/orchard profit).

We expect that once we have results from the bio-physical catchment model (in terms of water quality outcomes under different scenarios) and outputs from the Perrin Ag/Landcare Research mitigation economic analysis, the community group would be in a good position to revisit desired water quality outcomes and methods to achieve them, reflecting on the freshwater values identified earlier in the process.

Attached as Appendices 2 and 3 are reports from Perrin Ag/Landcare Research on suggested mitigation bundles and baseline farm/orchard profit estimations, against which mitigation costs will be estimated. The full reports are provided for members that would like to dive into the detail but the key sections to consider are Tables 2 to 4 (pp. 18 – 20 in Appendix 2) and the estimated baseline profit figures in Appendix 3.

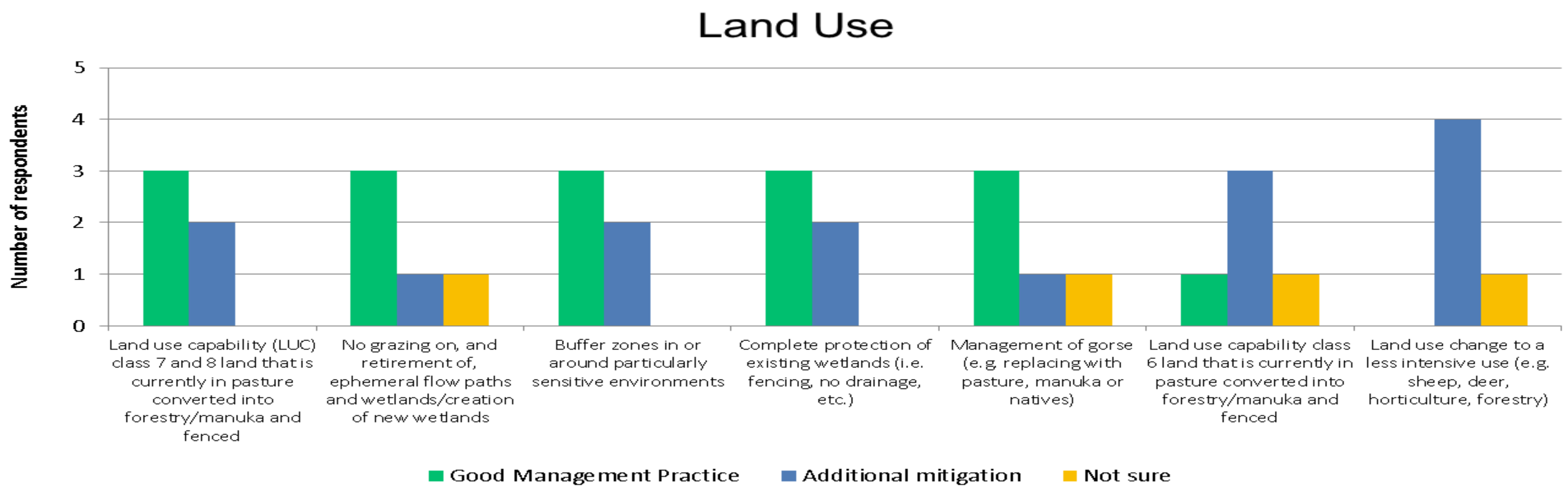
5 Feedback we would like from you

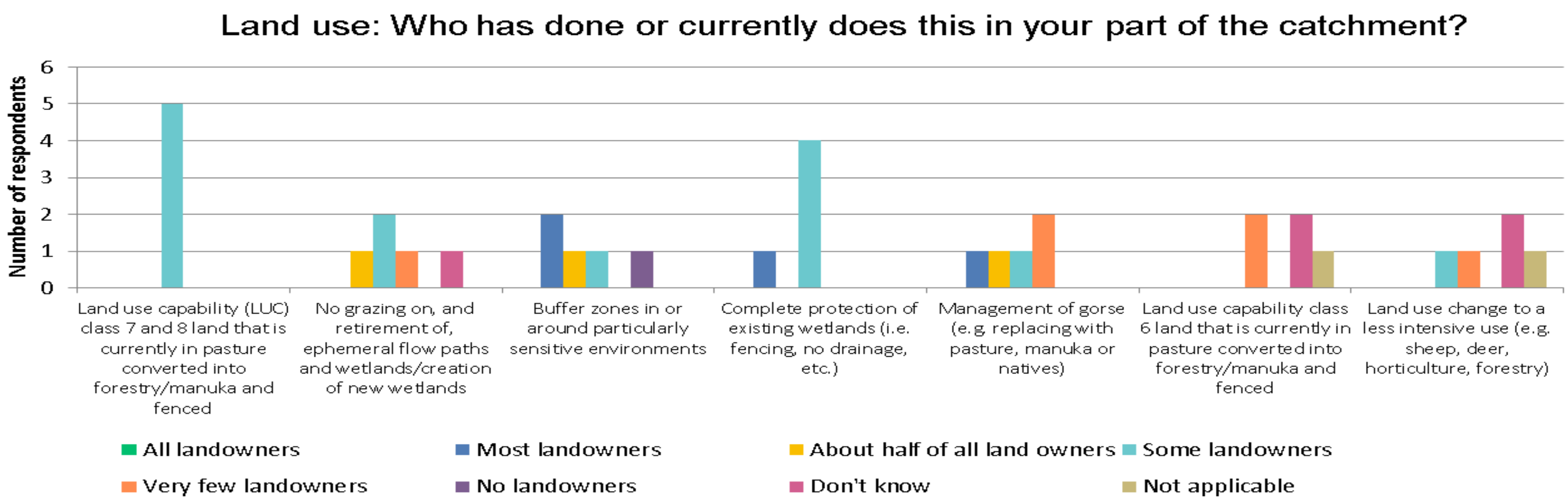
Feedback that we would like from you during Workshop 7 includes:

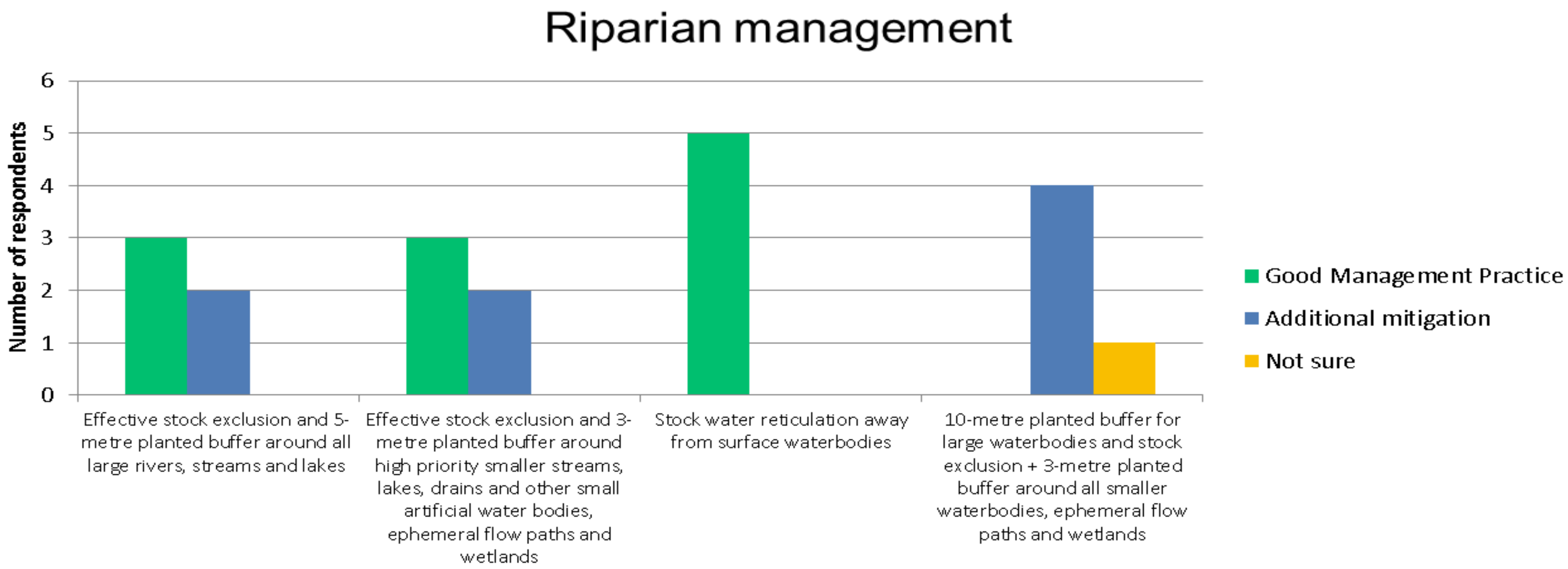
- Do the proposed mitigation bundles seem OK to you?
- Are the proposed increases in riparian fencing/buffering/planting practices reasonable and realistic?
- Is there anything from the original longlist that is no longer included that you think should still be included?
- Anything included in the bundles that you think should not be?
- Would you make any changes to the bundle make up?
- What are the current levels of implementation of all these practices?
- Are the baseline profit estimates within the ballpark of what you expected?

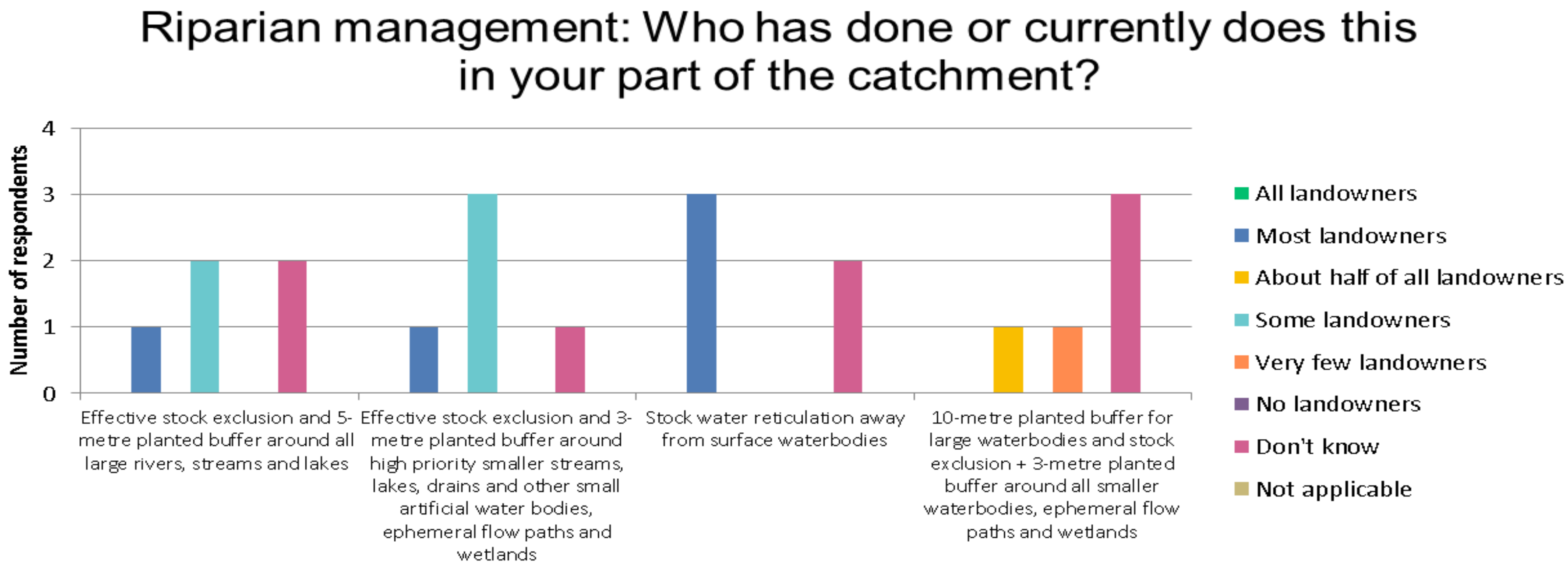
Appendix 1 – Summary of results from community group survey on methods to achieve water quality objectives

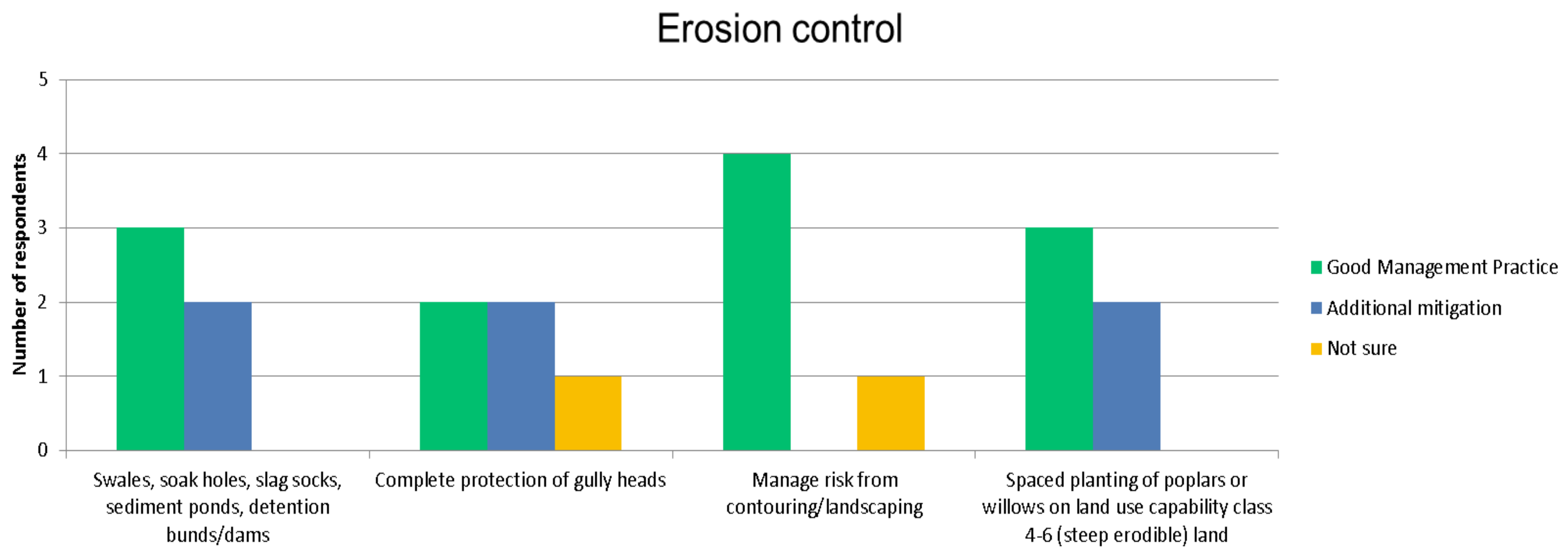
Total responses: 11 (5 from Lower Rangitāiki, 6 from Mid-Upper Rangitāiki)



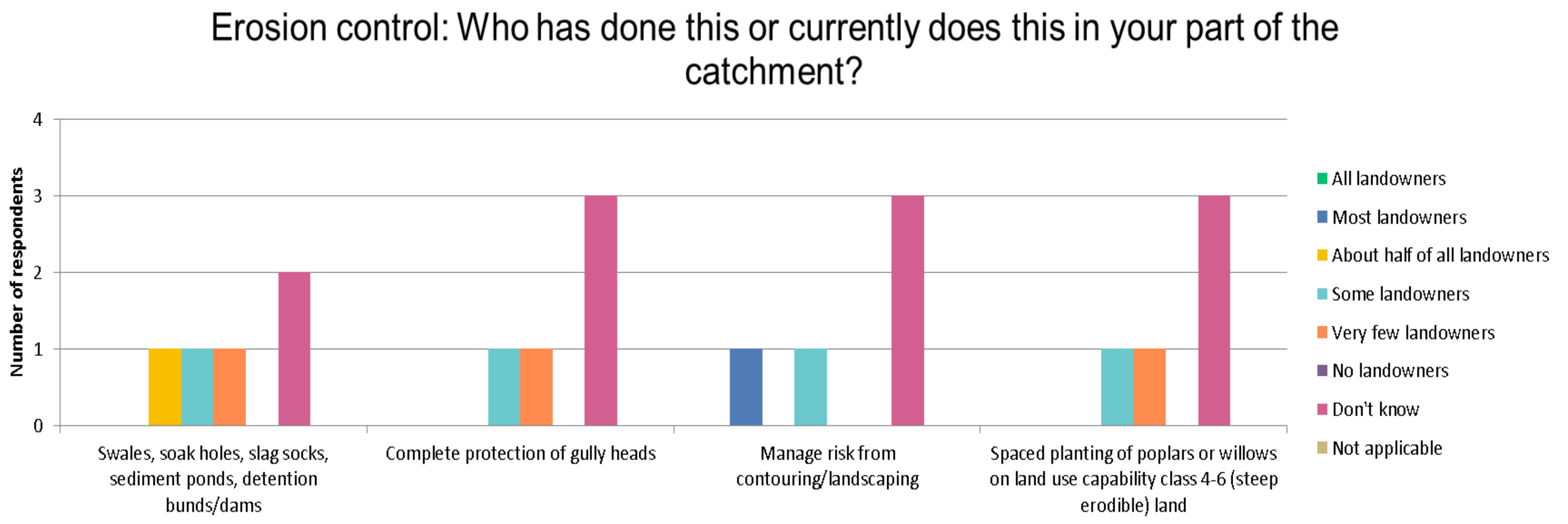



Riparian management
Number of respondents
0
1
2
3
4
5
6
Effective stock exclusion and 5-metre planted buffer around all large rivers, streams and lakes
Effective stock exclusion and 3-metre planted buffer around high priority smaller streams, lakes, drains and other small artificial water bodies, ephemeral flow paths and wetlands
Stock water reticulation away from surface waterbodies
10-metre planted buffer for large waterbodies and stock exclusion + 3-metre planted buffer around all smaller waterbodies, ephemeral flow paths and wetlands
Good Management Practice
Additional mitigation
Not sure


Riparian management: Who has done or currently does this in your part of the catchment?
Number of respondents
0
1
2
3
4
Effective stock exclusion and 5-metre planted buffer around all large rivers, streams and lakes
Effective stock exclusion and 3-metre planted buffer around high priority smaller streams, lakes, drains and other small artificial water bodies, ephemeral flow paths and wetlands
Stock water reticulation away from surface waterbodies
10-metre planted buffer for large waterbodies and stock exclusion + 3-metre planted buffer around all smaller waterbodies, ephemeral flow paths and wetlands
All landowners
Most landowners
About half of all landowners
Some landowners
Very few landowners
No landowners
Don't know
Not applicable



Erosion control
Number of respondents
0
1
2
3
4
5
Swales, soak holes, slag socks, sediment ponds, detention bunds/dams
Complete protection of gully heads
Manage risk from contouring/landscaping
Spaced planting of poplars or willows on land use capability class 4-6 (steep erodible) land
Good Management Practice
Additional mitigation
Not sure



