Freshwater Management Tool

August 2021

FWMT Report 2021/8

Report 8

Lifecycle Costs and Benefits for Rural Mitigations in the Freshwater Management Tool

Auckland Council
Te Kaunihera o Tāmaki Makaurau

Freshwater Management Tool:
Report 8. Lifecycle Costs and Benefits for Rural Mitigations in the Freshwater Management Tool

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Contributing authors:

Perrin Ag Consultants Limited
Carla Muller

Koru Environmental Consultants Limited
Sue Ira

Auckland Council Healthy Waters Department
Tom Stephens

Auckland Council Healthy Waters Department
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Lifecycle Costs and Benefits for Rural Mitigations in Freshwater Management Tool

Prepared for

Auckland Council

Report prepared by

Perrin Ag Consultants Ltd
Koru Environmental Consultants Ltd

Final report 22 June 2020

Prepared by Perrin Ag Consultants Ltd

Registered Farm Management Consultants
1330 Eruera Street, PO Box 596
Rotorua 3010
New Zealand

Phone: +64 7 349 1212
Email: consult@perrinag.net.nz
www.perrinag.net.nz

perrin ag

Document Quality Assurance

Written by:	Carla Muller BApplEcon, MEnvMgmt (Hons), MNZIPIM. ASNM Senior Consultant, Perrin Ag Sue Ira MSc Director, Koru Environmental Consultants Dr Tom Stephens PhD Principal – Integrated Catchment Healthy Waters, Infrastructure & Environmental Services, Auckland Council	
Reviewed by:	Lee Matheson BApplSc (Hons), MNZIPIM (Reg.) ASNM Managing Director Perrin Ag Consultants	
Approved for release:	Lee Matheson BApplSc (Hons), MNZIPIM (Reg.) ASNM Managing Director Perrin Ag Consultants	
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Executive Summary

Auckland Council (AC) has requested that as part of their ongoing development of the Fresh Water Management Tool (FWMT), a staged approach is pursued to support rural costs and benefits of mitigations being assigned logical conditions for cost-optimisation. In the first step, rural literature was reviewed by Muller et al. (2020) and Muller and Stephens (2020) with the aim to provide initial estimates of mitigation options, cost and effectiveness.

This report takes cost and benefit information from Muller et al. (2020) and Muller and Stephens (2020) and translates it into a suitable format for the FWMT Stage 1. Recommendations extend to the applicability of mitigations across a hydrological response unit (HRU) framework, the land typology utilized by the FWMT. Baseline (2013-2017) and potential maximum levels of rural mitigation adoption are also considered to inform FWMT Stage 1 scenario modelling for water quality management.

The FWMT Stage 1 continuously simulates the baseline or current state of water quality (2013-2017) via process-modelling across the entire Auckland region, and enables optimization modelling across intervention types, to identify potential future states and associated management strategies (e.g., choice of intervention, targeted HRU type and sub-catchment, prioritised for cost over a 50-year discounted life-cycle). The FWMT Stage 1 enables both current and future states to be simulated for nutrients (nitrogen, phosphorus), heavy metals (copper, zinc), sediment and faecal indicator bacteria (*E. coli*). The FWMT thereby supports Auckland Council decision-making and management of water quality for existing, future development and climate associated pressures.

This report translates literature on rural water quality mitigation into a 50-year Life Cycle Cost (LCC). The LCC approach is consistent with urban water quality intervention recommendations produced in Ira, Walsh and Batstone (2020). This ensures the FWMT Stage 1 offers an integrated platform for water quality decision-making across the entire Auckland region. LCC estimates are based on capital, maintenance, replacement and where suitable, opportunity cost or reduced profit, throughout a 50-year period. LCC are supplied in Appendix 1 for discount rates of 2%, 4% and 6%.

The literature has been reviewed for bundled practice and system changes and land retirement, as well as edge-of-field (EOF) interventions, for reduced contaminant loss from pastoral and horticultural farming, including: wetlands (small, large), riparian management (fence only, grassed or planted setback only, fenced and grassed or planted setback), detainment bunds and space-planted erosion-control trees. For each, recommending reasonably assured cost and benefit for reduced total nitrogen (TN), total phosphorus (TP), total suspended sediment (TSS) and/or *E. coli* loss. Also, for each, ensuring applicability to the 50 HRU types spanning variation in pastoral and horticultural contaminant responses to climate within the FWMT (e.g., stratified over soil group, slope class, cover and use).

The rural mitigation literature was found frequently lacking key detail about components of cost, benefit, opportunity and/or baseline adoption rate, to enable application to individual HRU types. Instead, recommendations generally distinguish pastoral and horticultural HRU groups (e.g., by stock or crop, e.g. vegetable or tree, type). For instance, land retirement LCC estimates vary between dairying, intensive beef or sheep and beef farms for markedly varying likely opportunity cost.

This report is not an isolated piece of work, but a part of the broader FWMT development process and as such should be read in conjunction with the other ongoing technical work being undertaken by AC, underpinning a decadal model development programme. The FWMT Stage 1 is the first iteration which despite the complexity of a continuous and process-based approach, spanning 5,465 sub-catchments,

107 HRUs and multiple contaminants, is being developed from a principle of "defensible simplicity". The granularity, cost and benefit estimates assigned to rural mitigations reflect that principle, ensuring only as fine a recommendation as defensible from the literature (e.g., to HRU group).

To aid ongoing FWMT development, the report identifies areas of rural water quality knowledge to prioritise for improved scenario modelling and freshwater accounting. Recommendations can be implemented through input from the rural sector, expert caucusing, field trials, and farm system modelling. Adoption of recommendations will improve the FWMT by improving LCC and benefit estimates, if not also increasing granularity thereof.

This report is structured as follows; Section 1 provides background information of the FWMT program. Section 2 provides a brief overview of key modelling components, including the Life Cycle Cost Model and FWMT. Section 3 provides details on how each mitigation was included into the Life Cycle Cost Model and FWMT. Section 4 covers the applicability of each mitigation to the HRU framework and what information could be used to inform baseline and potential adoption rates. Section 5 provides summary points and further recommendations. Finally, Appendix A provides key outputs from the Life Cycle Cost Model.

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1 Background

Auckland Council (AC) has requested as part of their ongoing development of their Fresh Water Management Tool (FWMT) Stage 1, a three-phased approach is pursued to support rural costs and benefits of mitigations being assigned logical conditions for cost-optimisation. In the first step, rural literature was reviewed by Muller et al. (2020) with the aim to provide initial estimates of mitigation options, cost and effectiveness. In the second phase, further examination will be given to incorporating both additional mitigations (e.g. especially for sediment and pathogens) as well as tailoring mitigations to the Auckland region whilst recognizing for the sectoral and contaminant uncertainty of mitigations (see Muller et al. 2020). This report is an extension to the Stage 1 output (Muller et al., 2020) to detail the assumptions that have been made in incorporating the rural sector costs and benefit estimates into the Life Cycle Cost (LCC) model for inclusion into the FWMT Stage 1.

The build of the AC FWMT is a continuous improvement process. Further builds will add complexity as necessary to better represent land use effects on water quality. A key principle of the FWMT's continuous development is that, where possible, defensible simplicity is adopted first.

The FWMT Stage 1 is already a relatively complex model build for freshwater contaminant accounting, including 50 rural land types (hydrologic response units – HRU) spanning pastoral and horticultural activities in the Auckland region (e.g., stratified on differing slope, soil, cover and intensity classes).

Similarly, the FWMT is being developed not simply to assess spread in modern-day or baseline (2013-2017) water quality, but also cost-optimised strategies to drive improved water quality and/or maintain water quality in the face of increasing pressures (e.g., development, intensification of productivity and/or climate change). For that purpose, pastoral and horticultural HRUs in particular, require a library of mitigation options to be developed, either targeted at, or across groups of, HRUs. However, unless the literature demonstrates marked differences in impact of cost or benefit, those have been applied in more simplified approaches (e.g., in line with a principle of defensible simplicity).

This report is an extension of Muller et al. (2020) and Muller and Stephens (2020). Muller et al. (2020) reviewed literature and provided a set of cost benefit estimates for bundled mitigation options and edge of field (EOF) mitigation options for pastoral and horticultural land uses for total nitrogen (TN), total phosphorus (TP), sediment (total suspended solids – TSS) and *E. coli*, offering indicative estimates for AC use in FWMT stage 1. Muller and Stephens (2020) provided a more in-depth analysis of the costs and benefits specifically for riparian management options. This third report details the combined cost and benefit information recommended by Muller et al. (2020) and Muller and Stephens (2020), for incorporation into the LCC model developed for both urban and rural mitigation options in the FWMT Stage 1 as well as providing detail on assumptions required to adjust the cost and benefit information from the previous reports to the LCC model framework. More detail on the LCC model can be found in Ira et al. (2020).

This report describes rural mitigation options able to be incorporated through "reasonable assurance"[1] into the FWMT Stage 1 only, including bundled mitigation options (based on farm practice and farm system changes), EOF mitigations and land retirement. These options are discriminated by pastoral and horticultural HRU groupings, varying cost and benefit as appropriate. All cost information includes several distinct components annualised over a 50-year period, for: capital costs (including renewal costs if required in the 50-years), maintenance costs, and either opportunity cost (from retiring land in perpetuity for EOF and land retirement options) or reduced operating profit (from farm system changes in bundled mitigations). Annualised costings are as above, translated via various discounted rates into LCC estimates in Ira et al. (2020) (e.g., 2%, 4% and 6% for varying future scenarios to be costed in the FWMT Stage 1).

Important assumptions required prior to application in the FWMT Stage 1 are also highlighted in **bold**. These require consideration in configuring scenarios as well as constraints on the interpretation of FWMT Stage 1 scenario outputs.

This report builds on the assumptions outlined in Muller et al. (2020) and Muller and Stephens (2020). It is limited to the costs and benefits considered in these earlier reports as well as any costs and benefits included in this report. It therefore excludes benefits that do not relate to water contaminant generation or attenuation (e.g., carbon sequestration, amenity, biodiversity, cultural health values). Likewise, it excludes costs beyond the capital, maintenance and impact of mitigations on operating profit. It excludes the impact of costs on aspects such as debt repayment, interest, tax and land values. These are all important and should be considered alongside the results discussed in the FWMT Stage 1.