Erosion control: Who has done this or currently does this in your part of the catchment?
Number of respondents
0
1
2
3
4
Swales, soak holes, slag socks, sediment ponds, detention bunds/dams
Complete protection of gully heads
Manage risk from contouring/landscaping
Spaced planting of poplars or willows on land use capability class 4-6 (steep erodible) land
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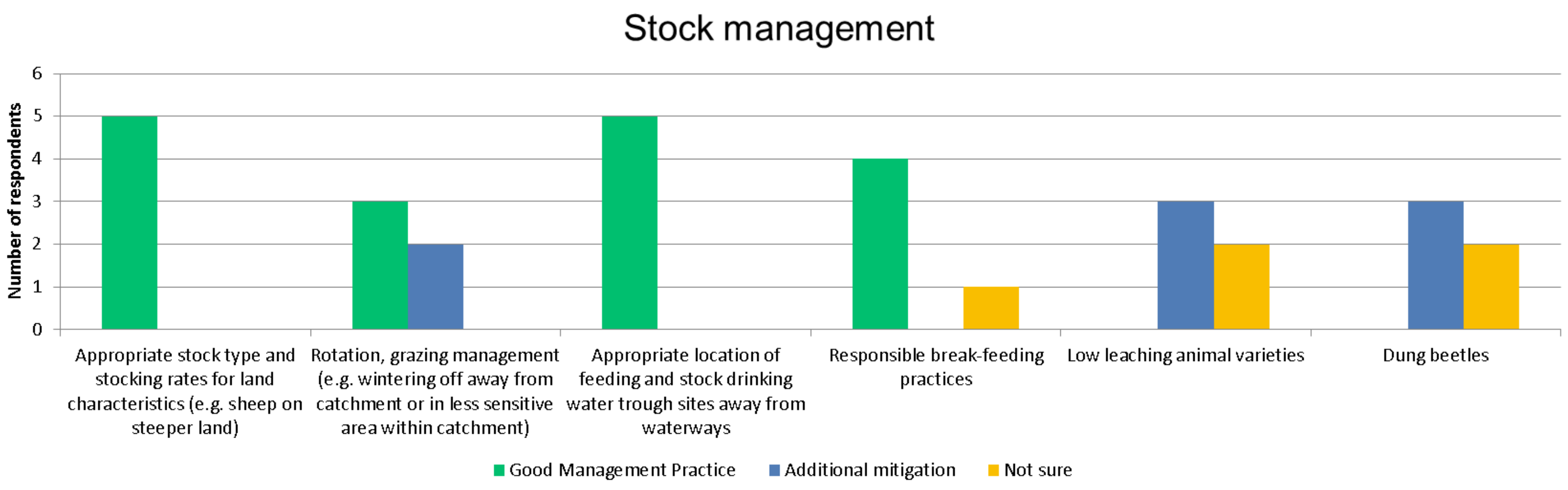
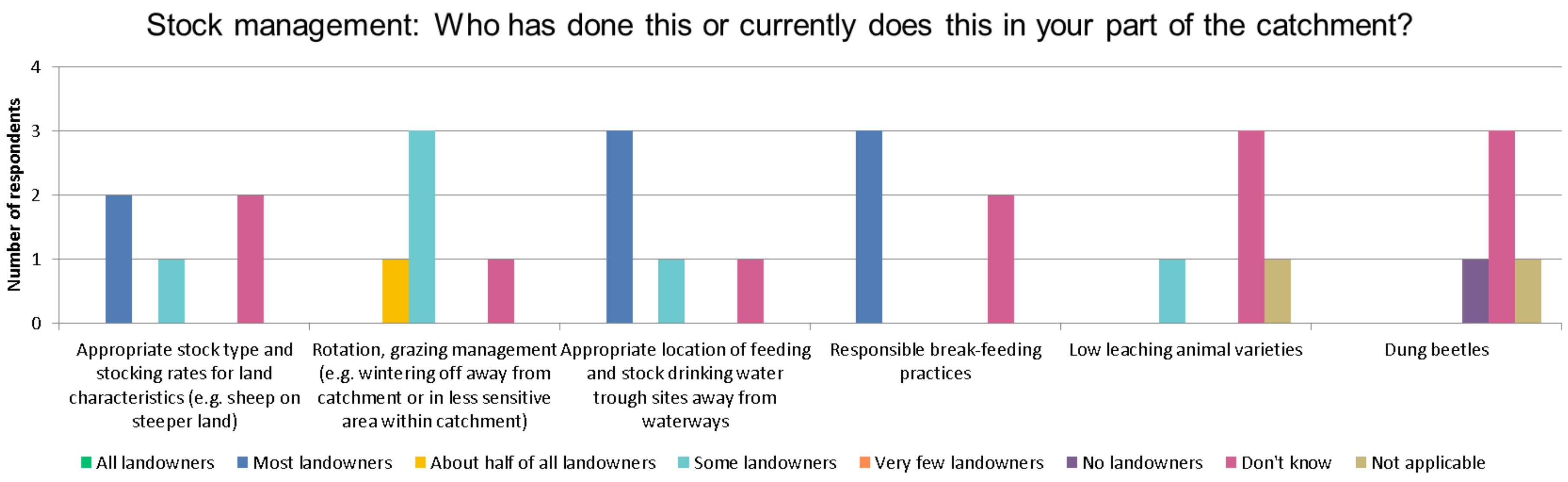
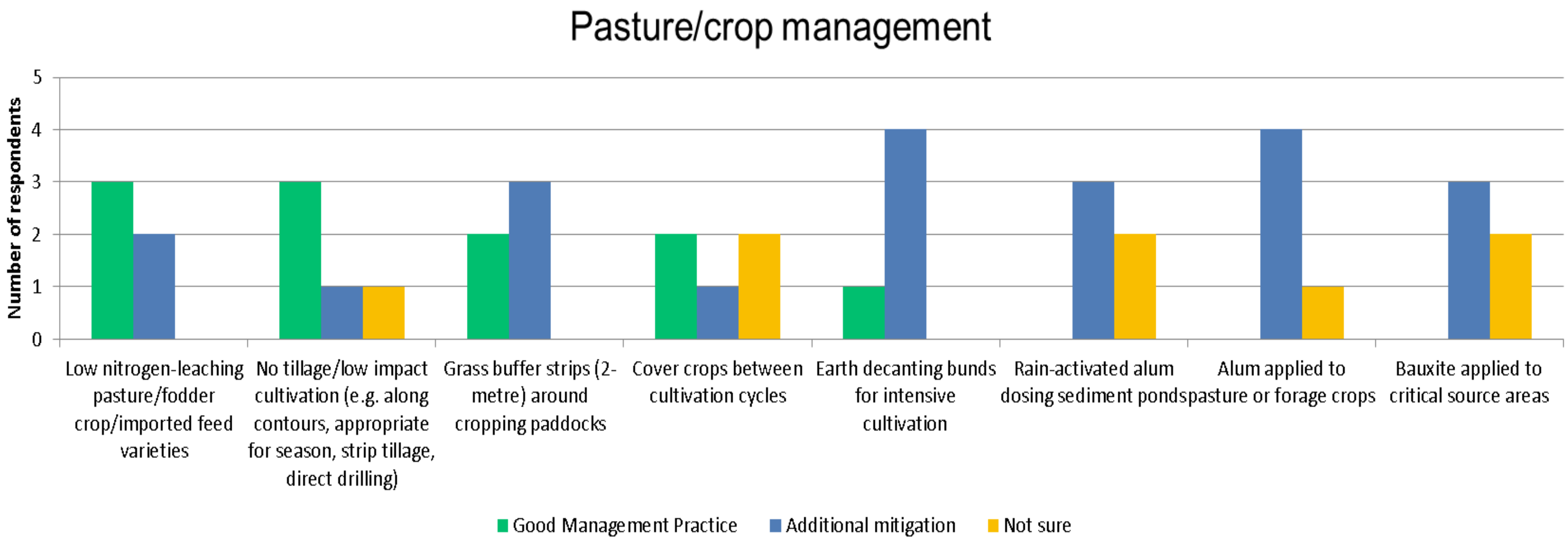
Most landowners
About half of all landowners
Some landowners
Very few landowners
No landowners
Don't know
Not applicable

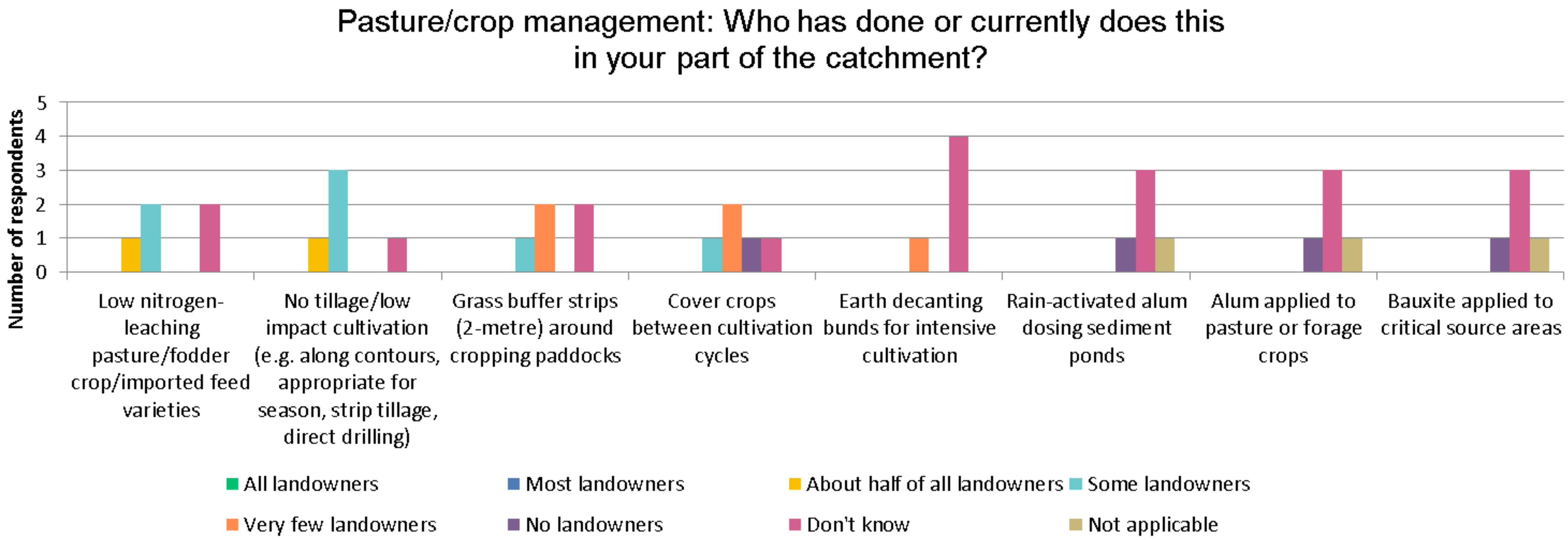


Stock management
Number of respondents
6
5
4
3
2
1
0
Appropriate stock type and stocking rates for land characteristics (e.g. sheep on steeper land)
Rotation, grazing management (e.g. wintering off away from catchment or in less sensitive area within catchment)
Appropriate location of feeding and stock drinking water trough sites away from waterways
Responsible break-feeding practices
Low leaching animal varieties
Dung beetles
Good Management Practice
Additional mitigation
Not sure



Stock management: Who has done this or currently does this in your part of the catchment?
Number of respondents
4
3
2
1
0
Appropriate stock type and stocking rates for land characteristics (e.g. sheep on steeper land)
Rotation, grazing management (e.g. wintering off away from catchment or in less sensitive area within catchment)
Appropriate location of feeding and stock drinking water trough sites away from waterways
Responsible break-feeding practices
Low leaching animal varieties
Dung beetles
All landowners
Most landowners
About half of all landowners
Some landowners
Very few landowners
No landowners
Don't know
Not applicable


Pasture/crop management
Number of respondents
0
1
2
3
4
5
Low nitrogen-leaching pasture/fodder crop/imported feed varieties
No tillage/low impact cultivation (e.g. along contours, appropriate for season, strip tillage, direct drilling)
Grass buffer strips (2-metre) around cropping paddocks
Cover crops between cultivation cycles
Earth decanting bunds for intensive cultivation
Rain-activated alum dosing sediment ponds
Alum applied to pasture or forage crops
Bauxite applied to critical source areas
Good Management Practice
Additional mitigation
Not sure


Pasture/crop management: Who has done or currently does this in your part of the catchment?
Number of respondents
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2
3
4
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Alum applied to pasture or forage crops
Bauxite applied to critical source areas
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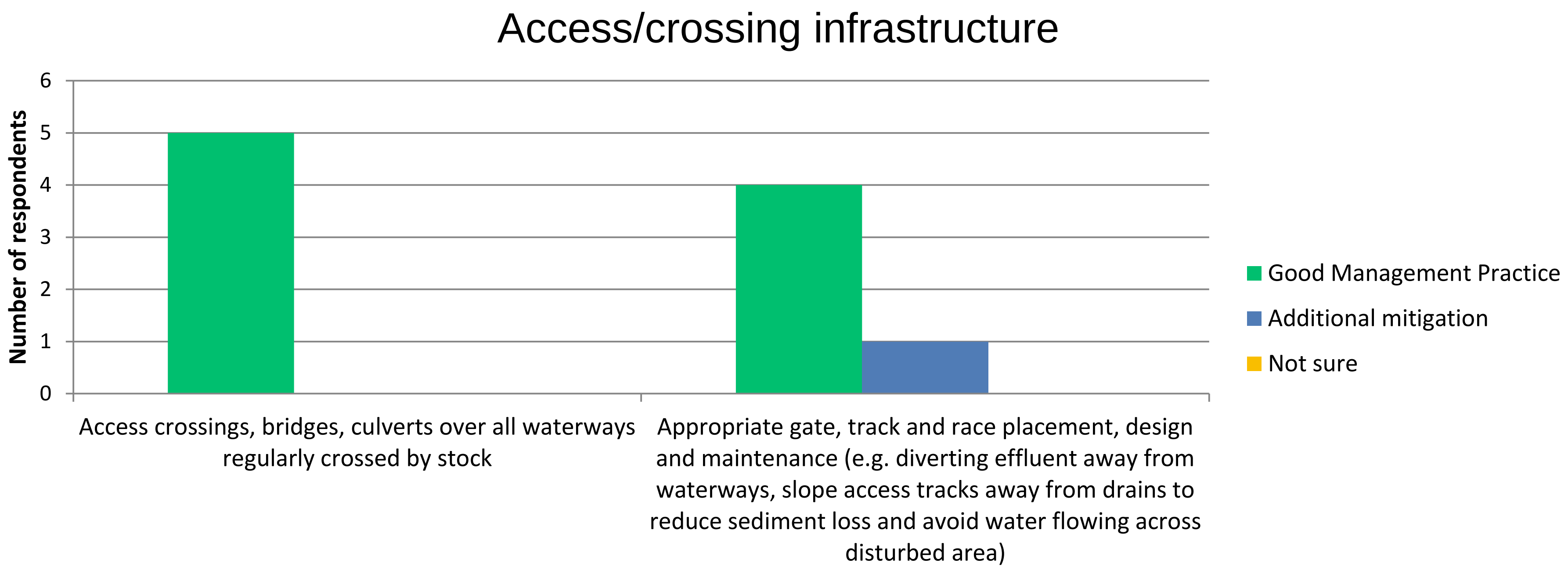
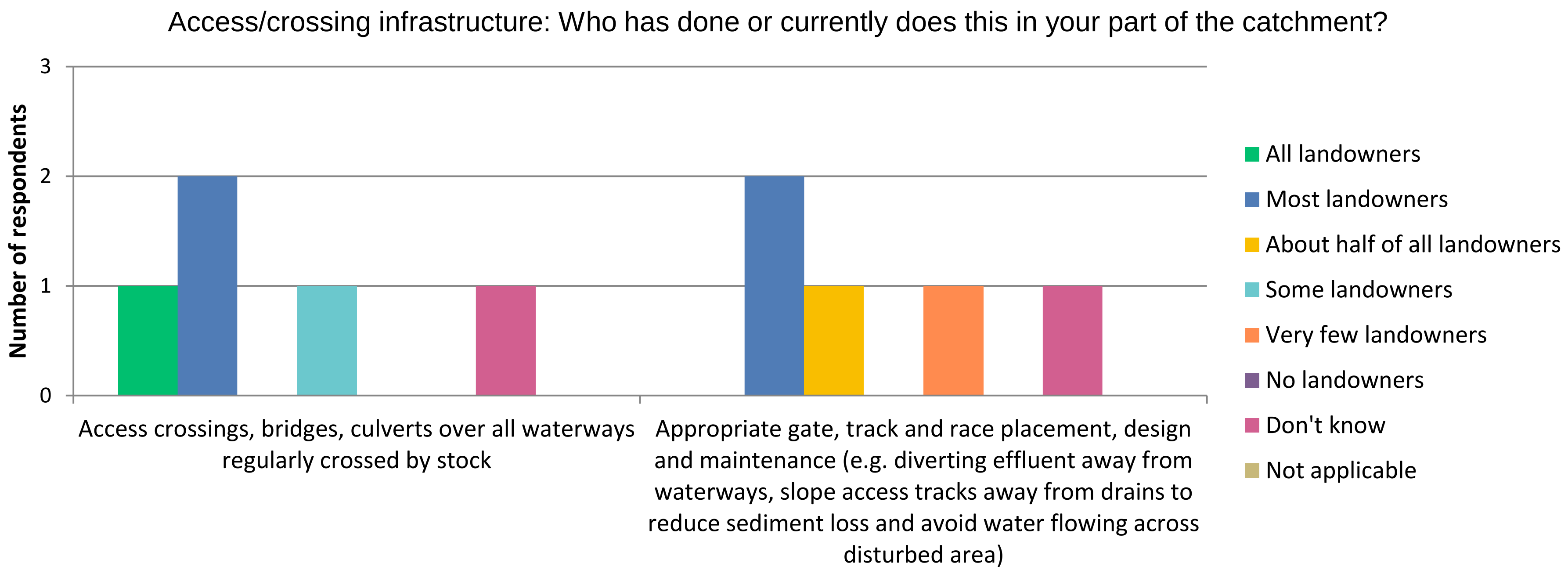
Most landowners
About half of all landowners
Some landowners
Very few landowners
No landowners
Don't know
Not applicable



Access/crossing infrastructure
Number of respondents
6
5
4
3
2
1
0
Access crossings, bridges, culverts over all waterways regularly crossed by stock
Appropriate gate, track and race placement, design and maintenance (e.g. diverting effluent away from waterways, slope access tracks away from drains to reduce sediment loss and avoid water flowing across disturbed area)
Good Management Practice
Additional mitigation
Not sure



Access/crossing infrastructure: Who has done or currently does this in your part of the catchment?
Number of respondents
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2
1
0
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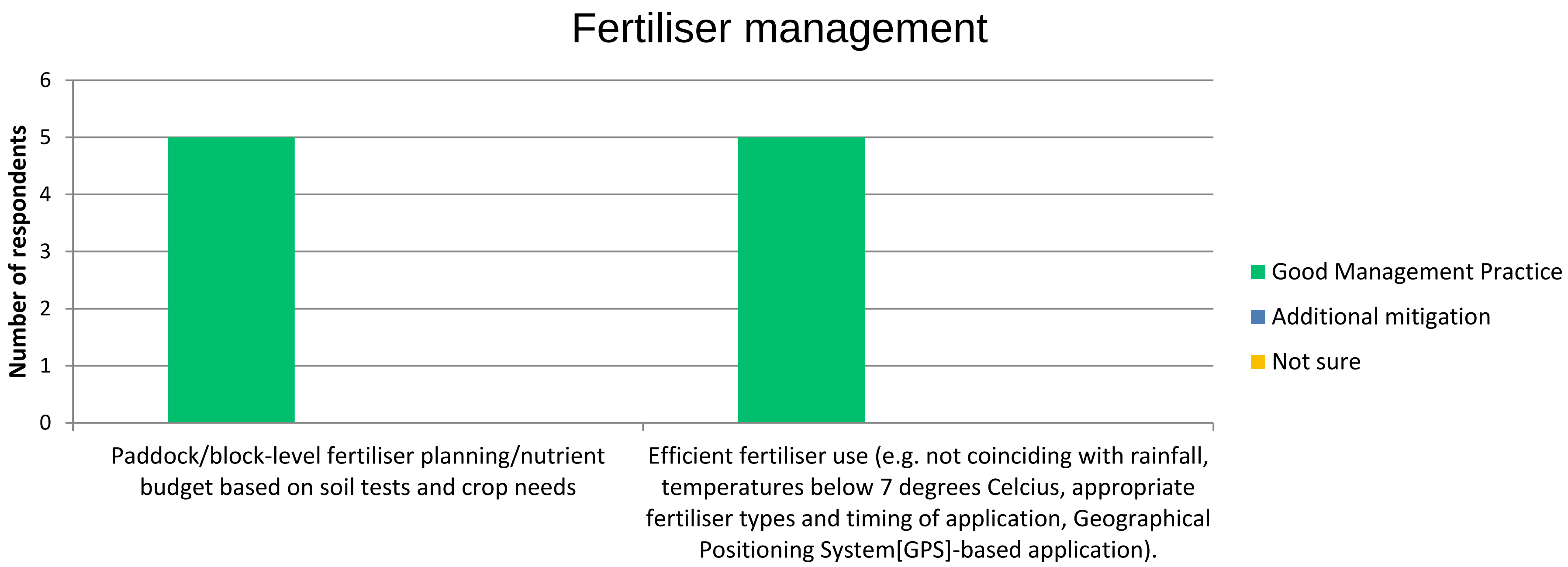
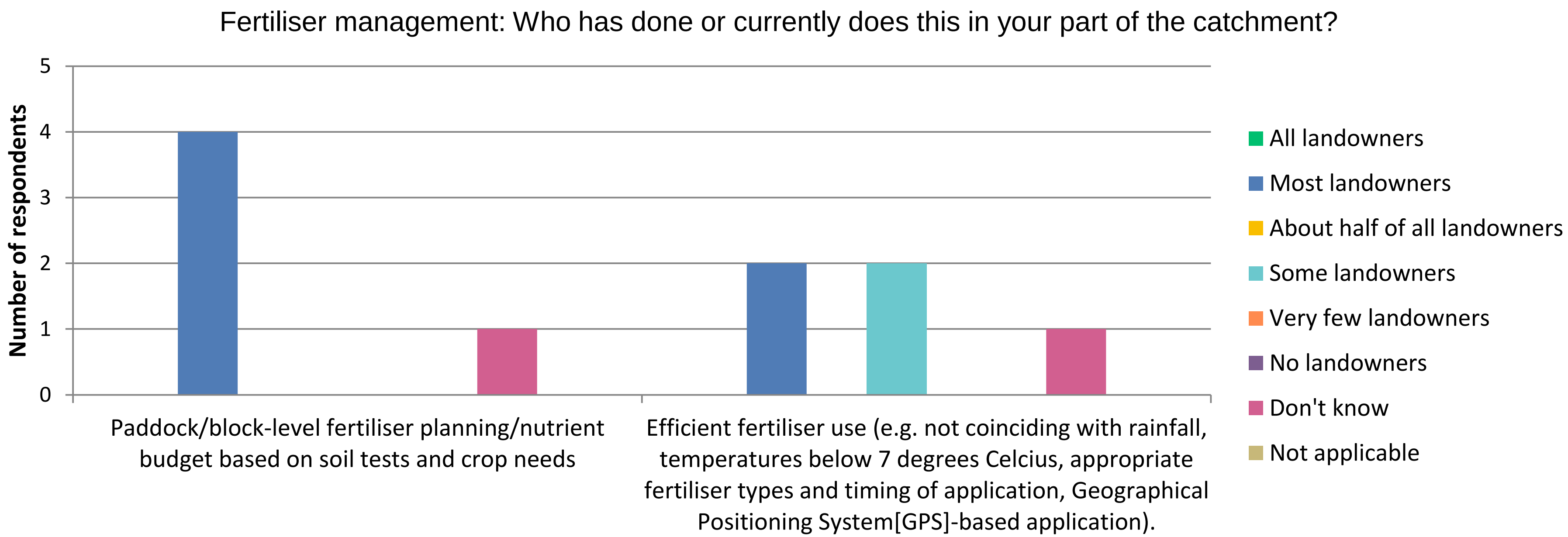
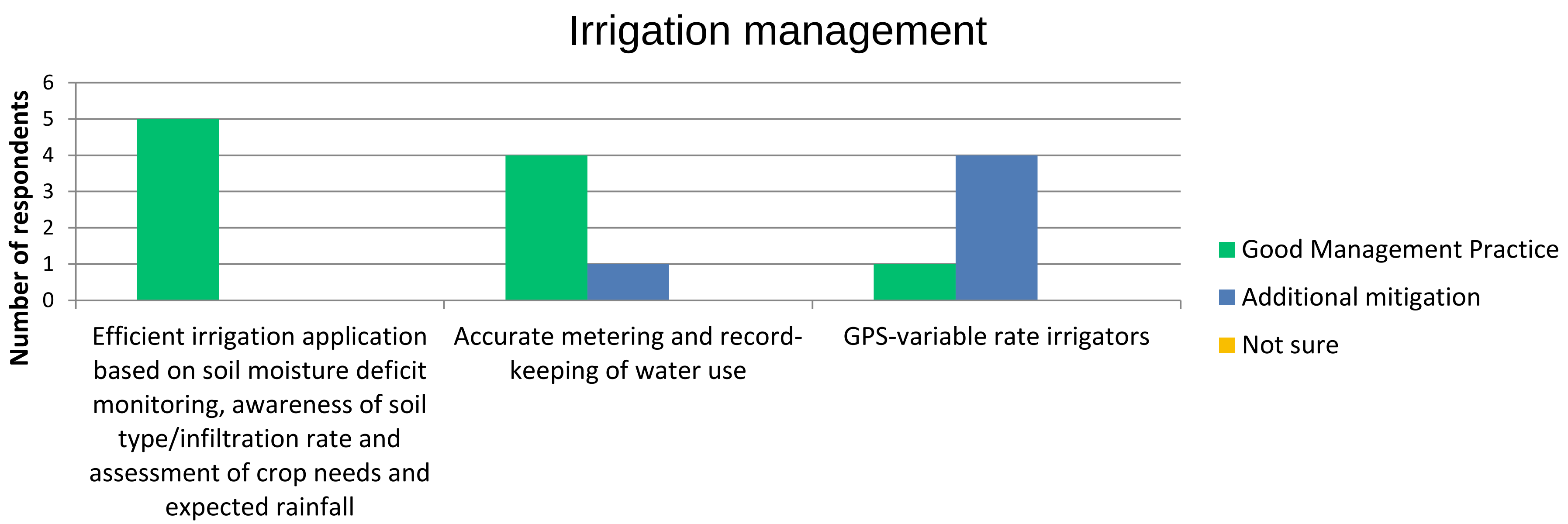
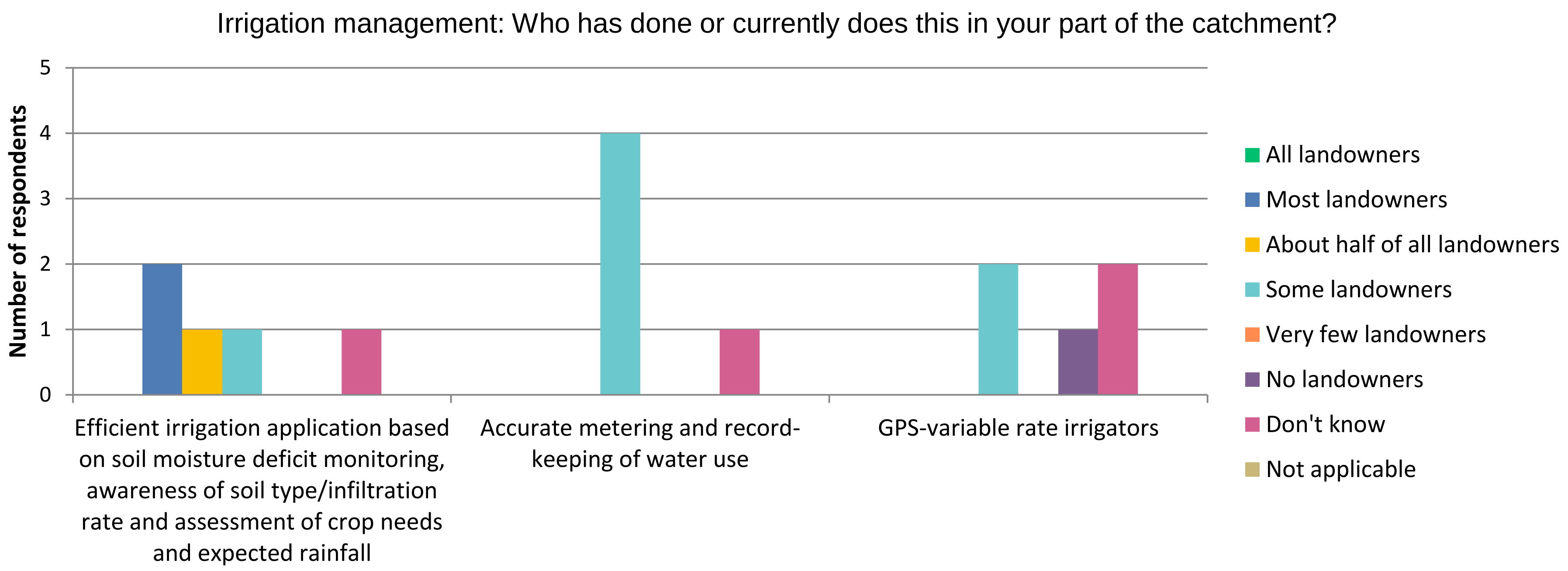
Very few landowners
No landowners
Don't know
Not applicable


Fertiliser management
Number of respondents
6
5
4
3
2
1
0
Paddock/block-level fertiliser planning/nutrient budget based on soil tests and crop needs
Efficient fertiliser use (e.g. not coinciding with rainfall, temperatures below 7 degrees Celcius, appropriate fertiliser types and timing of application, Geographical Positioning System[GPS]-based application).
Good Management Practice
Additional mitigation
Not sure


Fertiliser management: Who has done or currently does this in your part of the catchment?
Number of respondents
5
4
3
2
1
0
Paddock/block-level fertiliser planning/nutrient budget based on soil tests and crop needs
Efficient fertiliser use (e.g. not coinciding with rainfall, temperatures below 7 degrees Celcius, appropriate fertiliser types and timing of application, Geographical Positioning System[GPS]-based application).
All landowners
Most landowners
About half of all landowners
Some landowners
Very few landowners
No landowners
Don't know
Not applicable


Irrigation management
Number of respondents
0
1
2
3
4
5
6
Efficient irrigation application based on soil moisture deficit monitoring, awareness of soil type/infiltration rate and assessment of crop needs and expected rainfall
Accurate metering and record-keeping of water use
GPS-variable rate irrigators
Good Management Practice
Additional mitigation
Not sure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3
4
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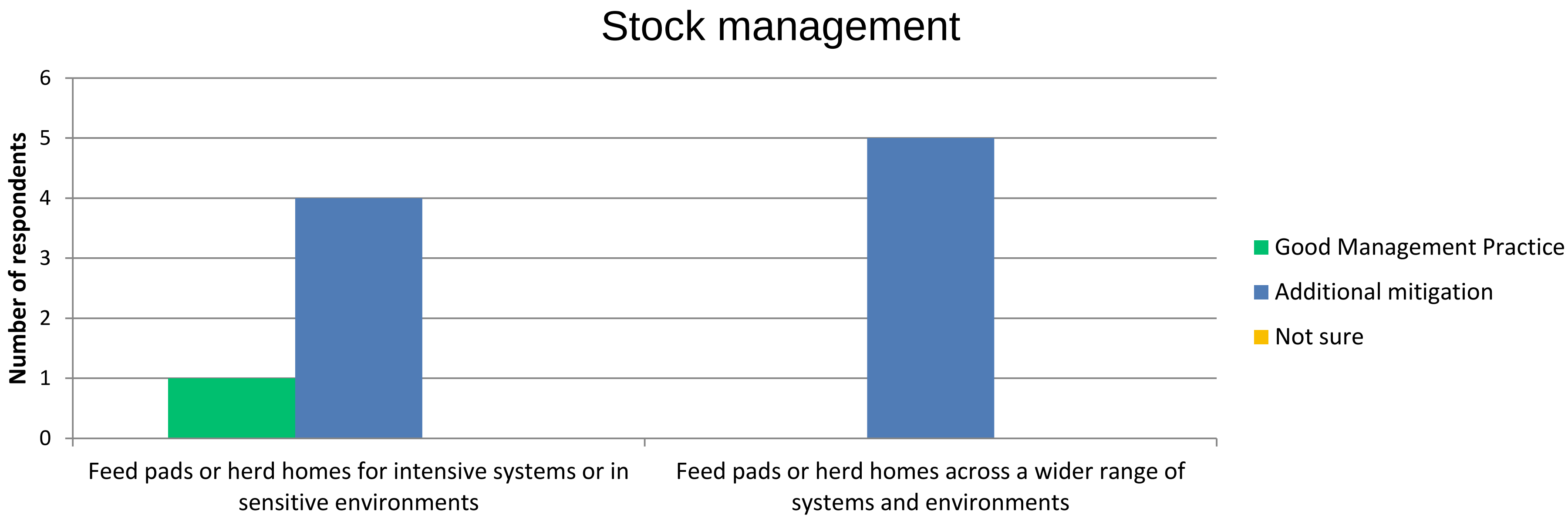
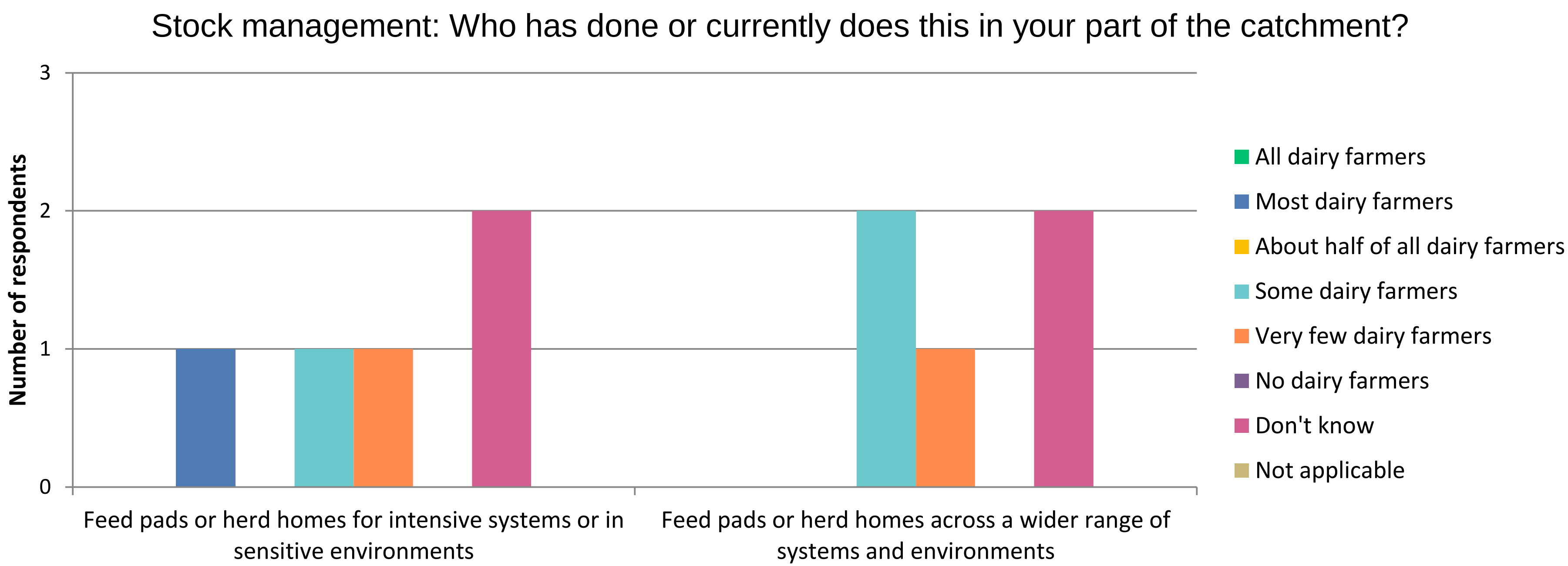
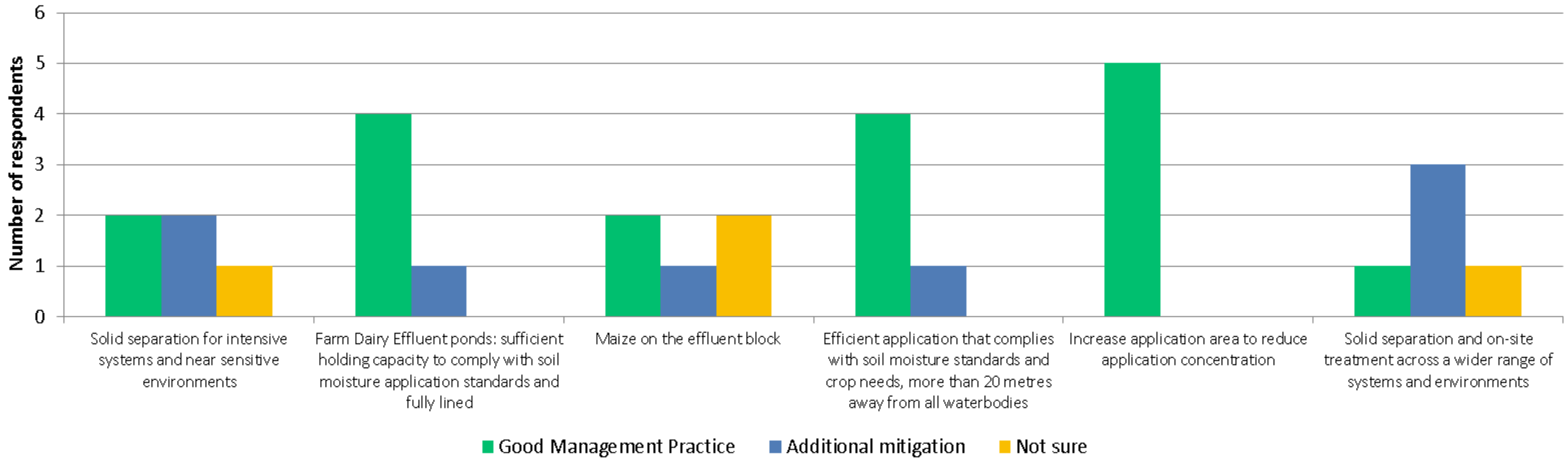
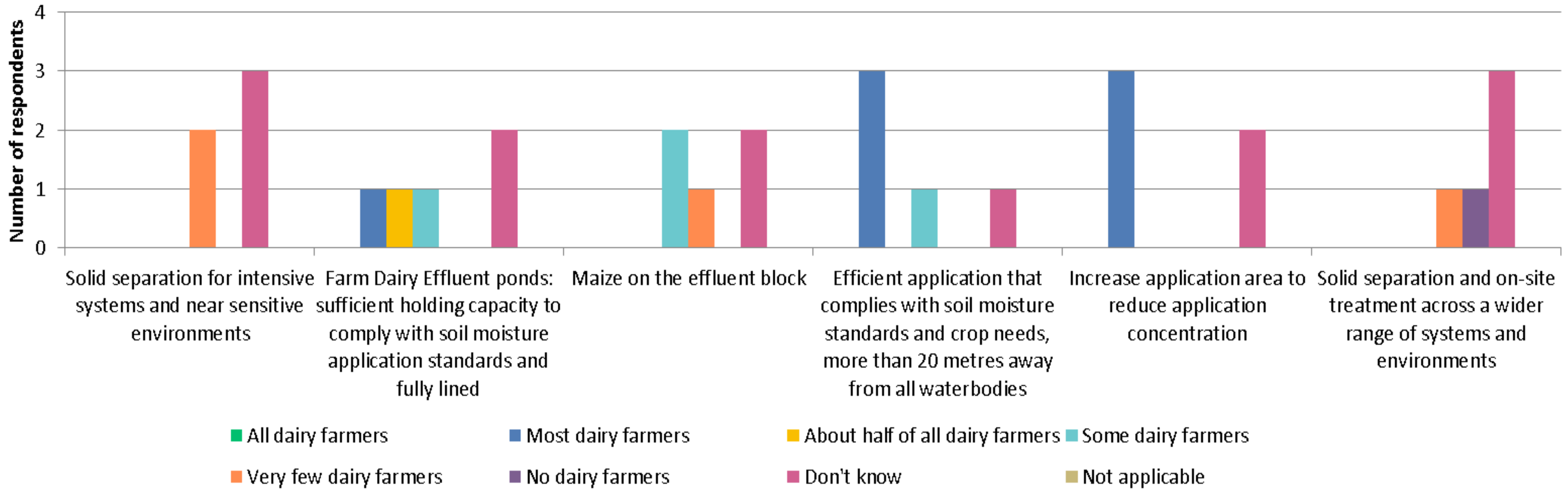