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[1]Reasonable assurance is a term used to define the appropriate input and configuration of water quality accounting modelling by the US-EPA, adopted here in line with the US-EPA origin of the two model components of the FWMT (e.g., US-EPA, 2017). It entails information of assured (peer-reviewed, published or reported by research agencies) and reasoned into a general measure, for use by any modelling framework – aligned in turn to the purpose of a model (e.g., being fit for purpose). Defensible simplicity is a notion also derived from wider modelling. exercises, where the continuous and process-based capability of the FWMT risks insufficient data and instead, simplification of processes, opportunities, costs and benefits are required where evidence does not permit finer granularity

2 Modelling process

Muller et al. (2020) reviewed literature and provided an indicative set of cost benefit estimates for bundled mitigation options and edge of field (EOF) mitigation options across pastoral and horticultural land uses, for total nitrogen (TN), total phosphorus (TP), sediment (TSS) and *E. coli* modelling by FWMT Stage 1. Muller and Stephens (2020) provides a more in depth analysis of the costs and benefits of riparian management options for the FWMT Stage 1. The latter alongside broader rural mitigation options here, are then utilised in the LCC Model which adjusts them into a consistent framework with urban sector costs for inclusion in the FWMT Stage 1. Combined, enabling the FWMT Stage 1 to both model and account for an integrated set of rural and urban future scenarios for water quality across the entire Auckland region (e.g., for contaminant effects instream, to lake, to coast or to Harbour).

2.1 LCC Model Overview

2.1.1 Overview

To ensure consistency with the urban mitigation cost modelling (Ira et al., 2020), an LCC modelling approach has been undertaken to assess costs of various rural mitigations for the FWMT Stage 1. The LCC incorporates the sum of acquisition and ownership costs of an asset over its life cycle from design, manufacturing, usage, and maintenance through to renewal or disestablishment (Figure 1). A "cradle-to-grave" time frame is warranted because future costs associated with a mitigation measure are often greater than the initial acquisition cost, and may vary significantly between alternative solutions (e.g., between grey and green infrastructure – Australian National Audit Office, 2001).

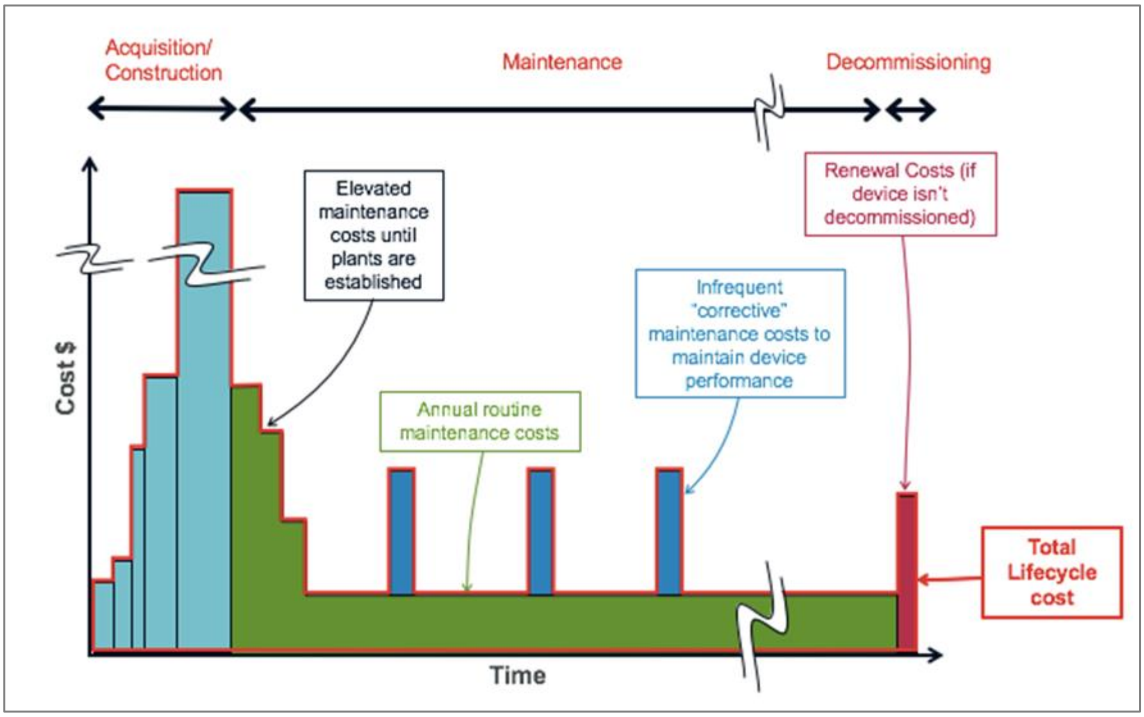

Figure 1: Phases in the life cycle of stormwater interventions and potential long term costs (Ira et al., 2020)

2.2 LCC model assumptions

A robust LCC model has been developed in general accordance with the Australian/New Zealand Standard (4536:1999) for LCC. The structure of the models is the same for all mitigations and is based on the following LCC assumptions:

- The default unit cost values provided in each of the LCC models are taken from Muller et al. (2020) and Muller and Stephens (2020) and have been applied in the models as described in Section 2 of this report;
- A 50-year life cycle analysis period has been used in order to provide consistency with the urban intervention LCC costs;
- Interventions have been modelled using a 2%, 4% and 6% discount rate, as recommended by Auckland Council's Chief Economist Unit (Ira et al., 2020);
- Base date for all costing is set to 2019 New Zealand dollars (e.g., capital, maintenance, operating profit or opportunity cost);
- All costs exclude goods and services tax (GST);
- The total acquisition cost (TAC) includes an overhead and indirect cost factor of 17.5% of the construction cost (this accounts for time needed to plan, consent or implement potential mitigations, and associated contingencies, and is based on a likely overhead cost for urban interventions of 15% - 20% [Ira and Simcock, 2019]). This is only applied to capital costs incurred in year 1, not successive years. TACs are only applied to EOF and land retirement mitigations, and not to bundled mitigations (as these have no capital cost);
- Construction costs are allocated in the first year of the model with renewal costs included in future years as applicable, maintenance costs are allocated from years 2 – 50, and either opportunity costs (from retiring land in perpetuity for EOF and land retirement mitigations) or reduced operating profit (from farm system changes in bundled mitigations) is considered annually;
- Where appropriate, full mitigation renewal costs are included in the relevant year(s).

2.2.1 Interpreting LCC results

Annualised LCCs generated via the LCC models are indicative estimates intended to enable comparison of various rural intervention scenarios – comparative accuracy will be far greater than absolute and intended to support optimisation assessments (i.e., where comparative costing is the means of developing "most efficient" integrated mitigation strategies across both urban and rural contaminant sources). Life cycle costing allows "like for like" comparison of additional costs between interventions, across the full spectrum of costs (e.g., outlay, maintenance, opportunity or profit cost). However, LCC assessments require further assumptions on the feasibility, timing, uptake or optimisation of interventions in specific location(s), or about financing, governance or distributions of costs for particular catchments or activities. The latter are considered key areas of "scenario configuration" for later development (e.g., when applying LCC estimates here to the FWMT Stage 1).

2.3 FWMT Stage 1

The FWMT is a continuous, process-based water quality model spanning the entirety of the Auckland region. The FWMT is being developed to support AC with watershed accounting, planning efforts, and implementation programmes to maintain and improve water quality. The FWMT serves dual purposes for the NPS-FM and Water Quality Targeted Rate (WQTR). Specifically, to fulfil freshwater accounting system requirements, decision-making and implementation requirements for AC as a unitary authority (i.e., regional and district government functions of the RMA and LGA). The FWMT is therefore required to support both policy development and infrastructure planning.

The FWMT scope includes both current (2013-2017) and future state freshwater accounting, region-wide at sub-catchment scale via continuous process-based modelling (i.e. to reasonably foresee the effects of targeted investment, development and climate change on freshwater quality, integrated across the Auckland region).

Future state modelling in the FWMT is undergoing development of a mitigation library incorporating the effects (impacts) and costs of various interventions, spanning source control through to targeted devices. The FWMT spans both urban and rural landscapes and stream environments in the region, with development ongoing for both urban and rural cost and impact information suited to Hydrological Response Units (HRU's). HRU's are the minimum accounting unit in the FWMT, effectively the landscape types divided into varying covers, impact (intensity of use), slope and soil groups (see Section 2.2.1). There are in excess of a 100 uniquely represented contaminant sources, across the mix of contaminants process-modelled continuously (at 15-min increments) by the FWMT – the FWMT is at the time of writing, the most sophisticated and advanced water quality accounting framework developed by the US-EPA and based on open-sourced frameworks peer-reviewed for international regulatory use.

The FWMT scope is supported by an iterative build to accommodate revisions to national policy statements, improved regional evidence (including monitoring datasets) and community engagement in decision-making. For Stage 1, the FWMT scope is limited to accounting for six contaminants in varying forms (dissolved, total): N, P, Cu, Zn, TSS and *E. coli*. Of these, only total forms are simulated for loss from land whilst instream physicochemical and plant processes are simulated instream to speciate total into dissolved and particulate forms. Those total forms are regionally configured for 107 unique HRU's whose composition varies uniquely again across 5,465 sub-catchments spanning ~490,000 Ha. Given the lack of equivalent enriched heavy metal (Cu, Zn) inputs to rural land, both Cu and Zn processes on rural HRU's are represented by TSS losses and transport. Hence, this report focusses only on benefits of rural mitigations for TN, TP, TSS and *E. coli*.

The Stage 1 FWMT is also limited in scope to direct accounting from land to stream, lake and coast environments, direct accounting instream (e.g., contaminants continuously transformed for instream processes), and indirect accounting of contaminant effects in-lake (e.g., contaminants transformed to steady-state lake outcomes on TN, TP, Chl-a and SD via optimised Vollenweider equations – Abell and Van-Dam Bates, 2018) or in harbour (e.g., to coastal hydrodynamic models).

Accommodating the FWMT's ambitious scope for a process-based and comprehensive (continuous, region-wide, sub-catchment and diverse HRU-resolved) freshwater contaminant accounting model, is not feasible within a short timeframe and single modelling stage. Instead, a prioritised and iterative approach underpins the FWMT development, of both baseline and scenario capability (e.g., for concentration and/or load grading and optimisation).

An iterative approach enables the FWMT to better accommodate (ongoing) changes to the NPS-FM, inform a targeted monitoring programme for greater understanding of freshwater contaminant processes, incorporate such data in revised configuration (for improved performance) and provide an increasingly strengthened evidence base for freshwater objective-setting, limit-setting and implementation decisions.

Development of Stage 1 FWMT commenced in November 2017 using a diversity of monitored data collected up to 30th June 2017, with a multi-year and incremental programme for Baseline and Scenario Modelling. Stage 1 FWMT current state capability is anticipated for delivery by early 2020 and scenario state including optimisation capability, by late 2020.

Design and development of Stage 2 FWMT will occur in response to delivery, engagement, policy, regional planning and operational planning uptake of Stage 1 output. Scenario and sensitivity testing using Stage 1 FWMT will proceed only after development is complete (Figure 2).