Stock management
Number of respondents
0
1
2
3
4
5
6
Feed pads or herd homes for intensive systems or in sensitive environments
Feed pads or herd homes across a wider range of systems and environments
Good Management Practice
Additional mitigation
Not sure

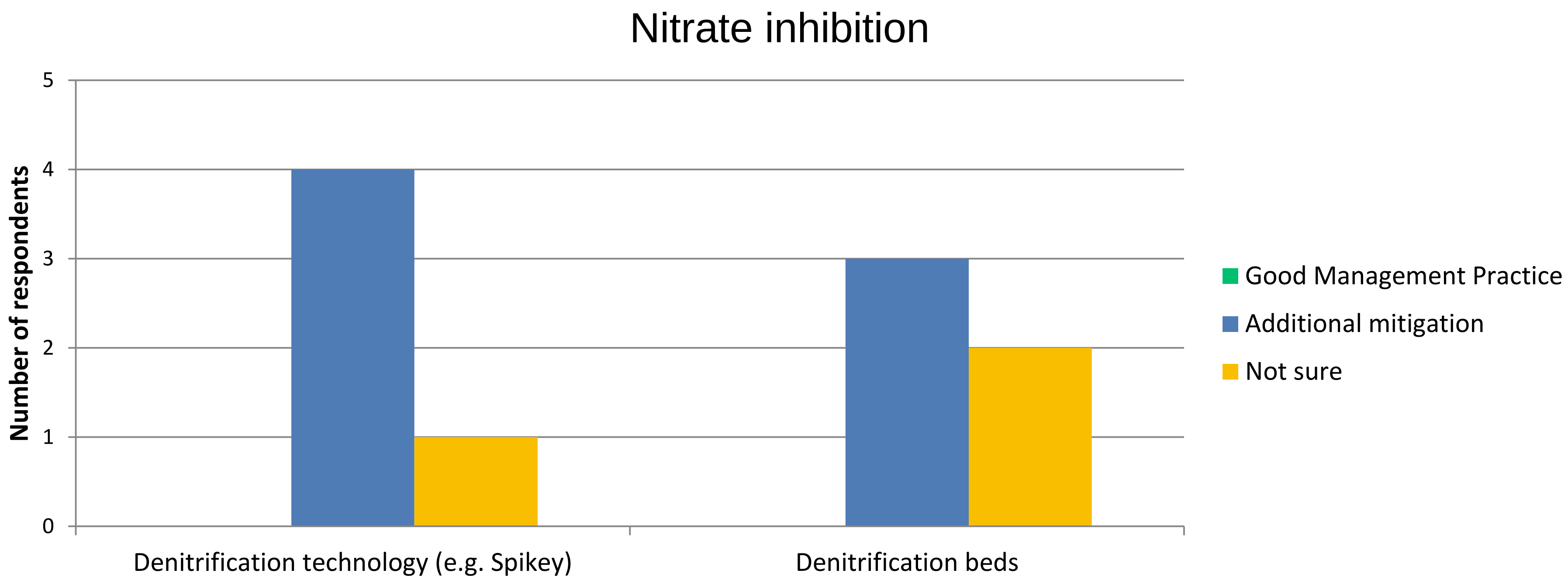

Stock management: Who has done or currently does this in your part of the catchment?
Number of respondents
0
1
2
3
Feed pads or herd homes for intensive systems or in sensitive environments
Feed pads or herd homes across a wider range of systems and environments
All dairy farmers
Most dairy farmers
About half of all dairy farmers
Some dairy farmers
Very few dairy farmers
No dairy farmers
Don't know
Not applicable

Effluent management

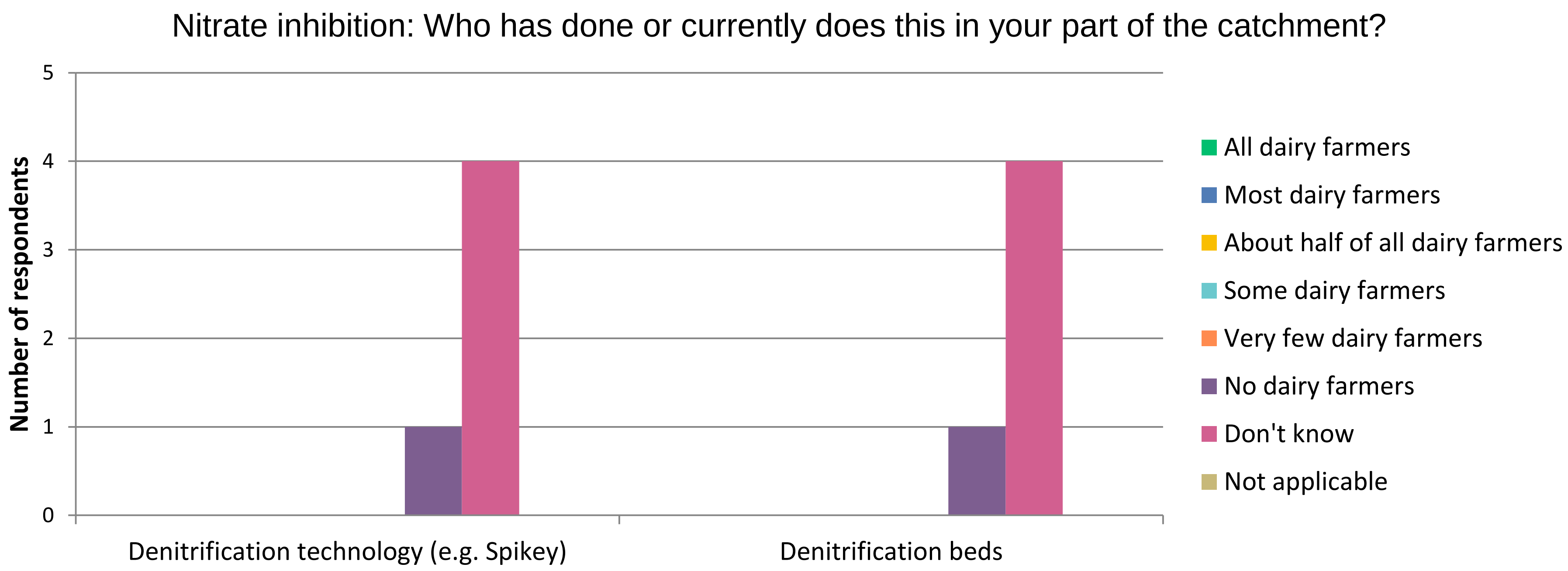


Effluent management: Who has done or currently does this in your part of the catchment?





Nitrate inhibition
Number of respondents
0
1
2
3
4
5
Denitrification technology (e.g. Spikey)
Denitrification beds
Good Management Practice
Additional mitigation
Not sure



Nitrate inhibition: Who has done or currently does this in your part of the catchment?
Number of respondents
0
1
2
3
4
5
Denitrification technology (e.g. Spikey)
Denitrification beds
All dairy farmers
Most dairy farmers
About half of all dairy farmers
Some dairy farmers
Very few dairy farmers
No dairy farmers
Don't know
Not applicable

Section	Respondent comments
Land use	▪ Not sure what ephemeral flow paths are ***BOPRC comment: ephemeral flow paths are temporarily flowing streams (e.g. after heavy rainfall).***
Riparian management	▪ Buffer widths mentioned are minimalist - not sufficient. Dairy farms seem to fence right on the edge of the bank which doesn't allow for stream stabilisation. Stock exclusion and buffer is definitely good practice but planting is possibly additional mitigation ▪ Most water bodies have stock exclusion, but not necessarily a 3 metre buffer planted yet.
Stock management	▪ I know very little about farm practices, in particular current practice. ▪ Need discussion of effluent irrigation to land v pond treatment ▪ wintering off only moves the problem to another catchment
Pasture/crop management	▪ Cover crops not always possible due to the winter conditions in this catchment
Irrigation management	▪ Note absentee landowners, particularly on kiwifruit blocks, irrigate regardless of rainfall. ▪ GPS- variable rate instigators would mean one would have to remove more trees in a catchment where trees have enhanced the climate.
Stock management	▪ Need to balance these practices with other considerations e.g. climate change and energy efficiency, animal welfare and rural amenity issues
Effluent management	▪ Separating solids is a no-brainer - the amount of water needed to dilute/move solids is massive.
Nitrate inhibition	▪ Science is still out on this
Forestry	▪ NES-PF provides adequate practise to manage impacts ▪ In the lower Rangitāiki there are giant kokopu in the Omataroa forest and spring-fed streams below the Manawahe hills. Don’t know yet if NPS-PF will sufficiently protect these... Don’t know yet ▪ I am sure that this has impacted on the state of the Whirinaki River and the build up of the river. There are implications for the flood management also.
Hydro-electricity	Review peak flows/ramping rate frequency/in-out flow conditions and flushing rates: ▪ Should be a component of the overall work ▪ Ramping is possibly the biggest contributor to bank erosion/sedimentation ▪ Needed Any other methods or comments: ▪ Review amount of water allocated. Aniwhenua needs some creative thinking about the impacts it is having
Storm water	Water sensitive urban design (e.g. swales, wetlands, rain gardens): ▪ Should be good practise ▪ These should be standard practice for all new developments. ▪ recycle/ water collected for use Road and track maintenance: ▪ Need a guide - such as NES-PF ▪ Farmers should use retention ponds/elephant holes, similar to forestry

Section	Respondent comments
	Standard and limits for storm water discharges: ▪ Need standards that are attainable and measurable ▪ Yes Land use restrictions (e.g. percentage of impervious site coverage): ▪ Use natural capital ▪ Yes Any others?: ▪ Green rooves substantially reduce run-off ▪ an increase in urbanisation leads to an increase in storm water
Wastewater	Treatment plant upgrades to relevant standard for load reduction: ▪ Yes x 2 ▪ Needed Standard for on-site effluent treatment: ▪ Yes ▪ Yes but depends on density Peak flow management at wastewater treatment plants: ▪ Yes Standards and limits for wastewater discharges: ▪ Yes ▪ needed
Restrictions	Nutrient Discharge Allowance allocation (property, sub-catchment or nutrient user group level): ▪ urban sewerage needs to be applied to land ▪ yes ▪ Based on natural capital ▪ Yes where nutrient levels are too high ▪ Possible Fertiliser use restrictions: ▪ Not as a general rule. Dairy farmers already have their N leaching figures so those leaching too much can be targeted ▪ good farm practice i.e. nitrogen app rate ▪ Based on natural capital ▪ As above ▪ , more so better use of fertiliser Restriction on winter grazing on certain soil classes: ▪ not needed ▪ Yes x 2 ▪ Where this is necessary ▪ this one has to be looked at across all of NZ to understand the impacts Stock type and stocking rate restrictions ▪ not needed ▪ Yes x 2

Section	Respondent comments
	▪ Based on natural capital ▪ this catchment already has lower stocking rates due to the soil type Land use restrictions in or around particularly sensitive environments: ▪ okay as long as balanced between protecting environment & viability of land use ▪ Yes x 2 ▪ Based on natural capital ▪ this is possible Transferable land development rights [A type of economic instrument where the development of land or certain land uses are limited, yet landowners can transfer the limited rights to develop land (or undertake land use changes) amongst themselves]: ▪ sounds dangerous as the value could become so inflated that only large corporates can afford them ▪ not sure ▪ Based on natural capital, NOT grandfathered ▪ Depends on context if it will achieve the overall outcome ▪ this does protect the whole of the catchment but unsure of the long term effects
Other methods	Stabilise susceptible streambanks: ▪ Yes x 2 ▪ Should be undertaken ▪ There is a trade-off with natural character and habitat for wildlife. Better to fence off wider buffer, plant and allow natural vegetation. Mechanical removal of sediment: ▪ yes ▪ An option as required ▪ Extensive and creates further sedimentation. Maybe necessary in extreme cases but don't see any current need. Pumped drains/flood pumping stations quality requirements: ▪ yes ▪ Oxygen levels important for aquatic life Re-diversion, changing drainage network: ▪ yes if it helps ▪ Possible but I do not know much on this ▪ not sure - maybe helpful for flood mitigation Lake remediation: alum dosing, weed harvesting, aeration, floating wetlands: ▪ management tools ▪ An option if required - short term ▪ Seem to be useful Dilution: Maintain greater water volumes/flows: ▪ yes ▪ Don't like this approach - reduce the source of pollution or treat before discharge/irrigate to land Any other engineering or remediation methods? ▪ In the Rangitāiki the answer is prevention in most cases, rather than engineering solutions which have side effects.

Appendix 2

Recommended mitigation bundles for cost analysis of mitigation of sediment and other freshwater contaminants in the Rangitāiki and Kaituna-Pongakawa-Waitahanui Water Management Areas

Prepared for the Bay of Plenty Regional Council

Final draft report, forming partial delivery for Milestone 1A

Version 1.2

26 March 2018

Perrin Ag Consultants Ltd and Landcare Research

Contents

1 Executive summary

A list of 42 agricultural land use management and land use change mitigations were evaluated for their effectiveness and cost to the farm or orchard system in order to develop mitigation bundles for use in evaluating the cost of improving water quality in the Kaituna-Pongakawa-Waitahanui and Rangitāiki water management areas.

Similar to Vibart et al. (2015) and Daigneault and Elliot (2017), a cumulative three-layer framework, was developed to bundle the mitigations. However, in this case, bundles were primarily determined based on cost at the farm gate, filtered for effectiveness at reducing contaminant losses. These mitigation strategy bundles, designed to be applied cumulatively to farm and orchard systems, are:

(i) M1: low barrier to adoption; primarily defined by being of low cost (equivalent to less than 10% of EBIT[1]) with at least a low effectiveness;

(ii) M2: moderate barrier to adoption; primarily defined by direct costs and/or lowered revenue equivalent to more than 10% but less than 25% of EBIT and at least medium effectiveness for the targeted contaminant;

(iii) M3: high barrier to adoption, primarily defined by significant reductions in pre-mitigation profitability (>25% EBIT) and high effectiveness at contaminant reduction;

Total land use change mitigations were considered a separate bundle (M4) and excluded from consideration.

These bundles were then further considered for applicability on each of the five major land use categories used in the APSIM model, which will be the basis for the economic analysis to be completed in April and May 2018.

Testing both the definitions of the bundles and farmer/grower familiarity with the individual mitigations themselves at the planned community group and industry meetings will be critically important.

[1] Earnings (or profit) before interest and tax

2 Overview

In this report, we aim to provide guidance on the suggested bundling of different practices to reduce sediment and other freshwater contaminants from rural land use in the Bay of Plenty Region. Such bundling needs to be structured around both the cost to growers from implementation and the effectiveness of the mitigation(s) in reducing contaminant load.

Studies looking at the effectiveness and cost of both individual and suites/bundles of on-farm and on-orchard mitigations to improve water quality have been regularly undertaken in the last decade. These have tended to look at the four primary contaminants to water – nitrogen (N), phosphorus (P), sediment and bacteria such as *Escherichia coli (E. coli).* As a result, there is reasonable understanding amongst the scientific and farming community about the relative costs and benefits of various systems and land use changes with regard to mitigating contaminants to water from agricultural land use.

Previous publications that summarise mitigation options for farmers include Low et al (2017), McDowell et al (2013), McKergow et al (2007), Ritchie (2008), Waikato Regional Council (2013) and Wilcock et al (2008). A bundled approach to considering mitigations has previously been considered in New Zealand, including by Vibart et al (2015), Daigneault & Elliot (2017) and Monaghan et al (2016). However, research to increase understanding around the applicability of and expected effect from the adoption of individual and bundled practice change within individual regions, freshwater management areas and sub-catchments is ongoing.

Accordingly, in this report we have attempted assess the costs of sediment and other freshwater contaminants' reduction from implementing different mitigations, with a long list of suggested practices used by the BOPRC in canvassing community groups in the targeted Water Management Areas as the starting point.

To make such assessment, we have completed a high-level review of the current literature related to on farm land use management practices and supplementary (technological) mitigation options, as well as our own experiences in evaluating cost to farmers and growers from implementing practice change, which has often involved analysis using Farmax and OVERSEER software.

We note that the literature reviewed is not consistent in its estimates or reporting of "cost" to farmers/grower in terms. "Cost" has previously been defined as everything from a relative cost assessment, gross (absolute) cost, cost as a percentage reduction in profit through to a cost per unit of contaminant reduced. With the emphasis in this piece of work being on the cost to farmers and growers, expressing the cost of a mitigation as the equivalent percentage reduction in annual operating profit (defined here as earnings before interest and tax) is probably of most help.

Based on the expected cost of mitigation options identified in the review, the potential mitigations will be structured into suggested low, medium and high cost mitigation bundles for subsequent modelling. Using a framework proposed by Macdonald (2018) (see Section 4 below), proposed mitigations will also be cross-referenced against effectiveness. This will ensure that potentially high cost mitigations with low effectiveness at reducing contaminant load will not be recommended.

2.1 Description of contaminants and key pathways to water

2.1.1 Sediment loss

Sedimentation happens in wetlands, lakes, slow-flowing parts of rivers and estuaries, when the sediment load received from the freshwater catchment exceeds their capacity to flush out the sediment. Sediment loads can be caused by mass movement, gully, sheet and rill, streambank and human induced ground erosions. Sedimentation might increase when there is land without (native and exotic) forestry[2] on steep slopes, land with heavily grazed vegetation, soils with poor infiltration and saturated soils. The sedimentation damages fish population, degrades benthic habitat, and smothers river beds.