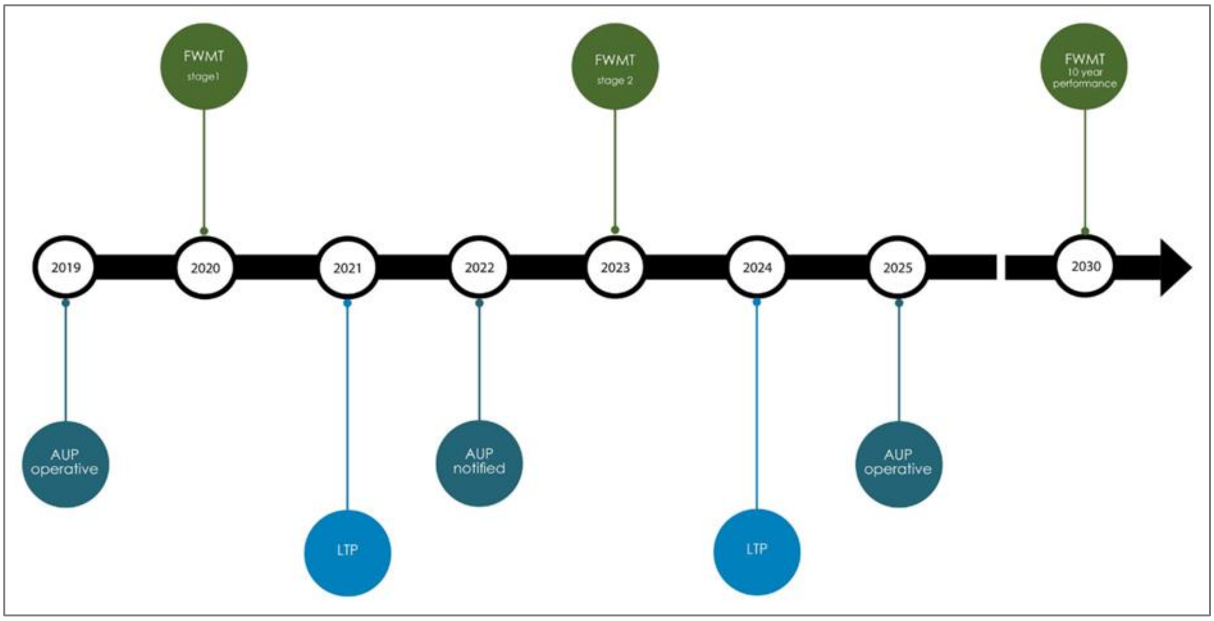

Figure 2: Delivery timeline of the FWMT through three iterative stages, with consistent scope between to deliver both baseline and scenario evidence on freshwater quality attribute states under existing and alternate management actions.

2.3.1 Hydrological response units

The FWMT simulates hydrology and contaminant response of land to climate and resource use, by typing all of the regions surface into one of 106 unique HRU classes on a two-meter grid. HRU classes are defined by combinations of land cover, intensity of use, hydrologic soil group and slope. All 4,650 sub-catchments configured within the FWMT have been assessed for the extent of all 106 HRU classes prior to continuous simulation of hydrological and contaminant processes (e.g., at sub-catchment scale, to modelled stream reach downstream of sub-catchment). Overall, 20 HRUs describe the range in pastoral land responses to climate and use, whilst 30 HRUs characterize horticultural responses to climate and use. Each HRU is uniquely parameterized for hydrological and contaminant processes, on a regional basis in the FWMT (i.e., land titles of equivalent class, under identical climate, are assumed to generate identical hydrological and contaminant mass – noting that there are 4,650 sub-catchments able to experience unique climate by HRU composition or generate unique contaminant outcomes despite the FWMT's regionalized configuration).

Rural productive HRUs are summarized in Table 1, as:

- Pastoral (land cover) by property parcel, classified further by:
  - *Intensity –*
  - *Less than 10 stock units per hectare (low),*
  - *More than or equal to 10 stock units per hectare (high).*
- Horticultural and arable (land cover), titles classified further by:
  - *Intensity –*

- *Orchards and idle fallow[2],*
- *Arable, citrus, fodder, nuts and viticulture,*
- *Berryfruit, flowers, fruit, kiwifruit, nursery, pipfruit, stonefruit, vegetables and greenhouses.*

Both soil and slope were also separated and were consistent between pasture and horticulture. In Muller et al. (2020), HSG have been grouped into three broader drainage classes to align with the literature: A and A+ (free draining), B (moderate draining), and C and D (poorly draining). In addition, high intensity pastoral land uses were split into dairy and sheep and beef. These changes were to enable alignment of mitigation studies in existing literature to the HRU framework.

- Hydrological Soil Group (HSG)
  - *A+ that are "very high infiltration" soils of "volcanic geology, medium to high soakage", highest free-draining soil types;*
  - *A that are "high infiltration" soils of "sand/loamy sand/sandy loam"*
  - *B that are "moderate infiltration" soils of "silt/silt loam/loam"*
  - *C that are "low infiltration" soils of "sandy clay loam"*
  - *D that are "very low infiltration" soils of "clay loam/silty clay loam/sandy clay/silty clay/clay"*
- Slope (defined from region-wide LiDAR) – less than 10% (~6 degrees; Low-Slope), flat to rolling land and greater than or equal to 10%, rolling to steep land (High-Slope).

The division of FWMT HRUs into Low-Slope and High-Slope groups, at a 10% threshold, creates multiple pastoral and horticultural farm types across the mix of slope classes (e.g., across various soils and stocking rate or crop). Whilst useful to configuring multiple differing responses of contaminants to variation in climate, a 10% threshold is not well aligned to New Zealand farming economic studies. For instance, in the Agribusiness Group (2016) slope is determined as flat (up to 7 degrees), rolling (between 7 and <16 degrees) and steep (between 16 and 28 degrees). Of the mitigations considered here, costs vary only by slope for fencing and at the threshold of low-to-flat and steep land (e.g., >16 degrees; affecting pastoral riparian management options only). To accommodate the marked differences in fencing costs, Low-Slope pastoral HRUs were all treated as equivalent to "flat-to-rolling" land from Agribusiness Group (2016). High-Slope pastoral HRUs should be split between "flat-to-rolling" and "steep" fencing costs, however, there is limited information to align the HRU slope classes with the rural sector fencing costs in the FWMT Stage 1. This approach invariably results in some High-Slope pastoral HRU's being assigned higher costs of fencing than likely (e.g., of land >6 but still <16 degrees in the High-Slope HRU pastoral HRU's being assigned fencing costs of land typically of >16 degree slope). Hence, actual riparian costings for High-Slope pasture will likely be lesser than reported here but deemed necessary to represent the marked differences of fencing "steep" land. Whilst this alignment is relatively simple, a more sophisticated approach can be taken in FWMT scenarios by examining the proportion of High-Slope pastoral streams on land of >16 degrees and only applying "steep" fencing costs to that.

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[2] Noting the terminology is confusing in that "orchards" are accounted for in other impact classes with any remaining land identified by LCDB4 as of orchard but lacking Agribase information to qualify as such, then assigned into the idle fallow HRU.

Table 1: Summary of HRUs used in Muller et al. (2020)

Land cover	Intensity	Soil group	Slope
Pastoral	Less than 10SU/ha	Free draining	Flat to rolling
			Rolling to steep
		Moderately draining	Flat to rolling
			Rolling to steep
		Poorly drained	Flat to rolling
			Rolling to steep
	More than 10SU/ha	Free draining	Flat to rolling
			Rolling to steep
		Moderately draining	Flat to rolling
			Rolling to steep
		Poorly drained	Flat to rolling
			Rolling to steep
Horticulture	Low Impact Horticulture - Orchards & idle fallow	Free draining	Flat to rolling
			Rolling to steep
		Moderately draining	Flat to rolling
			Rolling to steep
		Poorly drained	Flat to rolling
			Rolling to steep
	Medium Impact Horticulture - Arable, citrus, fodder, nuts & viticulture	Free draining	Flat to rolling
			Rolling to steep
		Moderately draining	Flat to rolling
			Rolling to steep
		Poorly drained	Flat to rolling
			Rolling to steep
	High Impact Horticulture - Berryfruit, flowers, stonefruit, kiwifruit, nursery, pipfruit, fruit, vegetables & greenhouses	Free draining	Flat to rolling
			Rolling to steep
		Moderately draining	Flat to rolling
			Rolling to steep
		Poorly drained	Flat to rolling
			Rolling to steep

This report informs use of the FWMT Stage 1 and hence aligns rural mitigation evidence to the HRU framework that underpins the water quality model. HRU classes and groups are not all well aligned to the literature, meaning the following assumptions are required to better align the HRUs with the rural mitigation literature. This is summarised in Table 2.

Notably, pastoral land uses of more than 10SU/ha were distinguished into dairy or sheep and beef groups given both, their markedly differing cost profiles (e.g., operating profit, mitigation outlay) and contaminant benefit profiles (e.g., varying contaminant reduction effects of equivalent interventions). This is consistent with the adjustment made in Muller et al. (2020). This adjustment reflects a high likelihood that sheep and beef farms of more than 10SU/ha exist in the North Island. For instance, Beef+LambNZ Economic Farm Survey noting that intensive finishing farms in the Northern North Island possessed an average SU/ha of 12.6 (2018-19) (Beef+LambNZ, 2020). When applying these sub-groups into the FWMT Stage 1, it requires assumptions of the proportion of HRU High Impact-Pasture in dairy and otherwise in other pastoral uses (by area). Equally, of whether to assign remaining (non-dairy) HRU High Impact-Pasture extent into beef, sheep and beef, deer or other forms of stock with a high likelihood of overall dominance by beef farming in the Auckland region (e.g., approximately half [56%] of pastoral farms in 2017 across Auckland were beef, 73% beef/sheep/beef & sheep, and 15% dairy with pig/deer/horse operations, StatsNZ, 2017). This is discussed further in Section 4, which discusses adoption/applicability of each mitigation option.

Whilst Low Impact Horticulture (idle, orchards and fallow) was included in Muller et al. (2020), that was predicated on kiwifruit returns. Auckland Council has since indicated that kiwifruit orchards are accounted for within the High Impact Horticulture HRU. High Impact Horticulture in Muller et al. (2020) and this report are both based on vegetables, for which there is more publicly available, assured evidence on contaminant losses, mitigation cost and mitigation effectiveness than orcharding. There is a lack of assured information for idle land, fallow land and “other” orchards (e.g., any such remaining outside of berry fruit, stone fruit, pip fruit, kiwifruit, other fruit and nuts – accounted for in Medium and High Impact Horticulture). Low Impact Horticulture HRUs include costs and benefits assigned from Medium Impact Horticulture to enable inclusion of such areas in decision-making. Doing so likely inflates such costs (e.g., carries greater opportunity cost) and possibly results in greater or lesser benefit (e.g., as based on other horticultural opportunities). However, the decision is likely to have marginal effect on scenario optimisation as Low Impact Horticulture accounts for <1% of any watershed area and also, <1% of edge-of-stream contaminant loads for all six contaminants simulated by the FWMT (see Bambic et al., 2020).