2.1.2 Nitrogen loss

Nitrogen typically enters waterways as nitrate (NO_3-) through drainage, with such losses variable throughout the season based on rainfall, underlying pasture growth and soil moisture conditions. OVERSEER modelling can account for some of these drivers of loss rates. While direct losses are possible through fertiliser or effluent application [via overland flow], the uneven redistribution of N via the livestock urine patch is the primary driver of N loss in pastoral systems. Mineralisation of soil organic matter from cultivation or the excessive applications of nitrogen (to ensure N is non-limiting to a developing plant) are more typical drivers of loss in arable and horticultural systems.

Most mitigation practices in relation to reducing N loss to water focus on improving the N conversion efficiency of the agricultural system.

2.1.3 Phosphorus loss

While OVERSEER modelling can estimate average P losses from farming activity, the reality is that such losses are neither uniform across the relevant parts of the property, either spatially or temporally. It is recognized that 80% of all P losses from a pastoral farming operation come from 20% of the property (Gburek & Sharpley, 1988), particularly those areas where transport mechanisms (i.e. water flows) and contaminant sources , such as stock camping areas, water trough surrounds, coincide. These have been defined by McDowell & Srinivasan (2009) as critical source areas (CSAs).

While it is impossible to eliminate the creation of these CSAs within a farming or horticultural environment, strategies to slow the movement of storm water through ephemeral channels (to facilitate sediment deposition) or break the connectivity between ephemerals and these risk areas tend to dominate P loss mitigation.

2.1.4 Bacterial contamination

E. coli is used as an indicator of freshwater bacterial contamination from animal faeces and is one of the attributes of the “Human Health” water quality value. The higher *E. coli* indicate an increasing risk of infection in humans who use fresh water for primary and secondary recreation activities. *E. coli* enters streams through a direct deposition of faecal matter of livestock, discharges of dairy effluent into streams, overland flow from excess irrigation water and drainage. The main source of such freshwater contamination is ultimately grazing livestock.

[2] Including after forestry harvest

3 Assessment of mitigations

Descriptions of sediment and freshwater contaminant reduction and costs of mitigation options are given in Table 1 overleaf based on a review of published research. More detailed description of each mitigation option is given in Appendix 1.

In considering the mitigations in Table 1 below, it is important to recognise that the evaluations of effectiveness (“expected reduction [in losses] from baseline”) have been developed from a mixture of empirical research and modelled analysis. The reality is that the impact in real situations could be highly variable depending on individual situations. As such, the information presented should be considered useful for the purposes of relative assessment, rather than absolute accuracy.

Table 1: Summary of water contaminant mitigation practices to be considered in the Kaituna-Pongakawa-Waitahanui and Rangitāiki Water Management Areas

? = Uncertain

*Will include the annual opportunity cost of capital associated with capital investment

** Can include the annual depreciation cost of capital investment

Aspect	Mitigations	Expected reduction from baseline				Cost (% reduction in EBIT)* level	Initial capital	Operating (recurring) costs**	Additional details	References
		N leaching	P loss	Sediment	*E. Coli*					
Land use	Land use capability (LUC) class 6, 7 and 8 land that is currently in pasture converted into forestry/mānuka and fenced	4%	15%	80%	?	Medium (steep land) to High (easy contoured land)	$1,000-$2,000/ha	0	Opportunity cost is 100% of profits from the area occupied by trees, but generates income from trees over time.	Daigneault et al (2017); Doole (2015)
	Creation of new wetlands (assumes 1% of farm area)	40%	70%	80%	Up to 50%	High	$8,940/ha of wetland, including planting and fencing	$300/ wetland	One wetland can cover 400 ha of area	Daigneault and Samarasinghe (2015); Doole (2015); Low et al (2013)
	Management of gorse (e.g. replacing with pasture, mānuka or natives)	80%[1], 50%[2]	?	?	?	Medium	$1,000-$2,000/ha	0	Opportunity cost is 100% of profits from the area occupied by trees, but generates income from trees over time.	Magesen & Wang (2008)
	[Complete] Land use change to a less intensive use (e.g. sheep, deer, horticulture, forestry)	50%[3], 80%[4]	?	?	?	High		$140-$1,000/kg per N loss reduction	The cost levels occur depending on former and current land use practice. Excludes loss of capital value	Perrin Ag (2012)

[1] Area converting to trees

[2] Area converting to dry stock

[3] When converting from dairy to dry stock

[4] When converting from pasture to trees

Aspect	Mitigations	Expected reduction from baseline				Cost (% reduction in EBIT)* level	Initial capital	Operating (recurring) costs**	Additional details	References
		N leaching	P loss	Sediment	*E. Coli*					
Riparian management	Effective stock exclusion and planted buffer around water bodies	15% [1]; 5% [2]	10%[1] 5%[2]	40%	25-35%	Medium to high	$255/ha	0	A minimum of $255/ha, subject to the opportunity cost of buffer, its width and range of waterbodies are excluded.	Doole (2015); Keenan (2013); Monaghan and Quinn (2010)
	Stock water reticulation away from surface waterbodies	15% [1]; 5% [2]	10%[1] 5%[2]	40%	25-35%	Medium	$142-$601/ha	$3.13-$12.56/ha	Results in good medium-term payback, but some benefit may be extracted through higher carrying capacity, which may increase N losses	Doole (2015); Journeaux and Van Reenen (2017)
Erosion control	Swales, soak holes, slag socks, sediment ponds,	0	0-20% from swales	Swales: 40%; Sediment ponds: 50%	0	Medium to high	$255-$1,300/ha	0	Swales cost $255/ha; sediment ponds cost $750-1,300/ha,	Keenan (2013)
	Detainment bunds	0	Variable	Variable	?	Medium	$300-$500/ha of catchment	Elimination of P fertiliser from ponding areas	Detention bunds appear to be effective at catching particulate P in overland flow, but what this actually equates to on a farm or catchment scale is not fully understood. Not modelled in OVERSEER.	Clarke et al. (2013), Paterson (n.d.)
	Complete protection of gully heads	None	None	70-90%	0	High	$1,000-1,650/ha	0	Considering protection using afforestation	Daigneault et al (2017)
	Manage risk from contouring/ landscaping	?	?	40%	0	Low	0	$82/ha cropped	Implemented on cropped area	Keenan (2013)
	Spaced planting of poplars or willows on land use capability class 4-6 (steep erodible) land	None	20%	70%	0	Low to Medium		$34/ha	Costs are annualized	Daigneault and Elliot (2017)

[1] for dairy
[2] for dry stock

Aspect	Mitigations	Expected reduction from baseline				Cost (% reduction in EBIT)* level	Initial capital	Operating (recurring) costs**	Additional details	References
		N leaching	P loss	Sediment	*E. Coli*					
Access/crossing infrastructure	Access crossings, bridges, culverts over all waterways regularly crossed by stock	?	95%	99%	?	High	?	?	Can be a significant cost depending on the size of the catchment the waterway drains.	Low et al. (2017)
	Appropriate gate, track and race placement, design and maintenance (e.g. diverting effluent away from waterways, slope access tracks away from drains to reduce sediment loss and avoid water flowing across disturbed area)	?	?	?	?	Low to medium	?	?	Maintaining water tables and laneway camber is cheap to achieve, but shifting gateways out of flow paths can be costly if an existing race network also needs to be altered. At a whole farm level, contaminant reduction can be significant (up to 80% if all managed effectively)	McDowell & Srinivasan, 2009
Stock management	Appropriate stock type and stocking rates for land characteristics (e.g. sheep on steeper land)	21%	2%	None	?	Low to Medium	35% reduction in profits per hectare in comparison to baseline practice	None	Reductions in stocking rate of lamb finishing farms with some beef finishing	Doole (2015)
	Change in sheep to cattle ratio by increasing sheep ratio	19%	4%	None	?	Low	91% increase in profits per hectare in comparison to baseline practice		Includes hill-country beef farm with no sheep. Mitigation practice is introduction of sheep. Impact on profitability does depend on market.	Doole (2015)

Aspect	Mitigations	Expected reduction from baseline				Cost (% reduction in EBIT)* level	Initial capital	Operating (recurring) costs**	Additional details	References
		N leaching	P loss	Sediment	*E. Coli*					
Stock management	Rotation, grazing management (e.g. wintering off away from catchment or in less sensitive area within catchment)	36% for dairy; 16% for S+B	30% for dairy; 20% for S+B	40% for dairy; 10% for S+B	10% for dairy; 10% for S+B	Low	None	$2-$30/head/ week, depending on stock class and species	Can be costly, but a regular component of many dairy farm systems due to high rate of return. However, applicability as a mitigation moving forward ?	McDowell et al (2005); McDowell and Houlbrooke (2009)
	Appropriate location of feeding and stock drinking water through sites away from waterways	None	Varia ble	Variable	Variable	Medium	Variable		Extent of contaminant reduction depends on the extent of hydraulic connectivity from these CSAs	
	Responsible break-feeding practices	None	Up to 80%	Up to 80%	?	Low	None	2.5% reduction in crop areas	Should be no significant cost associated with this change in management approach.	Orchison et al (2013)
	Low leaching animal varieties	9%	None	None	None	Medium	Variable	Variable		Perrin Ag (2013)
	Dung beetles	?	?	?	?	Medium	$7,000 per farm for colony establish ment.		Insufficient field data in NZ to warrant serious consideration	
	Barns for intensive systems or in sensitive environments	15%- - 17%	15%	None	10%	High	$1,000- $2000/ cow	$171/ha	Less than half case study farms in Journeaux & Newman generated a return that exceeded their cost of capital. Utilising a barn to reduce N losses is unlikely to be profitable	Greenhalgh (2009); McDowell (2014); Perrin Ag (2013); Journeaux & Newman (2015); Daigneault et al. (2017)

Aspect	Mitigations	Expected reduction from baseline				Cost (% reduction in EBIT)* level	Initial capital	Operating (recurring) costs**	Additional details	References
		N leaching	P loss	Sediment	*E. Coli*					
Fertiliser management	Paddock/block-level fertiliser planning/nutrient budget based on soil tests and crop needs	10%	10%	None	None	Low		$500 per year	Gains likely to be in association with other practices highlighted by appropriate nutrient budgeting	
	Maintaining optimal soil phosphate levels	None	18%	None	None	Low		Potentially as high as $200/ha/year savings while mining excessive soil P levels	Extend of gain will depend on level of above optimal soil enrichment	Perrin Ag (2017c)
	Use of low solubility P fertiliser	None	6%	None	None	Low		None	The value of P in RPR tends to be lower than in superphosphate, but sulphur will generally also need to be added as well. The availability of the P from RPR will be limited initially, so best used in conjunction with mining of soil Olsen P levels	
	Efficient fertiliser use (e.g. not coinciding with rainfall, temperatures below 7 degrees Celsius, appropriate fertiliser types and timing of application, GPS-based application).	3%	?	None	None	Low			Costs based on fertiliser application level	Perrin Ag (2017a)
	Reducing fertiliser N use	15%-33%	None	None	None	Medium	May result in reduction in stock numbers if being used to support capital livestock	Net benefit-$350/year/kg N loss reduction	The extent of any profitability change tends to relate to the cost of any feed purchased in to replace the N boosted pasture or the amount of production forgone by the loss of the feed.	AgFirst (2009), Perrin Ag (2012)
	Use of plant growth regulators (Gibberellic acid)	4-29%	?	None	None	Low		$36/ha	Application level is 20 g/ha	Ghani et al. (2014), Bryant et al. (2016)

Aspect	Mitigations	Expected reduction from baseline				Cost (% reduction in EBIT)* level	Initial capital	Operating (recurring) costs**	Additional details	References
		N leaching	P loss	Sediment	*E. Coli*					
Feed and crop management	Low nitrogen-leaching pasture/fodder crop/imported feed varieties	33%	6% increase	None	None	Low		$87-$391/ha reduction in profits depending on reduction of maize	Represents hill-country bee-breeding farm without sheep and the use of maize-silage crop for dairy support	Doole (2015
	No tillage/low impact cultivation (e.g. along contours, appropriate for season, strip tillage, direct drilling)	10%	50%	25%	None	Low		$171/ha	Expected reduction of 10% in EBIT from arable cropping	Daigneault and Elliot (2017)
	Grass buffer strips (2-metre) around cropping paddocks	10-20%	15-30%	65%	80-95%	Low		$175/ha to be mitigated	Price is dependent on area, buffer width and vegetation used	Barber (2014); Low et al (2017); Wilcock et al, (2009)
	Cover crops between cultivation cycles	70-80% if planted in March; 25% if planted in June	None	None	None	Low		$80/ha for cropped area		Low et al (2017)
	Earth decanting bunds for intensive cultivation	None	None	87.5%	None	Low		$130/ha	Recommended capacity is 0.5% (50m/ha) for catchments less than 5ha, and 1% (100m/ha for catchments over 5ha	Barber (2014), Low et al (2013), Doole (2015)
	Alum applied to pasture or forage crops	None	30% at grazed croplands; 5-30% at pasture	None	None	High		On grazed land $160-$260/kg of P conserved; On grazed cropland $150-$500/kg of P conserved		McDowell (2010)
	Bauxite applied to critical source areas									

Aspect	Mitigations	Expected reduction from baseline				Cost (% reduction in EBIT)* level	Initial capital	Operating (recurring) costs**	Additional details	References
		N leaching	P loss	Sediment	*E. Coli*					
Effluent management	Solid separation					Medium to high				
	Closed loop effluent recycling	?	?	?	?	Medium	$397,000 (based on stated payback of 7.5 years and a suggested $53,000 annual gap between annual costs of pond system versus the FORSI system)	$18,000 per annum	Still require solids separation (via a screen) and disposal of solids to land. No trial work available, but concept has long term potential for farms constrained by soil moisture levels for land-based liquid effluent disposal	Forsi systems
	Farm Dairy Effluent ponds: sufficient holding capacity to comply with soil moisture application standards and fully lined	?, but as much as 5%	10-30%	0	?	Medium	$30,000-$100,000 depending on size of farm	$30/kg of P conserved	High capital cost	McDowell (2010), Low et al. (2017)
	Maize on the effluent block	Variable	None	None	None	Low		$140/ha benefit assuming half of N fertiliser could come from effluent	Should allow a reduction in base N fertiliser requirements	FAR 2008, Johnstone et al 2010).
	Efficient application that complies with soil moisture standards and crop needs, more than 20 metres away from all waterbodies	Variable	Varia ble	0	Varia ble	Low to medium			$500 for basic soil moisture probe, but on high risk soils more investment may be required	
	Increase application area to reduce application concentration	Variable	Varia ble	0	Varia ble	Medium to high			Depends on spatial layout of the farm and existing effluent areas	

Aspect	Mitigations	Expected reduction from baseline				Cost (% reduction in EBIT)* level	Initial capital	Operating (recurring) costs**	Additional details	References
		N leaching	P loss	Sediment	*E. Coli*					
Irrigation	Efficient irrigation application based on soil moisture deficit monitoring, awareness of soil type/infiltration rate and assessment of crop needs and expected rainfall	10%	None	None	None	Low		\$58/ha of annualized costs		McDowell et al (2013), Strong (2001)
Denitrification	Use of nitrification inhibitors	10%	None			Medium			Products currently banned for use in NZ	Di & Cameron (2007)
	Denitrification technology (i.e. Spikey)	10%	None	None	None	Medium	Investment in equipment	Potentially increased pasture production could offset increased costs, but limited field trials	Moderate capital investment, returns potentially good, but inadequate field trials	Bates & Bishop (2016)
	Denitrification beds	25%	None	None	None	High		\$137/ha of annualised cost	High capital cost plus. Loss of some fertiliser value from dairy effluent	Schipper et al (2010); McDowell (2013)

4 Proposed mitigation bundles

In contrast to Vibart et al. (2015) and Monaghan et al. (2016), in this study the mitigation practices that are summarised in Table 1 have been bundled based on their cost level (expressed as a reduction in pre-mitigation farm profit as measured by EBIT), but first having been filtered based on their effectiveness as proposed by Macdonald (2018). This framework is presented in ***Figure 1*** below.

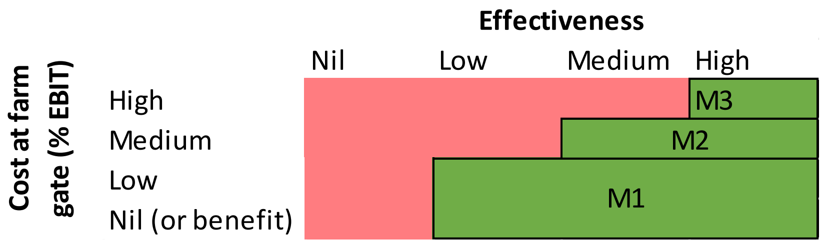


Figure 1: Bundling framework as suggested by Macdonald (2018)

For clarification, the "cost" of mitigation should include the opportunity cost of any capital employed and the loss of value (depreciation) over time, even though the former isn't captured in EBIT. These total mitigations are simply being considered in relation to amount of pre-tax profit that might be consumed as a result of its implementation.

The bundles are therefore broadly defined as:

(i) M1: low barrier to adoption; primarily defined by being of low cost (equivalent to less than 10% of EBIT) with a minimum least low effectiveness;

(ii) M2: moderate barrier to adoption; primarily defined by direct costs and/or lowered revenue equivalent to more than 10% but less than 25% of EBIT and at least medium effectiveness for the targeted contaminant;

(iii) M3: high barrier to adoption, primarily defined by significant reductions in pre-mitigation profitability (>25% EBIT) and high effectiveness at contaminant reduction;

The mitigation bundles are designed to be applied cumulatively to farm and orchard systems i.e. M2 mitigations are applied only after applicable M1 mitigations have been implemented on farm.

This framework potentially includes two additional bundles, which have not been listed in the following tables:

(i) M0: existing mitigation management practice already assumed to be largely in place within farm systems (such as stock exclusion of dairy cattle from some waterways) with essentially no cost to adoption.

(ii) M4: total land use changes

Based on the above, the proposed mitigation bundles M1 to M3 for this analysis are presented in Table **2** through to Table **4** overleaf.

Table 2: Summary of the proposed M1 mitigation bundles to be considered (as applicable) in the Kaituna-Pongakawa-Waitahanui and Rangitāiki Water Management Areas

Mitigation bundle	Land use type				
	Dairy pastoral	Non-dairy pastoral	Arable	Horticulture	Forestry
M1	▪ Full stock exclusion from all large waterbodies, all wetlands and 3m planted buffer[1] ▪ Relocation of troughs and placement of feeding equipment ▪ Adoption of low N leaching forages ▪ Reduced tillage practices ▪ Laneway run-off diversion ▪ Efficient fertiliser use: ○ Maintain optimal Olsen P ○ Improved nutrient budgeting ○ Use of plant growth regulators [to replace N] ▪ Efficient irrigation practices (soil moisture monitoring) ▪ Grow maize on effluent blocks ▪ Timing of effluent application in line with soil moisture levels (assumes sufficient storage)	▪ Full stock exclusion from all large waterbodies, all wetlands and 3m planted buffer ▪ Targeted space plating of poles ▪ Stock class management within landscape ▪ Relocation of troughs ▪ Adoption of low N leaching forages ▪ Some no tillage practices ▪ Maintain optimal Olsen P ▪ Efficient fertiliser use ▪ Appropriate gate, track and race placement, design	▪ Grass or planted buffer strips ▪ Complete protection of existing wetlands ▪ Cover crops between cultivation cycles ▪ Manage risk from contouring ▪ Reduced tillage practices ▪ Maintain optimal Olsen P ▪ Efficient fertiliser use	▪ Complete protection of existing wetlands ▪ Laneway run-off diversion ▪ Maintain optimal Olsen P ▪ Efficient fertiliser use ▪ Efficient irrigation practices (soil moisture monitoring)	▪ Management of gorse ▪ Laneway run-off diversion ▪ Complete protection of existing wetlands

[1] As noted above, it is assume some stock exclusion is already in place under current practice (M0).