In addition, Medium and High Impact Horticulture groupings are assigned mitigation estimates from limited assured evidence (e.g., arable information for Medium; vegetable growing for High). Doing so, whilst necessary if limiting evidence to the wider assured literature, fails to acknowledge various horticultural activities within each grouping might have widely varying profitability and contaminant cost or benefit. In addition, some mitigation options may not be applicable across all horticulture activity within an intensity grouping. For example, the applicability of vegetated buffer strips for tree crop orchards is likely to be much lower than on vegetable cropping (i.e., given lower presence of bare ground).

Whilst the FWMT Stage 1 is the first of several FWMT iterations, required to otherwise generalise and simplify complex contaminant mitigation options, it is strongly recommended that further development of the FWMT revisit the HRU framework to enable more robust, finer grained accounting. Potentially, with industry partners to support shared implementation uses for the FWMT (e.g., accounting for sustainable farming transitions). Included in that recommendation is further refinement of pastoral and horticultural classes (e.g., consideration of discretely representing deer farming operations whose mitigation costs and benefits can differ widely from other pastoral sectors).

Table 2: HRU groupings revised for FWMT Stage 1

<table>
<tr><th></th><th>Original Intensity Grouping</th><th>Revised Intensity Grouping</th></tr>
<tr><td rowspan="3">Pastoral</td><td>Less than 10SU/ha</td><td>Less than 10SU/ha
(assumed to be sheep and beef farms)</td></tr>
<tr><td rowspan="2">More than 10SU/ha</td><td>Sheep and Beef - More than 10SU/ha</td></tr>
<tr><td>Dairy - More than 10SU/ha</td></tr>
<tr><td rowspan="3">Horticulture</td><td>Low Impact Horticulture –
Orchards, idle & fallow</td><td rowspan="2">Medium Impact Horticulture –
Arable, citrus, fodder, nuts & viticulture
(Includes Low Impact Horticulture –
Orchards, idle & fallow, and is based on an arable farm model)</td></tr>
<tr><td>Medium Impact Horticulture –
Arable, citrus, fodder, nuts & viticulture</td></tr>
<tr><td>High Impact Horticulture –
Berryfruit, flowers, stonefruit, kiwifruit, nursery, pipfruit, fruit, vegetables & greenhouses</td><td>High Impact Horticulture –
Berryfruit, flowers, stonefruit, kiwifruit, nursery, pipfruit, fruit, vegetables & greenhouses
(based on a vegetable farm model)</td></tr>
</table>

3 Rural costs and efficacy data - Stage 1

This section details the data and key assumptions used for each rural mitigation reasonably assured for use in the FWMT Stage 1. Rural mitigations span source controls (changing diffuse contaminant losses from large areas of HRU) to edge-of-field mitigations (EOF; reducing diffuse contaminant loss from localised areas and/or intercepting diffuse contaminant losses from large areas of HRU albeit on a localised area). Detailed discussion on the broader literature behind each mitigation option is included in Muller et al. (2020) and Muller and Stephens (2020) and is not repeated here.

3.1 Bundled mitigations

Bundled mitigations (M1, M2 and M3) represent a mix of mitigation options applied to farm management and/or farm systems to try and minimise contaminant losses. In Stage one of the FWMT, these bundles are predefined based on existing literature (see Muller et al., 2020 for detailed description of actions in M1, M2 and M3 – wider literature is used without refinement to Auckland region). At a broad level, the three mitigation bundles explored in Stage 1 are:

- M1 – essentially the practice change[3] and minor system change that might be considered to represent GMP (that could be expected to be identified by and implemented as a result of a farm environment planning process). These will vary across farm types (dairy, horticulture & sheep and beef) and align with the generally accepted position of M1 being low cost and [relatively] easy for adoption on farm.
- M2 – this will represent a combination of less costly bundled system changes and de-intensification and be cumulative of the M1 options – i.e. M2 is applied in addition to, not instead of M1.
- M3 – same as M2 but more expensive or challenging system changes[4], and/or further de-intensification[5], again cumulative of the mitigations in M1 and M2

These mitigation bundles are designed to be cumulative (i.e., M1 is applied first, followed by M2 and then M3). Both benefits and costs are presented as cumulative figures (i.e., a percentage change in profit or contaminant loss in M2, includes the M1 results rather than in addition to the M1 results). Because of this, percentage changes in both profit and contaminant changes should be read from a pre-mitigation base. However, because the Stage 1 FWMT results are based on the most appropriate literature, not all results are from the same studies (i.e., for dairy, M1 is from a different base study to M2 and M3). This provides a bit of a challenge as the results are not explicitly comparable but are intended to recognise for an increasing level of effort by the farm to implement practice and system based changes. Because not all estimates are from the same studies, treating M1, M2 and M3 as cumulative does increase uncertainty (relative to if results were from the same study). However, because in the literature used M1, M2 and M3 are largely defined in similar ways, at this stage it is considered appropriate at this stage to apply M1, M2 and M3 cumulatively. Consistent modelling between M1, M2 and M3 should be sought to improve the FWMT Stage 1. Again, the FWMT Stage 1 is intended to utilise generalisations by HRU groupings to capture such challenges in a simple, cumulative

[3] Practice change is defined as modification to existing practices (how we do things) that do not change farm/orchard system parameters (what we are doing).
[4] System change is defined as modifications to an existing farm system (what we are doing) that do not alter farm intensity (how much we produce with what we are using).
[5] De-intensification is defined as modifications to an existing farm system (what we are doing) that reduces farm intensity (how much we produce with what we are using).

manner – any differences therein within HRU groupings should be considered when using scenario outputs (i.e., recognising that general costs and benefits are likely to be reasonable but will vary by individual farms).

Several bundled mitigation studies consider profitability (and therefore the impacts on operating profit) on a total hectare basis, whereas others report to effective hectares. Equally, the FWMT is configured to represent only total area by HRU. The operating profit estimates provided by land use type provided by Muller et al. (2020) were therefore adjusted to total hectare basis. To ensure consistency, additional costing and benefit information across all rural mitigations is presented on a total hectare basis here. Best professional judgement was used to estimate that horticultural HRU's possess 3% ineffective area, dairy HRU's 5% ineffective area, sheep and beef HRUs with more than 10SU/ha 5% ineffective area and sheep and beef HRUs with less than 10SU/ha 10% ineffective area. The revised profitability estimates before mitigation are provided in Table 3. For all assumptions related to operating profit, see Muller et al. (2020). All percentage changes to profit and contaminants were applied for total area following adjustment.

Table 3: Estimates of operating profit by HRU intensity class

Intensity class in HRU	Operating profit ($ per effective hectare per year)	Operating profit ($ per total hectare per year)
Less than 10SU/ha	$420	$378
Sheep and beef - More than 10SU/ha	$680	$646
Dairy - More than 10SU/ha	$1,330	$1,264
Low Impact Horticulture & Medium Impact Horticulture - (Orchards, idle, fallow, arable, citrus, fodder, nuts, viticulture)	$2,400	$2,328
High Impact Horticulture - Berryfruit, flowers, stonefruit, kiwifruit, nursery, pipfruit, fruit, vegetables, greenhouses	$4,000	$3,880

3.1.1 Mitigation Bundle 1

Table 4 provides the input data for mitigation bundle 1 (M1-GMP) – pastoral HRU's, while Table 5, provides the M1 bundle for horticulture HRUs, both are sourced from Muller et al. (2020). This mitigation is described in more detail in the following table but as above, is essentially the practice change and minor system change that might be considered to represent GMP (that could be expected to be identified by and implemented as a result of a farm environment planning process). These are generally low cost and [relatively] easy options for adoption on farm, for example improved nutrient budgeting.

Both the economic impact and contaminant impact are applied as annual percentage changes for total farm area. Base operating profit is based on operating profit per total hectare in Table 3. M1 mitigations are not able to be segregated by slope or soil group at this stage for sheep and beef intensity classes, based on the literature available. For dairy, results are not differentiated by slope, but they are by soil type.

Table 4: Input data for mitigation bundle 1 (M1-GMP) – Pastoral

Hydrological Response Unit[1]		Contaminant impact (kg contaminant/ha/yr)				Economic impact	Mitigation description
Intensity	**Soil group**	**N**	**P**	**Sediment**	***E. coli***	**Operating profit**	
Less than 10SU/ha[2]	Not differentiated	-2%	-9%			-37%	Bundled GMP including; improved nutrient budgeting and maintenance of Olsen P, efficient fertiliser use technology, stock class management within landscape, improved winter cropping practices, laneway run-off diversion, relocation of troughs, appropriate gate, track and race placement, targeted space planting of poles, slow release RPR fertiliser, adoption of low N leaching forages, full stock exclusion from all waterbodies greater than 1m wide at any point adjacent to farm (including drains) and wetlands (2m average vegetated and managed buffer around rivers, streams, lakes and wetlands; 1m around drains; 3m average buffer on slopes greater than 8 degrees; 5m average buffer on slopes greater than 16 degrees).
Sheep and beef - More than 10SU/ha[3]	Not differentiated	-1%	-18%			-81%	
Dairy - More than 10SU/ha[4]	Free draining	-16%	-75%	-15%	-79%	-20%	Bundled GMP including full stock exclusion from streams using single-wire fencing. Soil Olsen phosphorus levels reduced from 38 to 32. Effluent areas enlarged appropriate to effluent potassium loading rates. Additional one month's effluent pond storage; low application depth.
	Moderately draining	-17%	-68%	-15%	-62%	-9%	
	Poorly drained	-17%	-61%	-15%	-45%	+2%	
	Average of all soil groups	-17%	-68%	-15%	-186%	-9%	

1. *No differentiation in slope*
2. *Based on Rangitāiki sheep and beef farm in Matheson et al. (2018; mitigation bundle M1).*
3. *Based on Kaituna-Pongakawa-Waitahanui sheep and beef farm in Matheson et al. (2018; mitigation bundle M1).*
4. *Based on NIWA (2010) for free draining and poorly draining.*

Both the economic impact and contaminant impact are applied as annual percentage changes for total farm area. Base operating profit is based on operating profit per total hectare in Table 3. Table 5 provides the input data for mitigation bundle 1 (M1-GMP) – horticulture HRU's, sourced from Muller et al. (2020). This mitigation is applied to two horticulture HRU groups, Medium and High Impact

Horticulture (Low Impact Horticulture is assigned Medium Impact Horticulture costs). Neither of the Horticulture HRU categories are able to be segregated by slope or soil group for this mitigation at this stage based on the literature available. Both the economic impact and contaminant impact are applied as annual percentage changes for total farm area. Base operating profit is based on operating profit per total hectare in Table 3.