Table 3: Summary of the proposed M2 mitigation bundles to be considered in the Kaituna-Pongakawa-Waitahanui and Rangitāiki Water Management Areas

<table>
<tr><th rowspan="2">Mitigation bundle</th><th colspan="5">Land use type</th></tr>
<tr><th>Dairy pastoral</th><th>Non-dairy pastoral</th><th>Arable</th><th>Horticulture</th><th>Forestry</th></tr>
<tr><td>M2</td><td>▪ Full stock exclusion from medium size waterbodies and 3m planted buffer
▪ Detention bunds
▪ Complete protection of gully heads
▪ Reductions in seasonal stocking rate
▪ Controlled grazing with stand-off pads
▪ Reducing fertiliser N use
▪ Lined effluent storage
▪ Increase effluent application area</td><td>▪ Full stock exclusion from medium size waterbodies and 3m planted buffer
▪ Convert LUC class 6-8 pasture land into forestry/mānuka and fenced
▪ Management of gorse
▪ Stock reticulation away from surface waterbodies
▪ Detention bunds
▪ Complete protection of gully heads
▪ Whole paddock space planting of poles
▪ Reductions in seasonal stocking rate
▪ Changing stock ratios to reflect lower N leaching potential</td><td>▪ Swales
▪ Complete protection of gully heads
▪ Reducing fertiliser N use
▪ Strip tillage</td><td></td><td></td></tr>
</table>

Table 4: Summary of the proposed M3 mitigation bundles to be considered in the Kaituna-Pongakawa-Waitahanui and Rangitāiki Water Management Areas

Mitigation bundle	Land use type				
	Dairy pastoral	Non-dairy pastoral	Arable	Horticulture	Forestry
M3	▪ Stock excluded from, and planted buffers adjacent to, a wider range of waterways (e.g. ephemeral, seeps, small streams) ▪ Nil/restricted grazing (with barns) ▪ Partial afforestation of easier contoured land ▪ Creation of new wetlands ▪ Reducing stocking rates ▪ Alum applied to pasture ▪ Denitrification beds ▪ Adoption of new irrigation infrastructure	▪ Buffer around excluded water ways (7m) OR ▪ Stock excluded from, and planted buffers adjacent to, a wider range of waterways (e.g. ephemeral, seeps, small streams). ▪ Creation of new wetlands ▪ Alum applied to pasture ▪ Reducing stocking rates	▪ Creation of new wetlands ▪ Sediment traps		▪ Creation of new wetlands

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6 Appendix 1

6.1 Land use

6.1.1 Land use capability (LUC) class 6, 7 and 8 land that is currently in pasture converted into forestry/mānuka and fenced

In areas where potential pasture production is low (<4t DM/ha), conversion from pastoral farming to forestry is likely to have minimal impact on farm profitability when considered on the basis of long term pricing for timber and animal products. Costs are mainly related to tree plantation establishment and harvesting, and opportunity cost of alternative land use. For instance, Perrin Ag (2013) found that when afforestation of steep hill country was modelled on case study farms in the Upper Waikato, there was limited (if any) reduction of long term enterprise operating profit. However, the precise forestry regime, harvest requirements and location relative to ports and/or mills can have significant impacts on forest profitability. We note also that the recent National Environmental Standards for Plantation Forestry place limits on the afforestation of land deemed to be of very high erosion susceptibility.

The economics of plantation mānuka for honey production are questionable given current establishment costs, yields and price and the suitability of targeted lands for the cost-effective harvest of the biomass needed for oil extraction is likely to be low.

6.1.2 Wetland and ephemeral flow path management and protection

Stock exclusion from wetlands is recognised as having positive impacts on downstream water quality. A study of a Waikato hill country seepage wetland by Hughes et al (2013) found that cattle actually spent little time grazing in the shallow wetland and the direct effects of their grazing were minor, fluxes of cattle derived pollutants and damage to wetland margins and vegetation were detected. However, deeper wetlands tend to be avoided by livestock and don't spend sufficient time in them to have a notable effect on contaminant load or sediment disturbance.

On balance, given the loss of productivity from excluding livestock from wetlands is likely to be low and the concern about the long-term effect on water quality from stock access and exclusion is a sensible practice and likely to be achievable with limited cost.

The actual development of new artificial wetlands can be extremely expensive and as a result are often better considered at a whole-of-catchment scale. The review by Low et al (2013) suggested the cost could be between $550 and $7,500/ha, depending on the extent of nutrient and sediment capture desired and the nature of the existing flow in planned wetland area. In contrast, the study by Daigneault and Samarasinghe (2015) estimated that each new wetland can cost $100,000 that covers 400 ha of area. The capacity of new wetlands to take up nutrient losses from the receiving catchment is significant, although this can take a number of years to do so and such features will eventually reach equilibrium. Also, there are high positive impacts of wetlands in reducing *E. coli* (50%) and sediment losses (80%) (Low et al., 2013; Daigneault and Samarasinghe, 2015).

6.1.3 Management of gorse (e.g. replacing with pasture, mānuka or natives)

From a fundamental point of view, the eradication of gorse and conversion to alternative ground covers is likely to result in a reduction in N loss to water. Magesan & Wang (2008) calculated nitrogen losses to water from mature gorse stands in the Rotorua catchment at 36kg N/ha and 40kg N/ha, which would be equivalent to losses from either intensive dairy support activity or extensive dairy farm systems in the same area. However, there is insufficient information in the literature on the effect of gorse on P losses, sediment and *E. coli*.

6.1.4 Land use change to a less intensive use (e.g. sheep, deer, horticulture, forestry)

Land use change to less intensive activities can substantially change the nutrient leaching, erosion and *E. coli levels*. However, currently, such practice tends to have limited appeal for land owners. This is typically a result of the following factors:

- Cost of transition can be high i.e. cost of orchard development ($220,000/ha for kiwifruit pergolas and shelter), deer fencing (>$20/m) and handling facilities;
- Barriers to entry to the supply chain of lower intensity alternatives with profitable returns i.e. licences for crop varietals (G3 kiwifruit licence), supplier shares (i.e. Dairy Goat Co-op milk supply rights), limited markets for supply (sheep milk);
- Likely loss of capital value with “permanent” land use change including potentially low salvage value of prior investment (i.e. dairy land being planted in radiata pine);
- Perceived or real loss of profitability and annual cash flow, particularly where existing businesses are moderately or highly geared (pasture land converting to forestry);
- Inadequate land owner knowledge of the alternative land uses;
- Personal preference.

6.2 Riparian management

6.2.1 Effective stock exclusion and planted buffers around drains, rivers, streams and lakes

Effective stock exclusion and riparian fencing with planted buffer includes vegetation around rivers, streams and lakes. A summary of the existing literature by Doole (2015) suggests that the width of the buffer does have an impact on the extent of N loss reduction, but whether this is due to a greater interception area or a reduction in pastoral area (with a commensurate reduction in stocking rate) is unclear.

Such a mitigation option focuses on preventing livestock from direct deposition of manure into these waters or direct stream bank erosion using the planted buffer. This management option will have a substantial reduction in sedimentation and *E. coli*, while to a lesser extent in reduction of N leaching and P losses. There is a concern that nutrient cycling within the riparian areas can act as an indirect source of N and P loss if planted vegetation is not regularly cut and removed (Collier et al, 2013). According to Doole (2015), use of 5-metre pastoral buffer strip can reduce actual N leaching of about 15% and 5% for dairy and dry stock farms respectively, assuming livestock had access to water ways previously.

For P loss reduction the levels are even more modest than for N leaching mitigation, and is about 10% and 5% for dairy and dry stock farms (Doole, 2015). In addition, based on estimates of Keenan (2013), Daigneault et al. (2017a) showed that it is possible to reduce 40% of sediment with grass buffer strips. The type of vegetation within the buffer is unimportant as long as there is no bare ground. The cost of establishing riparian vegetation strip is around $255/ha for horticulture (Keenan, 2013), but this will vary depending on the choice of any planted vegetation.

To date, most of the regulation and voluntary practice change around riparian management has been centred on high order (i.e. large) water bodies and lowland drains. However, McDowell et al (2017) found that 77% of national contaminant load was coming from lower-order (i.e. smaller) streams that are not currently required to be fenced. With P being the primary nutrient entering water ways from overland flow and direct [stock] deposition, the fencing of low-order streams in areas of high P load may be extremely effective in reducing pollution.

As regards to the relative cost and challenge to adoption, Vibart et al (2015) considered excluding dairy cattle from waterways to fall into an M1 bundle, sheep & beef cattle into M2 and utilising a buffer strip (7m) within M3.

6.2.2 Stock water reticulation away from surface waterbodies

The replacement of natural water sources with reticulated supply for livestock has the potential to improve the profitability of the pastoral operations where it is implemented, although the installation of reticulated supply is likely to require additional co-investment. Journeaux & van Reenan (2017) found in a study of 11 farmers that stock water reticulation can result in the significant internal rate of return of 53% on average. Such mitigation option can reduce *E. coli* and sediment by about 30% and 40% respectively, and with contribution on N leaching and P loss of about 10% depending on livestock type. However, stocking rate tended to increase with the introduction of reticulated stock water in the case study farms, which may in practice, lead to limited (if any) reductions of N loss to water.

6.3 Erosion control

6.3.1 Swales, soak holes, slag socks, sediment ponds, detention bunds/dams

Sedimentation (or erosion) can be controlled using swales, soak holes, slag socks, sediment ponds, detention bunds/dams. Swales are broad grass strips (like riparian grass buffer strips) used to treat sedimentation. Such practice can reduce sedimentation by 40%, in contrast to the baseline land use practice such as horticulture and pasture grazing, but is highly slope dependent. The cost of such practice is about $255/ha (Keenan, 2013).

A constructed soak hole can act as a sediment trap, where sediment is collected and left to discharge to a controlled outlet or soak into the ground.

Slag socks are installed sock technologies/materials that intercept and address sedimentation of clay particles. Sediment retention ponds are constructed ponds to trap sediment at bottom of sub-catchment to tackle surface erosion and are suitable for all farm land use types. The sediment ponds can reduce erosion by 50% in comparison to farming practices, and cost of such mitigation option ranges between $750 and $1300/ha of catchment (Keenan, 2013). Detention bunds/dams or debris dams are effective in trapping erosion and associated P from water leaving pastoral farmland during rainfall and runoff events, and their effectiveness depends on influent load in the ephemeral stream. Detainment bunds temporarily pond ephemeral water (via controlled outflow) behind an earth bund (about 1.5 m high) for settling sediment and associated nutrients to onto the pasture and become part of the soil matrix (Clarke et al., 2013). Clarke et al. (2013) observed the largest retention of sediment and P was 2.7 t and 6.8 kg of P respectively in just one ponding event, but what this equated to on a whole far, scale wasn’t apparent. Average P retention in the Hauraki Stream catchment is 0.2 kg of P per ponding event that could save $28,000 for lake restoration costs over 20 years (Clarke et al., 2013).

6.3.2 Complete protection of gully heads

Once gullies have begun to form they must be treated as soon as possible to reduce negative consequences. To control gullies, building detention dams or bunds and revegetation such as afforestation and space-planting should be undertaken. Afforestation plantations can reduce erosion by 90% from the baseline if trees are not harvested (reduce erosion by 80% if trees are harvested) and can cost farmers $1000/ha (Daigneault et al, 2017). Space planting assumes that areas are planted and all tree plantations are maintained. Such land use practice can reduce sedimentation by 70% and costs $1650/ha (Daigneault et al, 2017). Typically dams are used in combination with tree plantations to control the runoff into gullies to trap sediment within gully systems.

6.3.3 Manage risk from contouring/landscaping

Tillage practices and cultivation on slope ridges can increase erosion. Contour strip cropping can be used and includes strip of pasture or small grain alternation with a strip of row crops. Ridges in contour strip cropping reduce the possibility of erosion. Contour strip cropping can reduce soil erosion by as much as 50% as comparing to farming up and down hills (USDA, 2013).

Cover crops are cultivated often solely to manage erosion. Planting cover crops can lead to the seasonal reduction in surface erosion in contour farming by planting legumes, cereal rye, clover and other crops in horticultural farms. According to Keenan (2013), erosion reduction effectiveness of cover crops is 40% from baseline erosion, which can cost $82/ha in an arable situation.

6.3.4 Spaced planting of poplars or willows on land use capability class 4-6 (steep erodible) land

While the space-planting poles on erosion prone hill country has long been accepted as an effective means of reducing erosion (Hicks 1995), the economic imperative for it is not great. Analysis by Parminter et al (2001) concluded that the productivity gain from soil retention was typically less than the suppression effect from shading on pasture dry matter production and that only on highly erodible soils and where farmers were happy with low returns on the investment from planting was the cost-benefit positive for the landowner. This analysis excluded the potential public good benefit from reducing soil erosion.

6.4 Stock management

6.4.1 Appropriate stock type and stocking rates for land characteristics (e.g. sheep on steeper land)

Treading damage to soils from livestock is recognised to have the potential to increase both the risk of surface run-off and the loss of sediment, phosphorus and nitrogen in any run-off. This risk is heightened in periods of high soil moisture, which in New Zealand typically coincides with the winter period. Nguyen et al (1998) concluded that intensive winter grazing on hill country pasture is potentially a major source of contaminant runoff to receiving waters. This is more likely to occur with [older] cattle than with sheep, but the lower pasture covers potentially achievable under sheep grazing regimes (albeit not desirable from an animal performance perspective) can expose soil to greater erosion risk. Limiting/excluding cattle older than 18 months from steeper hill slopes during winter is a recommended practice.

The risk of soil erosion from deer pacing fence lines on fragile soils can be significant but can be successfully managed by a combination of sensible fencing solutions (including remedial options for existing farms) and stock management practices (New Zealand Deer Farmers' Association 2012). However, the introduction/expansion of deer onto properties with more fragile soils (i.e. pumice) does need to be considered carefully.

The impact of stocking rate and stock type on N loss to water is reasonably well understood, with the urine patch the primary driver of N loss to water in pastoral grazing systems. As a result of urinary dynamics cattle will have a higher N loss signature than deer or sheep, and female stock a greater N loss signature than males. All things being equal, higher stocking rates will generate higher N loss to water as a result of higher quantities of N cycling through the farm system and more N therefore subject to the inefficient return via the urine patch. According to Doole (2015) appropriate stock type and stocking rates have lower P loss (2%) than N leaching (21%) reduction, and can lead to profit reduction of 35% per hectare in comparison to the baseline practice. Temporal dynamics are increasingly recognised as being important, with late summer/autumn urine patches to pasture potentially having more impact that those deposited in the late winter, even with higher underlying soil drainage.

6.4.2 Rotation, grazing management (e.g. wintering off away from catchment or in less sensitive area within catchment)

The grazing of stock off-farm as a management practice has typically been limited to dairy farm operations, where either:

(i) a reduction in dry period feed demand is a cost-effective solution to shift feed into the early spring period to support the higher feed demands associated with lactation; or
(ii) the removal of replacement heifer feed demand allows an increase in the stocking rate of cows in-milk, with an increase in the marginal return per kg DM consumed.

The improvement in system N conversion efficiency from both strategies, as well as the reduction in urinary N deposition at a period of high drainage and low pasture growth from these management practices has also typically resulted in a reduction in direct farm N losses to water. In addition, there is high conversion efficiency for P loss, *E. coli* contaminant and erosion reduction, depending on livestock type, from rotation and grazing management. For instance, implementation of such mitigation options at dairy farm can reduce 30%, 40% and 10% of P loss, sediment and *E. coli* with a $9-$30/head/week (McDowell et al., 2005; McDowell and Houlbrooke, 2009).

However, the “exporting” of N and P loss, *E. coli* and sediment from one catchment to another as a mitigation strategy is potentially only a short-term solution, as the importance of water quality in receiving water bodies across New Zealand is of increasing importance.

6.4.3 Appropriate location of feeding and stock drinking water trough sites away from waterways

The importance of reducing the hydraulic connectivity of critical source areas from flow paths and waterways has been highlighted by McDowell & Srinivasan (2009). However, to reduce the cost of installation the location of stock facilities (primarily troughs) have often been placed adjacent to stock access ways, which can commonly be in flow paths. The cost of mitigation will depend on the distance required for relocation and whether the reticulation system has sufficient pressure to deliver water to the new location.

6.4.4 Responsible break-feeding practices

Research conducted by Orchiston et al (2013) demonstrated that break feeding [winter] forage crops with a view to managing overland flow dynamics within the crop paddock (cows entering at top end of the paddock, strip grazed moving in a downhill direction, protection of critical source areas from grazing, back-fencing every 4-5 days) resulted in a considerable reduction in the yields of sediment and nutrients carried in the flow. The cost of achieving such reductions was assessed as low (including a loss of 2.5% of potential crop yield through loss of area cropped).

6.4.5 Low leaching animal varieties

The relative profitability of the sheep, cattle and deer enterprises has a significant impact on the likely profitability of using livestock system change to reduce nutrient losses. While increasing the sheep/deer to cattle ratio tends to lower nitrogen losses, depending on their positions within their respective commodity cycles, implementing such a change might not lead to an increase in profitability if the lamb price is low in comparison to the beef price. Changes in livestock policies, particularly where breeding stock is involved, often have significant lag periods before increases in profitability are achieved and are not easily reversed once implemented. Altering specie ratios may also present challenges for the management of pasture quality and parasite burden.

6.4.6 Dung beetles

Initial NZ research (Forgie et al 2014) is suggestive that dung beetle activity in New Zealand pastures will result in reduced surface run-off, which is in line with the limited global research in this area (Brown et al 2010, Doube 2008). However, the impact of such reduction in surface run-off would have on suspended solids, bacterial load and/or nutrient loss has not been quantified.

6.4.7 Stand-off pads or barns in dairy farm systems

Feed pads have limited impact on reducing contaminant loads to water given:

(i) the short period of time they tend to be in use; and
(ii) that the benefits from potential improvement in feed utilisation is typically captured by increased milk production, not reduced feed use, so the quantum of nutrients cycling through the farm system increases.

The use of stand-off pads in conjunction with duration-controlled[3] grazing throughout the season has, based on empirical trial work, the potential to significantly reduce the loss of N in drainage to water (in the order of 30%-40%). P loss reduction is lower than N leaching and is close to 15% reduction, while *E. coli* mitigation is about 10% lower than the current/baseline dairy farm practice (McDowell, 2014; Perrin Ag, 2013; Journeaux and Newman, 2015; Daigneault et al. 2017). However, this may come at the cost of lowered pasture production due to the changes in both the timing and form of the application of nutrients from animal excreta to the pasture (Christensen et al 2011).

Journeaux & Newman (2015) concluded, based on an analysis of 14 case study dairy farms that, in general, "inclusion of a barn without intensification of the farming system will result in a reduction in nitrogen losses, but at a (potentially significant) cost… [and] that intensifying the farm system to make the barn profitable often results in a rapid erosion of the environmental benefits". A 2013 analysis of a dairy support operation in the Taupo-Ohakuri catchment, part of the Upper Waikato Drystock Nutrient Study (Perrin Ag 2013), assessed that installing a wintering facility resulted in a reduction in EBIT of ($113)/ha (23%) for a 17% reduction in N loss. At the same time, in average terms the annual operating costs are about $171/ha (Greenhalgh, 2009; Daigneault et al. 2017). A significant increase in the rate charged for contract winter grazing was required to offset the loss in profitability.

[3] Where cows graze for only 4 hours each morning and evening to consume their desired daily pasture intake and are then removed from the pasture for rumination. This differs from restricted grazing, where cows are totally withheld from the pasture during a given period (say autumn & winter) and pasture is harvested and fed to the cows on a pad or barn facility.

Capital costs to farmers will tend to be less for stand-off pads than that for barns, but the costs can vary widely and can be between $1,000 and 2,000 (Greenhalgh, 2009; Daigneault et al. 2017).

6.5 Pasture/crop management

6.5.1 Low nitrogen-leaching pasture/fodder crop/imported feed varieties

There are a number of alternative forage species that early research indicates have the potential to lower farm N loss to water, albeit such impacts are not well captured in OVERSEER.

Lucci et al (2015) found evidence that suggested chicory planted after a winter brassica crop recovered greater amounts of winter deposited N than a conventional ryegrass white clover sward, but this is yet to be captured in OVERSEER. Analysis by Perrin Ag (2017) indicted replacing summer brassica crops with chicory had a positive impact on farm profit, but the impact on N loss reduction as expressed in OVERSEER was limited to differences in cultivation, not crop variety.

Modelling by Khaembah et al (2014) suggested that diverse pasture mixes (containing at least 50% of alternative species such as plantain and chicory) could result in reductions in urinary N concentration and hence N leaching), but the economic impact was not determined. Subsequently, Edwards et al (2015) observed a 20% reduction in cow urinary N concentration for cows grazing a diverse pasture sward compared to those on conventional ryegrass/white clover. In similar research, Box et al (2016) found cows grazing a monoculture of plantain had reductions in urinary N of up to 56% from that of cows grazing conventional pasture. Again, insufficient data exists to include such impacts within the OVERSEER model, but the impact on productivity through the introduction of high herb content swards is unlikely to be significant, particularly if winter active varieties are selected. Doole (2015) found that substitute of maize-silage crop with low nitrogen imported feed can reduce N leaching 33% than the current feed given to livestock. However, such imported feed increased P loss by 6% and resulted in profit reduction of $87 and $391/ha depending on reduction of maize.

The Forages for Reduced Nitrogen Leaching (FRNL) project (Dairy NZ 2017) has found that leaching from a urine patch was 25-35% lower under Italian ryegrass based pastures than under other types of pastures due to cool-season N uptake of Italian ryegrass.

6.5.2 No tillage/low impact cultivation (e.g. along contours, appropriate for season, strip tillage, direct drilling)

It is generally accepted that the establishment of crops or forages using conventional “full” cultivation methods result in greater rates of mineralisation of N in soil organic matter than no-till alternatives. However, the impact that this has on actual N loss on soil drainage can be variable. Carran (1990) found that a similar amount of nitrate was present in the sub-soil in mid-winter after establishment of spring sown wheat crops out of established pasture irrespective of tillage method. However, research to date in the FRNL project found that compared with conventional tillage, direct drilling autumn-sown forage crops reduced the compaction that results from winter grazing, leading to as much as a 20% improvement in the yield of a subsequent cereal [catch] crop, which in turn increases N uptake from the soil. According to Daigneault and Elliot (2017), eliminating crop disturbance from tilling can also reduce P loss and sediment along with N leaching but reduce EBIT of arable crops by 10%.

In practice, there is little difference in the cost of establishment of crops using no-till techniques, with greater weed and pest control often required. However, irrespective of the impact on freshwater and water contaminants reduction, direct drilling or strip tillage will lower the risk of run-off and soil loss and represent a useful practice change on farm.

6.5.3 Winter forage crop management

Lucci et al (2013) assessed that the major risk of N losses associated with winter forage crops was associated with the risk of redistribution of N in the crop via the urine returned to the soil via grazing animals. Their research on crop establishment on pumice soils demonstrated no loss of yields associated with direct drilling compared with conventional cultivation (which would typically be expected to lead to greater mineralisation) and the potential for forage brassicas to remove high levels of mineral N from the soil during growth. Their research also suggested that total DM yields did not increase with fertiliser N applications in excess of 200kg N/ha.

Research by Carlson et al (2013) also indicated the N losses from grazed winter forage brassicas might be reduced through later season (i.e. late July), rather than earlier season grazing (June), further complemented by ensuring the subsequent crop had the potential to uptake significant amounts of mineral N still in the soil.

6.5.4 Grass buffer strips (2-metre) around cropping paddocks

The appropriateness of grass buffer strips of this width is essentially limited in application where there is little risk of surface run-off and they are essentially in place to deliver livestock exclusion from flow paths or stream channels (McKergow et al, 2007). In a cropping context, such width strips are best used for the exclusion of stock from critical source areas whilst grazing forage crops (see Responsible break-feeding practices above). Grassed swales used for controlling overland flow through ephemeral flow paths amongst arable cropping activity should ideally be 3m wide (Barber 2014). Grass buffer strips are particularly effective in reducing sediment loss and *E. coli* (Wilcock et al., 2009; Barber 2014; Low et al., 2017).

6.5.5 Cover crops between cultivation cycles

Cover crops are usually grown to be ploughed into the soil, but not harvested or grazed, in order to improve soil quality. Cover crops stabilise soil, accumulate nutrients left from previous land uses, improve drainage and soil structure, and can fix nitrogen (for some cover crops). Such cropping practices are suitable for all farm land use practices (Low et al, 2017). The N leaching reduction from cover ranges depending on crop and season, and can be about 70-80% reduction from the baseline for cover crop sown in March, and about 25% reduction for cover crop sown in June. The cost of cover crop cultivation is approximately $80/ha, depending on cover crop. However, this land use has some limitations as it might lead to substantial reduction in N leaching for some crops, e.g. barely, while have meagre effect on the whole farm outcomes (Low et al, 2017).

6.5.6 Earth decanting bunds for intensive cultivation

An earth decanting bund for intensive cultivation is a temporary berm of compacted soil to create a damming area where ponding can occur (Low et al., 2017). Earth decanting is established along the flat contours at the bottom of paddocks. The paddock can hold the runoff to drop out the sediment by moving the headland further up the paddock (Low et al., 2017). According to Doole (2015) the efficacy in sediment reduction of earth decanting bunds in the Lower Waikato region is 87.5% and its cost is $130/ha.

6.5.7 Rain-activated alum dosing sediment ponds

TBC

6.5.8 Alum applied to pasture or forage crops

Another option to mitigate P loss is to decrease the source by adding P-sorbing agents such as aluminium sulphate (alum). In cases when alum can bind to the soil before being washed off, it can be effective to decrease P loss. Application of alum to grazed cropland can reduce P loss by 30%, compared to untreated land use and can cost between $160 and $260/kg of P conserved (McDowell, 2010). Alum use on pasture can be effective to reduce P loss by 5 to 30% than under the baseline land use practices, and costs range from $150 to $500 /kg of P conserved (McDowell, 2010). The cost-effectiveness will be influenced by the availability of a ready source of cheap materials. Alum for P loss reduction might be obtained as a by-product from the fertiliser industries.

6.5.9 Bauxite applied to critical source areas

TBC

6.6 Access/crossing infrastructure

6.6.1 Access crossings, bridges, culverts over all waterways regularly crossed by stock

Surface runoff from farming is a great source of P, sediment load and *E. coli* loss to waterways is considered even to have higher pollution than runoff from pasture (Low et al., 2017). Management requires good track design, bunding of culverts and bridges. Implementation of such mitigation options can help to decrease total P loss in runoff by 95% and suspend sediment by 99% (Low et al., 2017).

6.6.2 Appropriate gate, track and race placement, design and maintenance (e.g. diverting effluent away from waterways, slope access tracks away from drains to reduce sediment loss and avoid water flowing across disturbed area)

This essentially comprises the management of critical source areas (with hydraulic connectivity) discussed by McDowell & Srinivasan in 2009.

6.7 Fertiliser management

6.7.1 Paddock/block-level fertiliser planning/nutrient budget based on soil tests and crop needs

The value of whole farm paddock soil testing is questionable. Withnall (2015) suggests that dairy farms utilising this technique are reducing the range in soil fertility status over their farm (i.e. applying less nutrients to areas of high fertility and more nutrients to areas of low fertility), potentially implying that the incidence of [P] fertility above optimal levels is lowered. However, Edmeades (2011) notes the inherent variability in the soil test results for typically tested nutrients and fertility measures, highlighting the reality that a soil Olsen P measure of 20ppm and 30ppm could both be 25ppm. He suggests that taking soil tests (20 cores from a transect) from blocks of similar soil group, slope, land use, and past management history still represents the best process and cost-efficient method for identifying soil nutrient status.

6.7.2 Maintaining optimal soil phosphate levels

Lowering soil Olsen P status provides one of the most powerful mitigations as regards reducing P loss that is quantifiable in OVERSEER. For example, Morton and Roberts (1999) state that near maximum pasture production is achieved at soil Olsen P levels of 38 on pumice soils. However, on rolling contour, soil Olsen P levels of this nature massively increase the risk and extent of P loss. Given both the typical utilization of pasture grazed in situ on dry stock properties and the economic returns from dry stock farming activities, it is questionable as to whether there is an economic return from maintaining soil P reserves at these levels.

Econometric analysis presented by Edmeades in 2008 indicated that the economically optimal soil Olsen P level at a superphosphate price of $400/t can vary between 10 and 24 depending on the level of underlying farm profitability (as expressed in terms of gross margin).

6.7.3 Efficient fertiliser use (e.g. not coinciding with rainfall, temperatures below 7 degrees Celsius, appropriate fertiliser types and timing of application, Geographical Positioning System[GPS]-based application).

Analysis of Grafton et al (2011, 2013) infers that at an application rate of 100kg/ha of urea (46%), lowering the coefficient of variance (CV) of spread from 40% to 20% improves the observed DM response rate in pasture from N fertiliser from 10:1 to 11.2:1. This relationship was the basis for the assumption that N fertiliser application can be reduced to 89.2% of pre-precision technology levels without reducing DM production, cow intakes and milk production. Analysis by Perrin Ag (2017b) indicated that for farms of a suitable scale, use of precision fertiliser spreading technology was likely to increase profitability while reducing N losses.

Grafton et al also comment that reduction in CV of spread for superphosphate would reduce risk of accidental discharge into sensitive (i.e. riparian, drainage) areas etc. However, this is not able to be modelled in OVERSEER, nor is there sufficient research to establish whether phosphate fertiliser applications could be reduced as a result of this technology without compromising existing soil P reserves (as measured by Olsen P).

However, adoption of what is generally considered best practice in relation to the application of fertiliser would be expected to reduce the risk of direct nutrient loss to water. Such practices would include applications being undertaken in accordance with the Spreadmark Code of Practice, P fertiliser not be applied if the three-day weather forecast indicates there is likely to be heavy rainfall, avoiding P applications to ephemeral flow paths and during the months of May through August and considering withholding P fertiliser from all significant stock camping areas. Such practices are already encouraged in the guidance documents for the preparation of nutrient management plans required by farmers in the Rotorua Catchment under BOPRC Plan Change 10 and the Farm Environment Plans under the WRC Plan Change 1

6.7.4 Reducing N fertiliser use

The use of nitrogenous fertiliser, even when applied in line with best management practices has a contributory impact on increasing nitrogen losses from the farm system. This occurs through both increasing the quantity of N cycling through the farm system and typically allowing higher stock intensities to be farmed, normally through the higher risk winter leaching period. The elimination of N in dairy systems might be managed through the importing of additional feed or the use of gibberellin (see 6.7.5 below). However, in dry stock systems where the returns per kg DM eaten are typically lower than the cost per kg DM of imported feed, it is typically more profitable to lower feed demand (i.e. reduce stock numbers) than increase feed supply (i.e. purchase more feed).

Analysis in the Upper Waikato Drystock Nutrient Study (Perrin Ag, 2013) found that the cessation of fertiliser nitrogen usage, typically accompanied by a reduction in stocking rate, generally led to a reduction in system N losses with no reduction in EBIT. This was typically due to the marginal cost of the N fertiliser exceeding the return from the feed reduced.

6.7.5 Use of plant growth regulators (Gibberellic acid)

Gibberellic acid (GA_3) is a plant hormone that when applied to grasses and cereals typically results in the elongation of leaf, sheath and stem (a dry matter response), providing the plant has already experienced sufficient vernalisation (chilling) (Bryant 2014). GA is a growth promoter and won't work in the total absence of plant available N in the soil.

Ghani et al (2014) found that the %N in herbage of pastures treated with GA were significantly lower than those untreated which would reduce urinary-N excretion under grazing. Subsequent modelling suggested whole farm annual N losses could be reduced by 4-29%, although some of these reductions would be associated with the replacement of N fertiliser applications with GA (i.e. same DM production for less N applied). Bryant et al 2016 also concluded that using GA to increase DM yield with reduced herbage protein concentration may have reduced environmental impact through reducing N intake of livestock.

Unpublished PhD research from Woods (2017) indicated that in a lysimeter trial the application of GA had no direct impact on reducing N leaching [through promoting plant uptake of urinary N that would have otherwise leached] which suggests that any whole system N loss reduction from the use of GA is associated with the substitution of N fertiliser and an improvement in whole system N use efficiency. However, Bates & Bishop (2016) propose that this lack of N loss reduction was due to the GA being applied to pasture of insufficient mass to promote a response or that conditions were too cold to get any growth at all (Bates et al 2017).

In conjunction with the urease inhibitor NPBT, GA and (if required) and dissolved organic carbon (marketed as ORUN®) is being promoted as a means to increase the lateral movement of urine patches (the NBPT) and then utilise the N in the urine patch before it leaves the root zone (via the GA), with Bates & Bishop (2016) suggesting targeted application to the actual urine patch is the preferred method.

6.8 Irrigation management

6.8.1 Efficient irrigation application based on soil moisture deficit monitoring, awareness of soil type/infiltration rate and assessment of crop needs and expected rainfall

Metering irrigation water can help to adjust the irrigation application levels and avoid overuse of irrigation water that can increase the leaching of nutrients and bacterial contaminants. Also, technology can help to avoid poor timing of required irrigation for crops and thus improve crop growth.

6.9 Effluent management

6.9.1 Solid separation

Separation of the solid fraction from effluent is a mechanism to lower application depths for the liquid fraction of farm dairy effluent , in conjunction with conventional irrigation, and where effluent volumes are likely to be significant (such as from housing, pads) or contain greater volumes of coarse, fibrous material.

Separation of solids may also allow more targeted application of the nutrient in dairy effluent, as total %N is highly associated with the dry matter fraction of dairy effluent (Longhurst et al 2017).

The ability to lower the application rate will be beneficial on higher risk soils [that can't sustain higher application rates in achieving appropriate depths] or where targeted application of the nutrients in solids (such as in cropping programmes) may be more manageable than significant land based slurry application.

6.9.2 Farm Dairy Effluent ponds: sufficient holding capacity to comply with soil moisture application standards and fully lined

If farms have insufficient effluent storage they will be forced to irrigate when soils are actively draining, creating direct losses of nutrients and *E. coli*. While most regional authorities require that effluent is not applied in such conditions, the reality is that many farmers with permitted or consented effluent management facilities are unable to operate with full compliance all of the time.

It is also noted that Houlbrooke et al 2014 identified the losses from old two-pond systems that discharge to water as the single largest effluent risk to surface waters, which reinforces the move to eliminate these systems by regional authorities, where they still exist.

6.9.3 Maize on the effluent block

The main water quality benefit from growing maize for silage on pastoral areas receiving dairy effluent is a reduction in the quantity of fertiliser nutrient required to be applied in the first and potentially second year's crops, which reduces the risk of direct losses to water and lowers the introduction of mobile nutrients into the farm system. There is an expected improvement in farm profitability from doing so as well (FAR 2008, Johnstone et al 2010).

6.9.4 Efficient effluent application that complies with soil moisture standards and crop needs, more than 20 metres away from all waterbodies

The depth of applied effluent (measured in mm) should always be less than the soil moisture deficit at the time of application. If effluent irrigation occurs on soils that are too wet, then run off to surface water bodies or drainage below the root zone will occur, with valuable nutrients and also bacteria being lost from the farm and contaminating the environment (Dairy NZ 2014).

Deferred irrigation and low application irrigation systems (e.g. irrigation sprinklers) are effective options to reduce contamination related with land uses. The nutrient losses resulting from a single poorly managed irrigation event is estimated in the order of 12 kg N/ha and 2 kg P/ha, approximately one third of the average total whole farm N losses and three times the annual average pastoral P loss (McDowell, 2010). The potential to decrease nutrient losses with better irrigation techniques is great. Such irrigation techniques can be established based on the agro-ecological conditions such as soil types and climate as well irrigation requirement of crops. Deferred irrigation and low application irrigation systems are not only environmentally beneficial, but also can be cost effective.

6.9.5 Increase application area to reduce application concentration

Using N from the fertiliser effluent system to replace N fertiliser is a good mechanism for improving N conversion efficiency on a farm, which will typically result in lower N losses to water. Roach et al (2001) found that nitrate leaching increases significantly when pond FDE is applied at rates above 200 kg N/ha/year and that lowering the application rate to target 100kg FDE N/ha/year (increasing the application area) would deliver maintenance potassium requirements at the same time. The cost-benefit of this will depend on the fertiliser benefit of the additional K and the cost of expansion.

6.10 Nitrate inhibition

6.10.1 Denitrification technology (e.g. Spikey)

The use of dicyandiamide (DCD) as a means to limit N losses from grazed winter forage crops was successfully demonstrated by Shepherd et al (2012), but due to the presence of DCD found in milk products in 2013, this product is not currently available for use in NZ farming systems. When its use (as described by Shepherd et al) was previously modelled by Perrin Ag (2013) for the Waikato Regional Council, it did introduce a cost to the farm system that wasn't able to be recouped through productivity gains.

However, the "Spikey" technology developed by Pastoral Robotics Ltd (Bates & Bishop 2016), with the ability to detect individual urine patches and then apply an alternative treatment to prevent the rapid conversion of urea to nitrate (see 6.7.5 above) may be as equally effective as blanket DCD application, were it still a viable tool.

6.10.2 Denitrification beds

Denitrification beds have application when dealing with point source discharge, like effluent from a farm dairy parlour or a tile drain. Essentially lined containers filled with organic carbon (typically wood chip or coarse sawdust), the wood chips act as an energy source for denitrifying bacteria that convert NO_3^- to N gases. While initial trial work in NZ found a denitrification bed removed the entire N load from dairy effluent (Cameron et al 2010), the applicability of this technology on farm at this juncture is uncertain, given the economic value to the farm system of recycling the N fraction of FDE as a fertiliser and the need to still dispose [to land] of the treated FDE, which will still be high in other nutrients, such as K and P.

Appendix 3

Baseline land use models for cost analysis of mitigation of sediment and other freshwater contaminants in the Rangitāiki and Kaituna-Pongakawa-Waitahanui Water Management Areas

Prepared for the Bay of Plenty Regional Council

Initial draft report, forming partial delivery for Milestones 2A & 2B

Version 1.1

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Perrin Ag Consultants Ltd and Landcare Research

1 Dairy farms

Five dairy farm systems were modelled. The chosen farm variants and their suggested primary parameters were primarily informed by the work of Green et al (2017), which had utilised input from BOPRC Land Management personnel, community groups and DairyNZ staff.