Table 5: Input data for mitigation bundle 1 (M1-GMP) – Horticulture

Hydrological Response Unit[1,2]	**Contaminant impact (kg contaminant/ha/yr)**				**Economic impact**	**Mitigation description**
Intensity	**N**	**P**	**Sediment**	***E. coli***	**Operating profit**	
Low Impact Horticulture & Medium Impact Horticulture - (Orchards, idle, fallow, arable, citrus, fodder, nuts, viticulture)[3]	-9%	-1%			-7%	Bundled GMP including; grass or planted buffer strips, maintain optimal Olsen P and appropriate P fertiliser use, efficient fertiliser use technology, cover crops between cultivation cycles, manage risk from contouring, reduced tillage practices.
High Impact Horticulture - Berryfruit, flowers, stonefruit, kiwifruit, nursery, pipfruit, fruit, vegetables, greenhouses[4]	-2%				0%	Limiting any one application of N to 80 kgN/ha per month, no reduction in yield.

1. *No differentiation in slope*
2. *No differentiation in soil type*
3. *Based on 40 ha maize silage production system in Matheson et al. (2018; mitigation bundle M1).*
4. *Based on Agribusiness Group (2014) from work in the Lower Waikato catchment. Weighted average of their results based on 50% of extensive horticulture rotation, 45% intensive rotation and 5% market garden.*

The LCCs have been generated based on the economic impact of M1-GMP on operating profit and represent a loss in profit LCC $/ total ha/ year, over a 50-year time period (Appendix A). For both Table 4 and Table 5 as per the standard LCC Model, costs are discounted at 2%, 4% and 6%. Where the contaminant impact cell is blank, no contaminant impact is included for that mitigation and contaminant combination. Figure 3 shows the loss in profit LCC $/ ha/ year for a 4% discount rate. Of note is the result for dairying on poorly drained soils. This had a 2% improvement in annual operating profit, indicating that there was some level of efficiency that could be gained on that farm typology while applying the mitigation M1 bundled. This is shown as a negative LCC. It should be remembered that there will be a range around this depending on the farm system and mitigation applied for this farm typology.

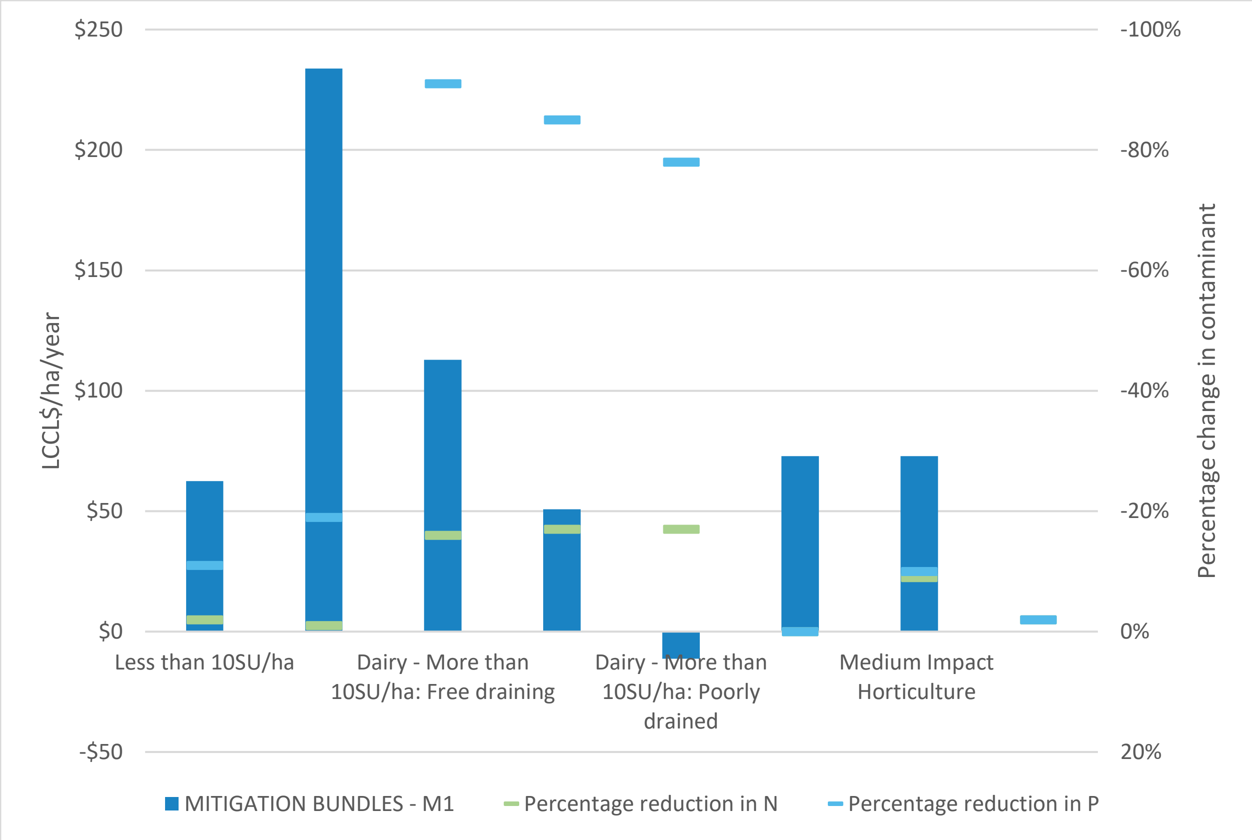

Figure 3: Mitigation Bundle M1 - $LCCL/ha/year (4% discount rate over 50 years)

3.1.2 Mitigation Bundle 2

M2 typically represents a combination of less costly bundled system changes and de-intensification and be cumulative of the M1 options – i.e. M2 is applied in addition to, not instead of M1. Table 6 provides the input data for M2 – pastoral HRU's, while Table 7 provides the input data for horticulture HRU's, both sourced from Muller et al. (2020). Both the economic impact and contaminant impact are applied as annual percentage changes for total farm area. Base operating profit is based on operating profit per total hectare in Table 3.

M2 is applied to three pastoral HRU groups (less than 10 SU/ha, more than 10 SU/ha – sheep and beef, and more than 10 SU/ha – dairy). These three categories are not able to be segregated by slope or soil group at this stage based on the literature available. The M2 values for dairy were cumulative with the average of the M1 dairy options.

For Table 6 two options are included for dairy HRU's, one relates to N targeted mitigations, and one to P targeted mitigations. The N mitigation option is considerably more robust for the Auckland region than the P mitigation. This is because the P mitigation is predicated on dairy farm modelling in Southland which has a different climate and likely a different farm system to dairy farms in Auckland (primarily the prevalence of wintering cropping). This means M2 P costs and benefits are considerably more uncertain than M2 N equivalent on dairy farms in the Auckland region. The segregation of the two is due to the literature available and intended to enable robust N-mitigation modelling should N-loss be prioritised, but otherwise support P-mitigation modelling (only with greater caution about such optimised strategies from FWMT simulations).

The M2 N and M2 P mitigations can be combined into an M2 intervention (i.e., ensuring both the contaminant and profit impact are added to the M1 bundle). However, such a combined M2 intervention will have greater uncertainty than the M2 N mitigation bundle and should be used with caution. If using the M2 N bundle, then the M3 N bundle should also be used (i.e., either M2 N and M3 N can be used, but not M2 N and M3 P as bundle studies note decisions made about farm change for M2 restrict subsequent bundling choices).

Table 6: Input data for mitigation bundle 2 (M2) – Pastoral

Hydrological Response Unit[1,2]	**Contaminant impact (kg contaminant/ha/yr)**				**Economic impact**	**Mitigation description**
Intensity	**N**	**P**	**Sediment**	***E. coli***	**Operating profit**	
Less than 10SU/ha[3]	-4%	-9%			-49%	Bundled mitigation: improved nutrient budgeting and maintenance of Olsen P, efficient fertiliser use technology, stock class management within landscape, improve winter cropping practices, laneway run-off diversion, relocation of troughs, appropriate gate, track and race placement, targeted space planting of poles, slow release RPR fertiliser, adoption of low N leaching forages, elimination of N fertiliser applied to accelerate liveweight gain, develop a detention bund, complete protection of gully heads, management of gorse, whole paddock space planting of poles, full stock exclusion from permanently flowing waterbodies less than 1m wide (REC Order 2 and above) and 1m average vegetated and managed buffer (2m average buffer on slopes greater than 8 degrees, 3m average buffer on slopes greater than 16 degrees [with associated stock water reticulation, if any]), afforestation of erosion prone land, changing stock ratios to reflect lower N leaching potential.
Sheep and beef - More than 10SU/ha[4]	-25%	-38%			-156%	
Dairy (M2 N) - More than 10SU/ha[5]	-36%	-68%	-15%	-62%	-15%	Based essentially on reducing N inputs (feed and fertiliser) and stocking rates. Stocking rate reduced from 3.1 to 2.9 cows/effective hectare. N fertiliser reduced from 116 to 60 kg N/ effective hectare. Bought feed (as % of total offered) reduced from 17 to 16%.
Dairy (M2 P) - More than 10SU/ha[6]	-17%	-78%	-15%	-62%	-24%	Based on reducing P inputs as per OVERSEER, fertiliser, effluent and cropping and adjusting stocking rates as needed.
Dairy (M2 combined) - More than 10SU/ha	-36%	-78%	-15%	-62%	-30%	Combined M2 N and M2 P options with the simple average of M1 for dairy.

1. *No differentiation in slope*
2. *No differentiation in soil type*
3. *Based on Rangitāiki sheep and beef farm in Matheson et al. (2018; mitigation bundle M2).*
4. *Based on Kaituna-Pongakawa-Waitahanui sheep and beef farm in Matheson et al. (2018; mitigation bundle M2).*
5. *Based on DairyNZ (2014; mitigation level 2) utilising the Waipa and Franklin weighted average farm.*
6. *Based on Newman & Muller (2017) which utilised Southland dairy farms.*

Table 7 provides the input data for mitigation bundle 2 (M2) – horticulture HRU's, sourced from Muller et al. (2020). This mitigation is applied to two horticulture HRU groups (with Low Impact Horticulture being assigned the same costs and benefits as Medium Impact Horticulture). These categories are not able to be segregated by slope or soil group at this stage based on the literature available. While Muller et al. (2020) provided estimates of M2 for Low Impact Horticulture, for the reasons outlined earlier, Medium Impact Horticulture estimates are assigned instead for Stage 1 of the FWMT.

Table 7: Input data for mitigation bundle 2 (M2) – Horticulture

Hydrological Response Unit[1,2]	Contaminant impact (kg contaminant/ha/yr)				Economic impact	Mitigation description
Intensity	N	P	Sediment	*E. coli*	Operating profit	
Low Impact Horticulture & Medium Impact Horticulture – (Orchards, idle, fallow, arable, citrus, fodder, nuts, viticulture)[3]	-15%	-1%			-42%	Reduce N fertiliser use from 216kgN/ha/yr across feed wheat, milling wheat and barley to 140kgN/ha/yr. The reduction in fertiliser yield is modelled to reduce yield from 12t/ha (wheat) and 10t/ha (barley) to 8t/ha (wheat and barley).
High Impact Horticulture – Berryfruit, flowers, stonefruit, kiwifruit, nursery, pipfruit, fruit, vegetables, greenhouses[4]	-10%				-60%	Reduce N fertiliser use by 10% with a reduction in yield of 10% (summer potatoes, onions & carrots), 15% (squash, broccoli, lettuce, cabbage, spinach & cauliflower) and 25% (winter potatoes & barley).

1. *No differentiation in slope*
2. *No differentiation in soil type*
3. *Based on Mathers (2017; mitigation level 1) which focused on Southland feed wheat, milling wheat and barley crops.*
4. *Based on Agribusiness Group (2014) from work in the Lower Waikato catchment. Weighted average of their results based on 50% of extensive horticulture rotation, 45% intensive rotation and 5% market garden.*

The LCCs have been generated based on the economic impact of M2-GMP on operating profit and represent a loss in profit LCC $/ total ha/ year, over a 50-year time period (Appendix A). For both Table 6 and Table 7, as per the standard LCC Model, costs are discounted at 2%, 4% and 6%. Where the contaminant impact cell is blank, no contaminant impact is included for that mitigation and contaminant combination. Figure 4 shows the loss in profit LCC $/ ha/ year for a 4% discount rate.

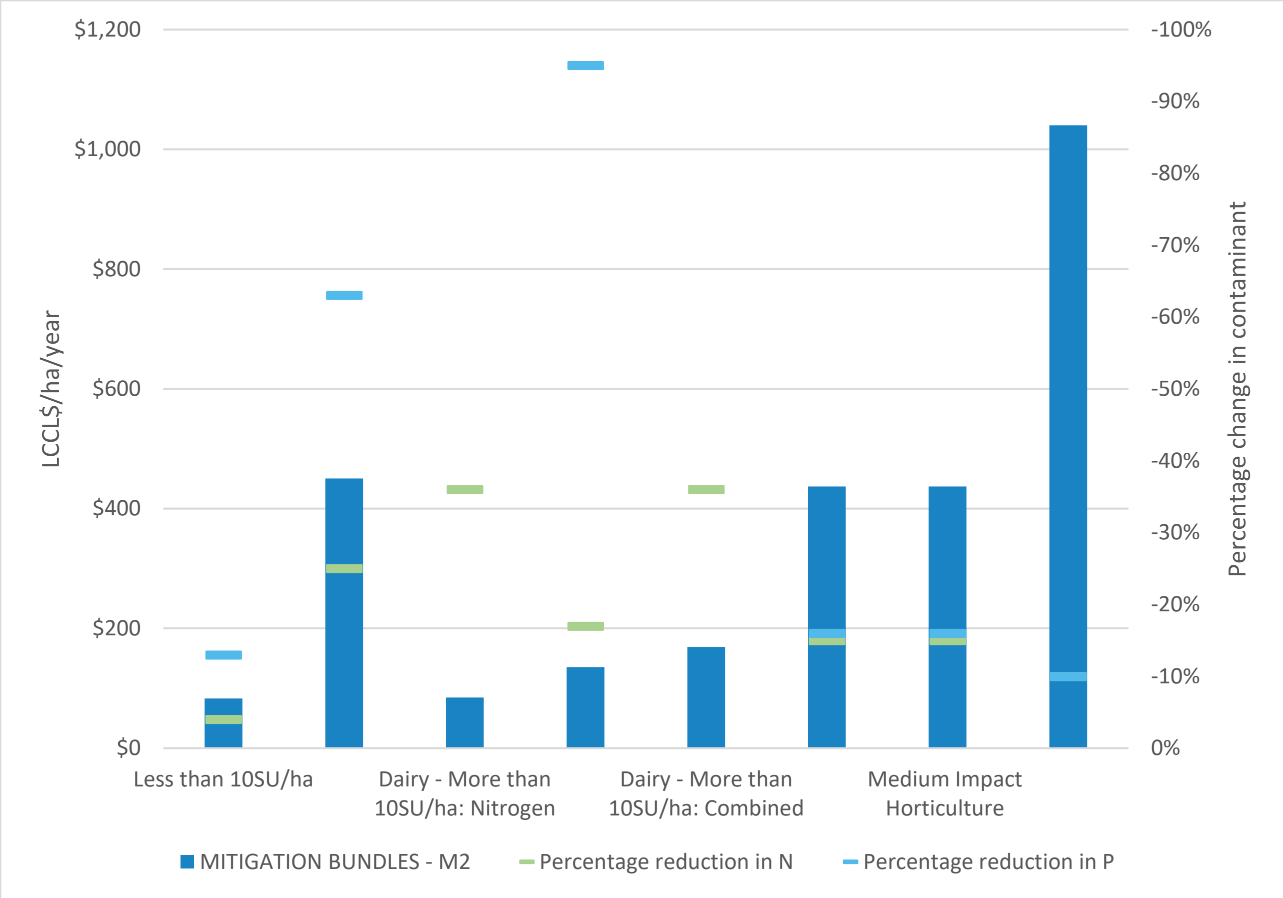

Figure 4: Mitigation Bundle M2 - $LCCL/ha/year (4% discount rate over 50 years)

3.1.3 Mitigation Bundle 3

M3 is typically designed to represent more expensive or challenging system changes, and/or further de-intensification, again cumulative of the mitigations in M1 and M2. In reality, sometimes the cost per unit of contaminant removed is less in M3 than earlier mitigations, however, the later mitigations are predicated on the changes made in earlier mitigations. Table 8 provides the input data for mitigation bundle 3 (M3) – pastoral HRU's. Table 9 provides equivalent estimates for horticulture. Both Table 8 and Table 9 are sourced from Muller et al. (2020). Both the economic impact and contaminant impact are applied as annual percentage changes for total farm area. Base operating profit is based on operating profit per total hectare in Table 3.

M3 is applied to three pastoral HRU groups (less than 10 SU/ha, more than 10 SU/ha – sheep and beef, and more than 10 SU/ha – dairy). These three categories are not able to be segregated by slope or soil group at this stage based on the literature available.

For Table 8 two options are included for dairy, one relates to N targeted mitigations (M3 N), and one to P targeted mitigations (M3 P). The M3 N mitigation option is considerably more robust for the Auckland region than the M3 P mitigation. This is because the M3 P mitigation estimates are derived from dairy farm modelling in Southland, under a markedly different climate and likely a different system to Auckland dairy farms (primarily the prevalence of wintering cropping). As above, M3 P costs and benefits are more uncertain than the M3 N intervention on dairy farms in the Auckland region. The segregation is based on the most appropriate literature is intended to enable robust N-mitigation modelling should N-loss be prioritised, but otherwise support P-mitigation modelling (only with greater caution about such optimised strategies from FWMT simulations).

The M3 N and M3 P mitigations can be combined into an M3 intervention (i.e., ensuring both the contaminant and profit impact are added to the M1 bundle). However, such a combined M3 intervention will have greater uncertainty and should be used with caution. As above, application of M3 N should only follow prior M2 N adoption (and likewise for a combined option).

Table 8: Input data for mitigation bundle 3 (M3) – Pastoral

Hydrological Response Unit[1,2]	Contaminant impact (kg contaminant/ha/yr)				Economic impact	Mitigation description
Intensity	**N**	**P**	**Sediment**	***E. coli***	**Operating profit**	
Less than 10SU/ha[3]	-14%	-10%			-59%	Bundled mitigation: improved nutrient budgeting and maintenance of Olsen P, efficient fertiliser use technology, stock class management within landscape, improve winter cropping practices, laneway run-off diversion, relocation of troughs, appropriate gate, track and race placement, targeted space planting of poles, slow release RPR fertiliser, adoption of low N leaching forages, elimination of N fertiliser applied to accelerate liveweight gain, develop a detention bund, complete protection of gully heads, management of gorse, whole paddock space planting of poles, afforestation of erosion prone land, changing stock ratios to reflect lower N leaching potential, full stock exclusion from REC Order 1 watercourses less than 1m wide and 1m wide average vegetated buffer, creation of new wetlands, elimination of N applications to support capital livestock.
Sheep and beef - More than 10SU/ha[4]	-31%	-38%			-184%	
Dairy (M3 N) - More than 10SU/ha[5]	-61%	-68%	-15%	-62%	-24%	Based essentially on reducing N inputs (feed and fertiliser) and stocking rates. Stocking rate reduced from 3.1 to 2.8 cows/effective hectare. Nitrogen fertiliser reduced from 116 to 29 kg N/ effective hectare. Bought feed (as % of total offered) reduced from 17 to 15%.
Dairy (M3 P) - More than 10SU/ha[6]	-17%	-93%	-15%	-62%	-49%	Based on reducing P inputs as per OVERSEER, fertiliser, effluent and cropping and adjusting stocking rates as needed.
Dairy (M3 combined) - More than 10SU/ha	-61%	-93%	-15%	-62%	-64%	Combined M3 N and M3 P options with the simple average of M1 and combined M2 for dairy.

1. *No differentiation in slope*
2. *No differentiation in soil type*
3. *Based on Rangitāiki sheep and beef farm in Matheson et al. (2018; mitigation bundle M3).*
4. *Based on Kaituna-Pongakawa-Waitahanui sheep and beef farm in Matheson et al. (2018; mitigation bundle M3).*
5. *Based on DairyNZ (2014; mitigation level 3) utilising the Waipa and Franklin weighted average farm.*
6. *Based on Newman & Muller (2017) which utilised Southland dairy farms.*

Table 9 provides the input data for mitigation bundle 3 (M3) – horticulture HRU's, sourced from Muller et al. (2020). This mitigation is applied to two horticulture HRU groups (with Low Impact Horticulture being assumed to be combined with Medium Impact Horticulture in Stage 1 of the FWMT). These categories are not able to be segregated by slope or soil group at this stage based on the literature available.