The farms were all modelled as long term feasible models in Farmax Dairy Pro software, utilising base pasture production curves (derived from cage cuts) that were subsequently adjusted to better reflect observed regional parameters. Stocking rates were based on regional dairy statistics, again slightly modified based on input from local industry experts. Operating profit (earnings before interest and tax) utilised a $6.00/kg MS milk price, with operating expenses (including an arms' length adjustment for [unpaid] wages of management) based on the latest published DairyBase Economic Survey data for the Bay of Plenty region. All grazing was assumed to be sourced externally, with all young stock assumed grazed off the farm area from weaning until returning as in-calf heifers. Effluent areas were assumed at 4ha per 100 cows, with maintenance fertiliser and nitrogen expenditure was based on modelled requirements. The key parameters of the five farm systems are each described briefly below and then summarised in **Table *1***. The baseline economic output for the dairy farm systems is presented in Appendix 1. All analysis currently excludes the impact of Fonterra supplier shares.

1.1 Lower Kaituna-Pongakawa-Waitahanui dairy (System 3)

This model is designed to be representative of the higher stocked dairy farms on the coastal flats of the Kaituna-Pongakawa-Waitahanui (KPW) Water Management Area. Largely comprising of gley soils with open drain systems, this 122ha farm calves down 390 cows (3.2 cows/ha), peak milking 374 cows (3.1 cows/ha) and producing 1,054kg MS/ha. No silage is made on farm and 50% of the milking herd are grazed off for six weeks. Palm kernel expeller is fed to cows in early and late lactation. Annual N fertiliser usage averages 173kg N/ha. A stand-off area was assumed to be used during the winter and early spring to protect soil from pugging. Operating profit is calculated at $1,946/ha.

1.2 Mid Kaituna-Pongakawa-Waitahanui dairy (System 3)

Representative of the farms on higher ground but less than 100m above sea level, the Mid KPW dairy model comprises 122ha of pumice soil, calving down 304 cows to peak milk 290. Milk production is 837kg MS/ha, but all cows are wintered on. With improved drainage, 3ha of maize silage is grown on-farm to help extend lactation in autumn. Palm kernel is fed to cows in both shoulders of the season and 19.2ha of grass silage is cut in late December and subsequently fed to dry cows over winter. N fertiliser use applied to pasture averages 131kg N/ha/year. Operating profit is calculated at $1,381/ha.

1.3 Upper KPW dairy (System 3)

The 122ha Upper KPW model is similar to the mid KPW model, but the farm system reflects lower pasture growth potential, both from increased altitude but also steeper contour. A summer chicory crop is utilised to buffer poorer summer growth rates and lower pasture quality and palm kernel expeller is used to feed milkers in the shoulders of the season. Lower winter pasture growth rates are buffered with 50% of dry cows grazed off for six weeks. N fertiliser use averages 123kg N/ha/year. Milk production is 805kg MS/ha. Operating profit is calculated at $1,092/ha.

1.4 Rangitāiki unirrigated dairy (System 2)

The 117ha Rangitaiki dairy model is designed to be representative of the non-irrigated dairy farms in the lower Rangitaiki plains. High pasture growth potential results in average production of 1,035kg MS/ha from 330 cows calved down. Only minimal maize silage imported into the farm system in autumn to extend lactation and all cows are wintered on. N fertiliser use is 120kg N/ha, with surplus pasture harvested in February that is subsequently fed to dry cows over winter. Operating profit is calculated at $2,561/ha.

1.5 Rangitāiki irrigated dairy (System 2)

Modelled off a partially (50%) irrigated (K line) dairy farm in the Galatea valley, this 117ha farm system produces 1,072kg MS/ha from 315 cows to calve down. The low winter growth rates require 25% of the herd to be grazed off over winter and calving date is assumed to be later than the other farm models. A summer chicory (6ha) and maize crops (4.8ha) are grown on the un-irrigated portion of the farm each year, with the maize fed to milkers both in the autumn and again in the spring. PKE is used to supplement milkers in early lactation and silage harvested off the irrigated portion of the farm fed to dry cows over autumn and winter. A total of 132kg N/ha is applied to pasture. Operating profit is calculated at $2,301/ha.

Table 1: Base parameters for the five dairy farm systems modelled

Model name	Lower KPW	Mid KPW	Upper KPW	Rangitaiki	Rangitaiki irrigated
System	3	3	3	2	2
Effective area (ha)	122	122	122	117	117
No. cows (to calve)	390	304	304	330	315
Cows peak milked	374	290	290	316	301
Stocking rate (SR; cows ha^{-1})	3.1	2.4	2.4	2.7	2.6
Comparative stocking rate	85	84.1	87.4	82.6	84.3
Pasture yield (t DM ha^{-1})	14.2	11.3	10.4	15.6	13.9
Pasture consumed (t DM ha^{-1})	11.9	9	8.5	12.1	10.4
Imported feed/total feed (%)	16%	13%	14%	3%	3%
Annual milk solids production (kg)	129,572	102,122	98,234	121,102	126,215
MS (kg cow^{-1})	346	352	339	383	419
MS (kg ha^{-1})	1062	837	805	1035	1079
MS (as a % of liveweight; LW)	83.6	84.9	80.2	91.7	98.6
Feed conversion efficiency (kg DM eaten kg MS $produced^{-1}$)	13	12.8	13.1	12.3	11.1
Financial indicators					
Operating profit (\$ ha^{-1})	1,946	1,381	1,092	2,561	2,301
Area receiving effluent (% total)	13%	10%	10%	11%	11%
Area irrigated (% total)	-	-	-	-	50%
Fertiliser inputs applied to pasture					
N (kg ha^{-1})	173	131	90	90	90
P (kg ha^{-1})	45	37	35	50	53
Soil Olsen P (mg L^{-1})					

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2 Sheep & beef farms

Three sheep & beef farms were modelled in Farmax Pro, two for the KPW FMU and a single model for the Rangitaiki catchment. As noted in Green et al (2017), sheep & beef farming in the Rangitaiki catchment is dominated by Landcorp's Rangitaiki Station. While it is important to recognise this farm system is unlikely to be representative of the smaller family operations that still occur in the catchment, it is difficult to ignore the specifics of this farm system given the scale of this operation. The partial integration of this property's deer operation with its cattle operation makes the specific modelling of this system to align with the parameters of the APSIM model impossible. As a result a representative Rangitaiki farm system with a low sheep:cattle ratio has been modelled to complement the exclusive Rangitaiki deer system (see below). While only a single KPW S+B model, comprising dairy support, had been proposed, a second farm system model was subsequently developed, comprising a breeding ewe flock and breeding cows, in addition to dairy heifer grazing.

The size of the modelled farms were informed by the annual Beef + Lamb New Zealand Economic Service Sheep & Beef Farm Survey, with general parameters for the Class 3, 4 and 5 survey farms providing base physical and economic parameters for the Rangitaiki S+B (Class 3), KPW S+B and Rangitaiki D (Class 4) and KPW DS (Class 5) models respectively. Maintenance fertiliser and nitrogen expenditure was based on modelled requirements

Operating profit was defined as earnings before interest and tax and included an adjustment for the market value of all labour (paid and unpaid) in the farm system, based off the FTE parameters in the survey. Income was assessed using base schedule relationships in Farmax Pro, with the sheep schedule set at $5.50 (per kg carcass weight), prime bull $5.50, prime steer $5.55 and venison at $7.50. Wool was set at a base price of $3.40/kg greasy and velvet at $100/kg. Grazing rates per head per week were set at $6.50 for calves, $9.00 for yearlings and $25 for cows.

2.1 KPW dairy support

This 234ha property has an average slope of 12.6 degrees, comprising 22ha of flats, 155ha of rolling land, 52ha of easy country and 5ha of steep land. It's assumed this farm operation grazes 445 dairy heifer replacements from 4 months of age through to 21 months of age and winters 334 cows on pasture and silage for 8 weeks. N use is limited to 30kg N/ha to 120ha in the autumn to build up covers ahead of the grazing dairy cows arriving in late May. Operating profit was estimated at $421/ha.

2.2 KPW S+B

This variant on the KPW dairy support model is a 324ha farm, with a similar area of flats, but a greater proportion of steeper land (16.4 degrees). The farm runs a flock of 1,250 MA ewes and 540 ewe hogget replacements. Lambing at 128%, all non-replacement lambs are finished before the start of winter at an average carcass weight of 17.5kg. The cattle policy comprises 50 Hereford x Friesian breeding cows, mated to a terminal sire and with all progeny sold store at weaning. Replacement in-calf cows are bought in the autumn. In addition to the breeding cows, 300 dairy heifer replacements are contract grazed from 4 months of age to 21 months of age. N fertiliser is applied at 30kg N/ha to the 94a of flats and rolling country in the autumn. Operating profit was estimated at $71/ha.

2.3 Rangitāiki Sheep + Beef

The Rangitaiki sheep & beef model is a 584ha farm system, with a low (36%) sheep component and a diverse cattle policy, with an Angus breeding cow herd (all progeny finished), additional yearling steers purchased and finished, a bull beef operation and a dairy heifer grazing operation. The breeding ewe flock lambs at 130%, with all non-replacement lambs finished to a carcass weight of 17.2kg by May each year. Approximately half the bulls are slaughtered before their second winter, with the balance sold before spring. Steers are killed at an average carcass weight of 320kg and heifers killed at 255kg carcass weight. Winter crops (4% of the farm area) are sown each year and 84ha of surplus pasture is harvested in early summer for winter feed. Over 80% of the farm receives an N application of 30kg N/ha; 40% in the spring and 60% in the autumn. Operating profit was estimated at $177/ha.

3 Deer farm

3.1 Rangitāiki Deer

The modelled deer farm is a breeding-finishing system modelled off that of Rangitaiki Station. At an assumed size of 324ha, the farm system winters 874 Ma and R2 hinds, fawning at 90% and 75% respectively. All non-replacement progeny are finished before their second winter, with the stags and hinds finished to 55kg and 51kg carcass weight respectively. As with the Rangitaiki sheep & beef model, 4% of the farm area is sown into winter crop and the 50% of the farm area gets an application of N fertiliser in the spring, with the other 50% receiving an autumn application. Surplus pasture (40ha) is conserved for use in the winter. Operating profit was estimated at $57/ha.

4 Arable farm

4.1 KPW Arable

A single variant arable model was developed, based around a 40ha maize silage production system (yielding 22t DM/ha), with the maize followed by an annual ryegrass crop that is able to support 300 dairy cows for eight weeks and then used to produce 300 wrapped bales of silage before being re-sown into maize again. Operating profit was estimated at $3,500/ha.

Table 2: Base parameters for the five dry stock and arable farm systems modelled

Model	KPW DS	KPW S+B	Rangitaiki S+B	Rangitaiki D	KPW A
Effective area (ha)	234	324	584	324	40
Stocking rate (RSU ha^{-1})	12.8	12.9	10.7	9.4	6.7
Pasture yield (t DM ha^{-1})	9.4	8.8	7.69	7.7	9
Pasture consumed (t DM ha^{-1})	7.05	7.12	5.87	5.15	3.7
Number of livestock carried through winter (1 July)					
Breeding ewes	-	1,250	1,454	-	-
Total sheep	-	1,826	1,786	-	-
Breeding cows	-	50	67	-	-
Dairy heifers	445	300	276	-	-
Dairy cows	334			-	300
Total cattle	779	352	693		-
Hinds	-	-	-	874	-
Total deer	-	-	-	1,681	-
Animal production					
Meat (kg net carcass weight ha^{-1})	336	239	233	124	86
Wool and velvet (kg net wool /velvet ha^{-1})	-	38	22	0	-
Total (kg net product ha^{-1})	336	277	255	124	86
Feed conversion efficiency (kg DM eaten kg $product^{-1}$)	21	26	23	41	43
Animal reproduction					
Ewe efficiency index (%)	-	55%	54.4%	-	-
Cow efficiency index (%)	-	39.5%	39%	-	-
Hind efficiency index (%)	-	-	-	41%	-
Financial indicators					
Operating profit ($ ha^{-1})	421	71	177	57	3,545
Fertiliser inputs applied to pasture					
N (kg ha^{-1})	15	9	27	32	
P (kg ha^{-1})	22	22	18	16	12
Soil Olsen P (mg L^{-1})					

5 Forestry

Two forestry models were considered – one a radiata plantation model and the other a mānuka plantation established for honey production.

5.1 Pinus radiata

TBC

5.2 Mānuka

TBC

6 Kiwifruit

TBC

Appendix 1: Summary of model development

Landuse	APSIM	Refinements from Green et al.	Revised Perrin suggestions	Final models	Model name
Dairy	Dairy	Lower KPW (flat) dairy	Lower KPW (flat) dairy	Lower KPW (flat) dairy	Lower KPW
		Mid-Upper KPW (hill) dairy	Mid-Upper KPW (hill) dairy	Mid KPW	Mid KPW
				Upper KPW	Upper KPW
	High intensity dairy	Rangitaiki (flat) dairy	Rangitaiki (flat) dairy	Rangitaiki (flat) dairy	Rangitaiki
			Rangitaiki (flat) irrigated dairy	Rangitaiki (flat) irrigated dairy	Rangitaiki irrigated
Sheep & Beef	Sheep & Beef	Sheep & Beef	Rangitaiki extensive breeding/finishing sheep cattle operation;	Rangitaiki extensive breeding/finishing sheep cattle operation;	Rangitaiki S+B
				Mid-Upper KPW sheep & beef	KPW S+B
			Mid-Upper KPW dairy support	Mid-Upper KPW dairy support	KPW DS
Kiwifruit	Kiwifruit	Green	Green	Green	Kiwi green
		Gold	Gold	Gold	Kiwi gold
		Organic	Organic	Organic	Kiwi organic
Deer	Deer	Deer - venison operation	Rangitaiki breeding/finishing vension operation	Rangitaiki breeding/finishing vension operation	Rangitaiki D
Arable	Maize	Maize silage	Lower KPW maize silage and dairy support (winter cows)	Lower KPW maize silage and dairy support (winter cows)	KPW A
Vegetables	Vegetables	Te Teko vegetable rotation	Lower Rangitaiki vegetable rotation		
Forestry	Forestry	Radiata pine	Radiata pine	Radiata pine	Radiata pine
				Mānuka	Mānuka
Numbe of models	*7*	*10*	*12*	*15*	*15*

Appendix 2: Baseline dairy farm model profitability estimates

	Lower KPW	Mid KPW	Upper KPW	Rangitaiki	Rangitaiki irrigated
	($)	($)	($)	($)	($)
Income					
Milk sales	777,411	612,730	589,289	726,611	757,404
Net Livestock Sales	44,346	33,178	33,724	34,647	34,250
Contract Grazing	-	-	-	-	-
Change in Livestock Value	-	-	-	-	-
Total Revenue	821,757	645,908	623,013	761,258	791,654
Expenses					
Labour costs	136,884	106,140	106,140	115,656	110,166
Stock expenses					
Animal Health	33,461	26,048	25,941	28,148	27,051
Breeding	10,628	8,241	8,241	8,980	8,553
Farm Dairy	6,009	4,783	4,530	5,300	4,894
Electricity	16,082	12,470	12,470	13,588	12,943
Feed expenses					
Pasture Conserved	-	6,720	-	7,840	10,468
Feed Crop	-	8,400	11,250	-	16,860
Bought Feed	51,223	44,173	29,728	16,320	4,358
Calf Feed	2,335	1,829	1,817	1,877	1,871
Grazing	95,355	47,966	79,123	49,238	61,652
Other Farm Working					
Fertiliser (Excl. N)	36,356	29,524	27,328	36,621	37,557
Nitrogen	32,034	24,343	22,891	21,341	23,539
Irrigation	1,098	1,098	1,098	1,053	43,875
Regrassing	7,200	1,800	5,400	7,200	2,220
Weed & Pest Control	5,002	5,002	5,002	4,797	4,797
Vehicle Expenses	13,176	13,176	13,176	12,636	12,636
Fuel	8,418	8,418	8,418	8,073	8,073
R&M Land/Buildings	32,086	32,086	32,086	30,771	30,771
Freight & Cartage	8,228	6,380	6,380	6,952	6,622
Overheads					
Administration Expenses	18,300	18,300	18,300	17,550	17,550
Insurance	8,540	8,540	8,540	8,190	8,190
ACC Levies	4,514	4,514	4,514	4,329	4,329
Rates	18,178	18,178	18,178	17,433	17,433
Total Farm Working Expenses	545,107	438,129	450,551	423,893	476,408
Depreciation	39,284	39,284	39,284	37,674	45,981
Total Farm Expenses	584,391	477,413	489,835	461,567	522,389
Earnings before interest and tax	237,366	168,495	133,178	299,691	269,265
per ha	1,946	1,381	1,092	2,561	2,301

Appendix 3: Baseline dry stock and arable farm model profitability estimates

Land use		Sheep & beef			Deer	Arable
Model		KPW DS	KPW S+B	Rangitaiki S+B	Rangitaiki D	KPW A
		($)	($)	($)	($)	($)
Income						
Sheep						
	Sales - Purchases	-	94,132	128,547	-	-
	Wool	-	43,983	44,499	-	-
		-	138,115	173,047	-	-
Beef						
	Sales - Purchases	-	20,626	225,046	-	-
	Contract Grazing	339,661	150,908	162,422	-	48,000
Deer						
	Sales - Purchases	-	-	-	274,002	-
	Velvet	-	-	-	6,764	-
Crop & feed sales		-	-	-	-	278,500
Total Revenue		339,661	447,764	733,561	280,766	326,500
Expenses						
Labour (at arms length)		78,960	67,626	74,269	67,301	13,500
Stock						
	Animal Health	-	11,009	11,263	8,568	-
	Shearing	-	18,878	20,706	-	-
	Velveting	-	-	-	1,043	-
Feed/Crop/Grazing						
	Conservation	30,460	7,684	29,460	14,000	11,100
	Forage Crops	-	-	-	-	144,000
	Regrassing	-	-	14,400	7,800	-
Other Farm Working						
	Fertiliser (Excl. N 8	24,570	35,640	47,865	23,328	2,040
	Nitrogen	5,472	4,284	22,348	14,791	-
	Lime	2,160	2,991	5,390	2,991	369
	Weed & Pest Cont	4,898	6,781	12,223	6,781	837
	Vehicle Expenses	7,200	9,969	17,970	9,969	1,231
	Fuel	5,644	7,815	14,086	7,815	965
	Repairs & Mainter	29,809	41,674	61,984	30,229	2,677
	Freight & Cartage	7,497	10,481	15,590	7,603	673
	Electricity	3,869	5,408	8,044	3,923	347
Standing Charges						
	Administration Ex	9,112	12,617	22,741	12,617	1,558
	Insurance	4,666	6,461	11,645	6,461	798
	ACC Levies	2,015	2,809	5,051	2,798	344
	Rates	11,115	15,390	27,740	15,390	1,900
Total Farm Working Expense		227,447	267,517	422,775	243,408	182,339
Depreciation		13,712	18,986	34,222	18,986	2,344
Total Farm Expenses		241,159	286,503	456,997	262,394	184,683
Earnings before interest and		98,502	161,261	276,564	18,372	141,817
per ha		421	71	177	57	3,545