Table 9: Input data for mitigation bundle 3 (M3) – Horticulture

Hydrological Response Unit[1,2]	Contaminant impact (kg contaminant/ha/yr)				Economic impact	Mitigation description
Intensity	N	P	Sediment	*E. coli*	Operating profit	
Low Impact Horticulture & Medium Impact Horticulture - (Orchards, idle, fallow, arable, citrus, fodder, nuts, viticulture)[3]	-21%	-1%			-100%	Reduce N fertiliser use from 216kgN/ha/yr across feed wheat, milling wheat and barley to 100kgN/ha/yr. The reduction in fertiliser yield is modelled to reduce yield from 12t/ha (wheat) and 10t/ha (barley) to 6t/ha (wheat and barley).
High Impact Horticulture - Berryfruit, flowers, stonefruit, kiwifruit, nursery, pipfruit, fruit, vegetables, greenhouses[4]	-14%				-121%	Reduce nitrogen fertiliser use by 20% with a reduction in yield of 20% (summer potatoes, onions & carrots), 25% (squash, broccoli, lettuce & barley), 30% (cabbage, spinach & cauliflower) and 35% (winter potatoes).

1. *No differentiation in slope*
2. *No differentiation in soil type*
3. *Based on Mathers (2017; mitigation level 2) which focused on Southland feed wheat, milling wheat and barley crops*
4. *Based on Agribusiness Group (2014) from work in the Lower Waikato catchment. Weighted average of their results based on 50% of extensive horticulture rotation, 45% intensive rotation and 5% market garden.*

The LCCs have been generated based on the economic impact of M3-GMP on operating profit and represent a loss in profit LCC $/ total ha/ year, over a 50-year time period (Appendix A). For both Table 8 and Table 9, as per the standard LCC Model, costs are discounted at 2%, 4% and 6%. Where the contaminant impact cell is blank, no contaminant impact is included for that mitigation and contaminant combination. Figure 5 shows the loss in profit LCC $/ ha/ year for a 4% discount rate.

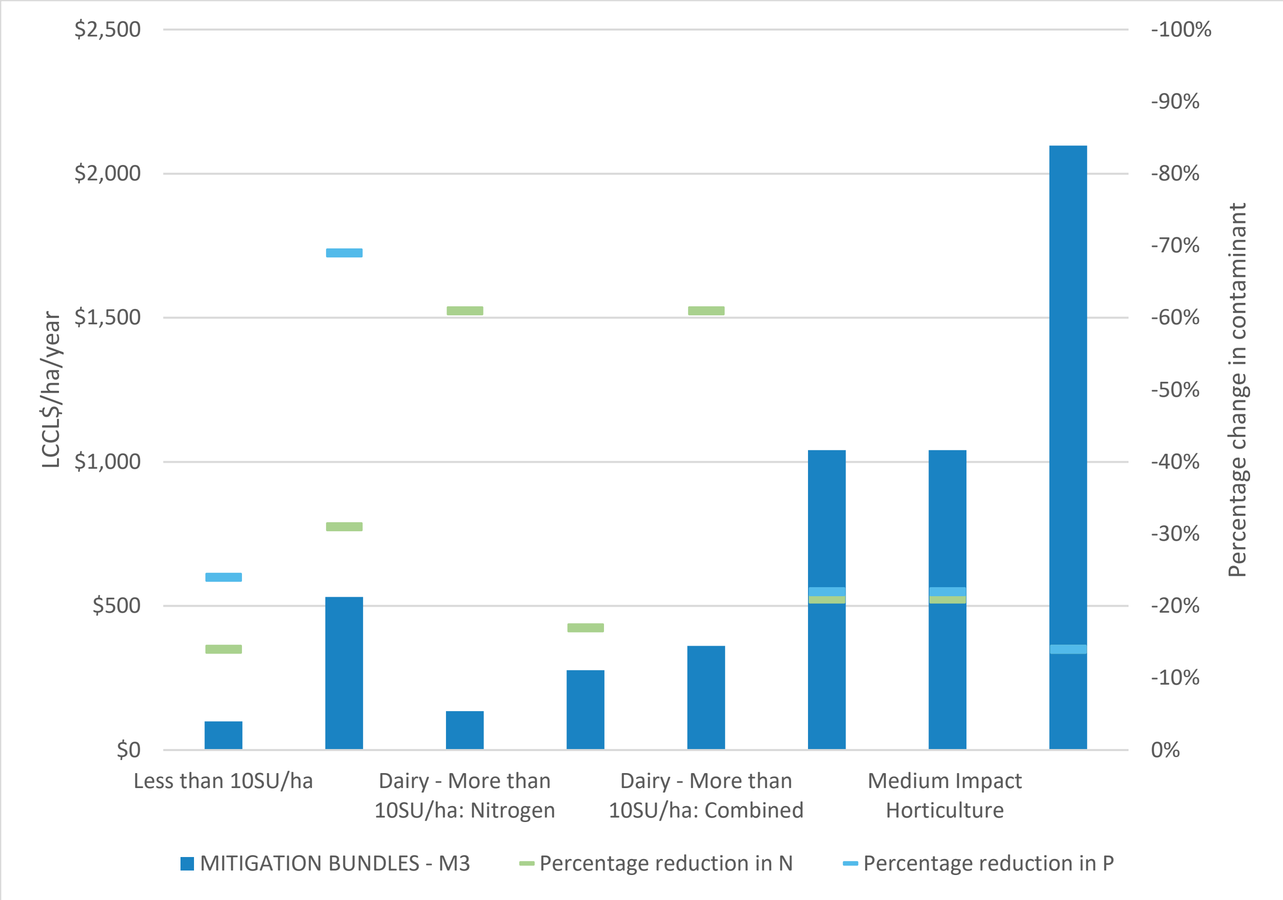

Figure 5: Mitigation Bundle M3 - $LCCL/ha/year (4% discount rate over 50 years)

3.2 EOF mitigations

EOF mitigations include mitigations that intercept contaminant loss typically through retirement of land from production with limited system changes required and may not be sector specific. Common examples include wetlands (creation or restoration), riparian buffers (grass filters, planted), detainment bunds, sedimentation ponds and filtration devices.

The EOF mitigations presented here are independent results – benefit and cost estimates are not cumulative, nor integrated (modified) as for bundled mitigations (e.g., M1, M2 or M3). The literature is not diverse enough to enable the variation in EOF mitigation costs to be understood and varied uniquely following adoption of M1, M2 or M3. As such, the percentage changes to profit are generalised and derived in isolation of wider farm-system change. So, caution is required in interpretation of FWMT scenario costs which include EOF and bundled mitigations depending on the order in which mitigations are applied.

A further limitation of the EOF data presented in this report is that some of the bundled mitigation options include some degree of EOF mitigation (depending on how the bundled mitigations were defined in the base study). Applying EOF options cumulatively with bundled mitigations will likely result in some double-counting of both applicability and costs and benefits (e.g., with the FWMT assigning greater opportunity for EOF mitigations than feasible). However, this reflects a necessity of the existing national literature and reliance thereupon by the FWMT Stage 1. Opportunities to refine national information and account for cumulative implementation should be prioritised to improve FWMT accounting.

As mentioned in Section 2.1.2 the total acquisition cost (TAC) portion includes an overhead and indirect cost factor of 17.5% of the construction cost. This component of TAC accounts for time needed to plan, consent or implement potential mitigations, and associated contingencies, and is based on a likely overhead cost for urban EOF interventions of 15% - 20% (Ira and Simcock, 2019). This component of TAC is only applied to EOF and land retirement rural mitigations because bundled mitigations have no capital costs.

As with the bundled mitigations, Low Impact Horticulture has been assumed to be equivalent in cost and benefit of rural EOF mitigations to Medium Impact Horticulture (i.e., in lieu of better information).

All EOF opportunity costs are based on dollars per total hectare (Table 3) and contaminant losses are based on percentage change for total farm area.

3.2.1 EOF – Wetlands

Table 10 and Table 11 contain the capital, maintenance and opportunity costs for wetlands, including earthworks and planting, but exclude fencing (which is included in Table 12 and should be added to the capital and maintenance costs for wetlands in pastoral HRUs). The costs are differentiated by HRU's for land classes (due to the difference in opportunity costs and fencing requirements for pasture) but not by slope or soil type – though it can reasonably be **assumed wetlands will only occur in flat and rolling areas.** Fencing costs are intended to be applied on pastoral EOF wetlands, using a wetland area to perimeter ratio of 0.15 m fencing/m^2 wetland, derived for dairy, sheep and beef farms in the Kaipara Moana Remediation business case (Martin Jenkins, 2020). Further refinement of the perimeter-to-area ratios of wetlands (small and large) across Auckland pastoral and horticultural land is recommended to improve the EOF-wetland LCC estimates as fencing is a considerable cost component for the intervention for pastoral land uses.

Wetlands are differentiated by size. Small wetlands are those less than one hectare, while large are greater than one hectare. Benefits are equivalent in both, though the costs change to reflect more efficiency in larger wetlands (e.g., of consenting and labour). Benefits will be applied in a generalised (implicit) manner by both, with an **assumption required on the proportion of HRU extent available to undergo EOF wetland treatment** (for both types). That contrasts with "regional wetlands", a third type of mitigation applied alike to rural and urban HRU's but whose benefits and costs are determined explicitly by area upstream relative to area of device within the FWMT Stage 1 (e.g., outside of this report scope). Implicit representation of small and medium rural EOF wetlands is necessary in the absence of detailed information on sub-farm level opportunities for and cumulative treated area across differing HRU's.

Limited information is available for horticulture costs and benefits associated with EOF wetlands. However, wetlands can markedly attenuate nutrient and sediment loads to waterways (Rutherford et al., 2004, 2009; Rutherford, 2017). Whilst, corresponding contaminant yields are enriched from horticultural HRU's in the FWMT Stage 1 (Bambic et al., 2020). Combined, it seems prudent to ensure wetland opportunities are recognised by the FWMT and so, pasture HRU capital costs and benefits are applied to the small and medium-sized wetlands on horticulture (adjusted for horticultural opportunity costs and without fencing costs).

Small and medium EOF wetland costs are an average between facilitated and constructed wetland costs. The capital cost on horticultural HRU's includes the same capital cost (planting and earthworks in Table 11) as pastoral wetlands but excludes fencing. Likewise, any horticultural wetland maintenance costs include those in Table 10 and Table 11 but exclude fencing maintenance in Table 12. Wetlands on pastoral land will incur fencing and fence maintenance costs (Table 12). Those vary for pastoral type and by slope class, from Muller and Stephens (2020). No water reticulation is costed for small and large pastoral wetlands.

The opportunity costs assume that retired area was 50% less productive than wider, effective farm area (e.g., saturated areas most likely to receive spring and/or stormwater regularly without free drainage). This assumption is based on Muller et al. (2020) which notes that estimates range from 0% to 100% loss in productivity for the area being used for a wetland and there is no consensus, as such a mid-point of 50% was considered appropriate for Stage 1 of the FWMT in lieu of any better evidence. All costs in Table 10 and Table 11 are based on the area of the wetland, not the area of the catchment.

The capital costs related to the wetland are incurred in year 1 of the life cycle analysis period only, whereas fencing capital costs are incurred in year 1 and in year 25, assuming a 25-year life-span for fencing. Opportunity costs occur annually, as do both fencing and wetland maintenance costs over a 50-year interval (i.e., consistent with all other life cycle costing for rural mitigations).

As above, the capital and maintenance costs are determined by the assumed proportion of horticultural and pastoral HRU's retired into small or large wetlands. The LCCs are reported as $/m^2 wetland surface area/ year, over a 50-year time period (Appendix A), and costs are discounted at 2%, 4% and 6%.

Table 10: Costs and benefit of wetlands, excluding fencing - for pastoral HRU's

	HRU[1,2]	Contaminant impact[3]				Economic impact		
	Intensity	**N**	**P**	**Sediment**	***E. coli***	**Capital ($/m^2)[4]**	**Maintenance ($/ha/yr)[5]**	**Opportunity cost ($/ha/yr)**
Small wetland	Less than 10SU/ha	-10%	-45%	-65%	-55%	16.40	125	189
	Sheep and beef - More than 10SU/ha							323
	Dairy - More than 10SU/ha							632
Large wetland	Less than 10SU/ha	-10%	-45%	-65%	-55%	12.60	250	189
	Sheep and beef - More than 10SU/ha							323
	Dairy - More than 10SU/ha							632

1. *No differentiation in slope (assumes wetlands only apply to flat and rolling land)*
2. *No differentiation in soil type*
3. *Based on Daigneault and Elliott (2017)*
4. *Muller (2019) and NIWA (2007)*
5. *Muller (2019)*

Table 11: Costs and benefit of wetlands, excluding fencing – for horticulture HRU's

	HRU[1,2]	Contaminant impact[3]				Economic impact		
	Intensity	N	P	Sediment	*E. coli*	Capital ($/m²)[4]	Maintenance ($/ha/yr)[5]	Opportunity cost ($/ha/yr)
Small wetland	Low & Medium Impact Horticulture - (Orchards, idle, fallow, arable, citrus, fodder, nuts, viticulture)	-10%	-45%	-65%	-55%	16.40	125	1,164
	High Impact Horticulture - Berryfruit, flowers, stonefruit, kiwifruit, nursery, pipfruit, fruit, vegetables, greenhouses							1,940
Large wetland	Low & Medium Impact Horticulture - (Orchards, idle, fallow, arable, citrus, fodder, nuts, viticulture)	-10%	-45%	-65%	-55%	12.60	250	1,164
	High Impact Horticulture - Berryfruit, flowers, stonefruit, kiwifruit, nursery, pipfruit, fruit, vegetables, greenhouses							1,940

1. *No differentiation in soil type*
2. *Based on Daigneault and Elliott (2017)*
3. *Muller (2019) and NIWA (2007)*
4. *Muller (2019)*
5. *No differentiation in slope (assumes wetlands only apply to flat and rolling land)*

Table 12 highlights the capital and maintenance costs of fencing for wetlands on pastoral land uses. It is differentiated by land use type and only considers flat and rolling sloping land in Muller and Stephens (2020), reflecting **an assumption that natural wetlands are located in areas of gentler gradient** where water can pond.

Four key pastoral wetland fencing sub-categories are proposed: no fence, a 2-wire electric fence, a 4-wire electric fence and an 8-wire non-electric post and batten fence. These could be considered as broadly being suitable for dairy cattle (2-wire and 4-wire options), other cattle enterprises (4-wire option) and enterprises with a prevalence of sheep (8-wire option). Costs are based on Muller and Stephens (2020) and the associated assumptions contained within that report. Horticultural riparian management scenarios do not require stock exclusion. **Not all stock classes are considered in this report.** Deer farming in particular is not distinguished by HRU classes but is associated with a higher fencing cost than ascribed for dairy, beef and sheep and beef farming here.

Table 12: Capital and maintenance costs – fencing (2019$/m) (from Table 23 and Table 24 in Muller and Stephens, 2020)

Fence type	Slope[1]	Year 0	Year 1-24	Year 25	Year 26-50	Annual maintenance cost ($/m/yr)
		Capital costs ($/m)				
No fence	Flat & Rolling	0	0	0	0	0
2-wire electric		5.4	0	5.4	0	0.05
4-wire electric		8.4	0	8.4	0	0.08
8-wire non-electric post and batten		16.1	0	16.1	0	0.16

1. Only flat and rolling fencing costs are included here as wetlands were not included in steep slope areas

Total annualised LCC $/m^2 of wetland surface area (including fencing where relevant) are shown in Figure 6.

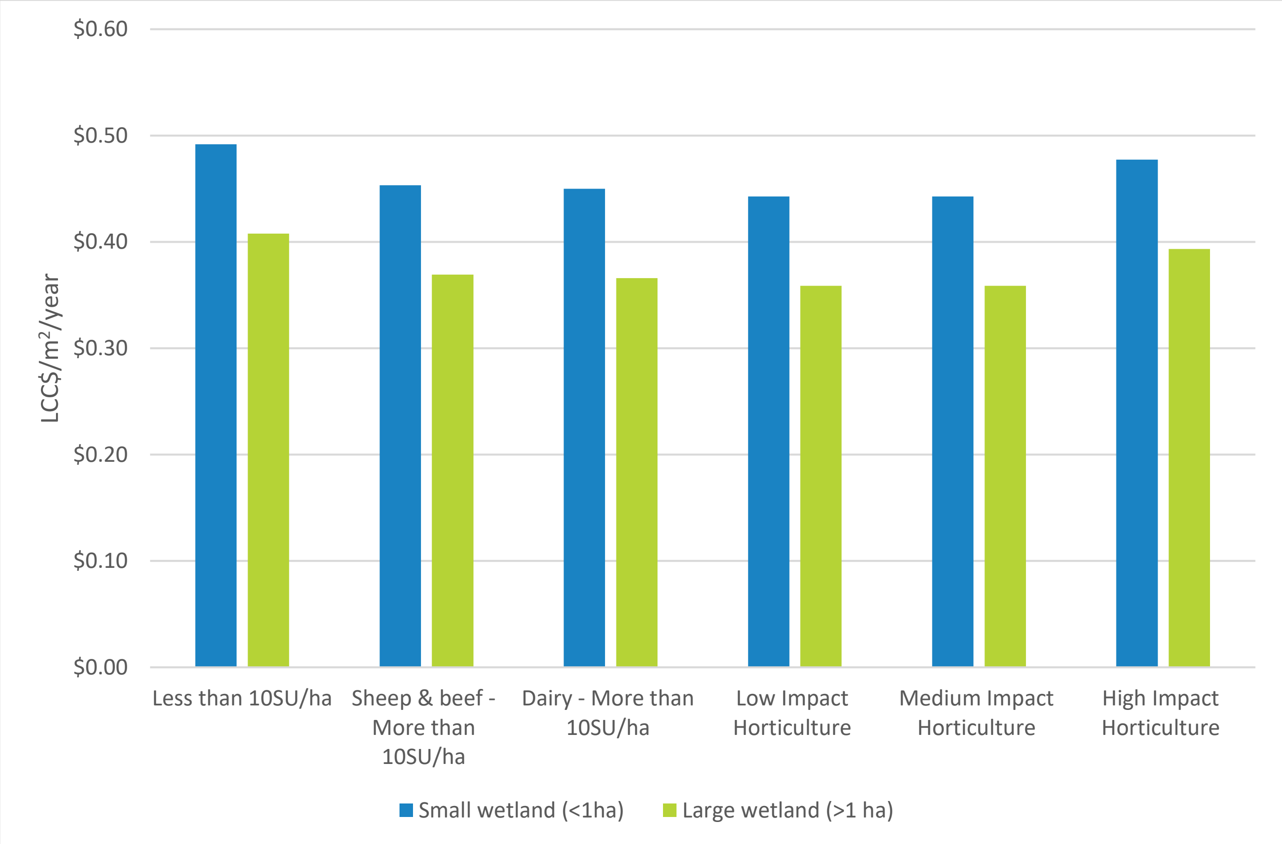

Figure 6: Wetland Surface Area $LCC/m^2/year (4% discount rate over 50 years)

3.2.2 EOF – Riparian management

A range of riparian management scenarios were considered in the LCC model, these were all based on Muller and Stephens (2020) and are summarised in Table 13. Stock water reticulation was only considered for sheep and beef pastoral land uses under the stock exclusion (1 metre buffer width) scenario. Scenarios varied by buffer width across 1 metre (considered stock exclusion only) and 5 metres, planting (rank grass or planted) and by land use and slope (for pastoral land uses).

The costs and benefits for the various riparian management scenarios are in Table 14 to Table 18 are based on the data provided in Muller and Stephens (2020) and should be read in conjunction with the assumptions in that report. The opportunity cost is adjusted relative to Muller and Stephens (2020) as operating profit by total hectares is used rather than by effective hectares. Slope is accounted for as it has a pronounced effect on cost; pastoral HRU's are configured by slope classes and the wider FWMT utilises region-wide LiDAR estimates of slope to drive contaminant and hydrological processes. In this case slope is varied at 16 degrees; with land with a slope less than 16 degrees this was flat to rolling and above this was steep land. However, there is a lack of reasonably assured data to vary the benefits by slope or soil groups.

Water reticulation includes capital and maintenance costs incurred in years 1 and 25 in line with fencing. Where stock water reticulation is included this is based on $10 per linear meter of waterway fenced (one-side) based on Doole (2015). Note Doole (2015) contains limited information on the breakdown of capital and maintenance costs preventing further variation for FWMT Stage 1. More recent water reticulation costing by Journeaux and Van Reenen (2016) lacked information on the lengths of stream excluded, preventing translation into a linear cost consistent with fencing and otherwise being omitted here.

Table 13: Riparian management scenarios

Land use	Intensity	Slope[1]	Buffer width	Planting	Stock water	Fencing
Pastoral	Less than 10SU/ha	Flat to rolling	1m (fence only)	Rank grass	Yes	8-wire non-electric post and batten
		Steep				
	Sheep and beef - More than 10SU/ha	Flat to rolling				4-wire electric
		Steep				
	Less than 10SU/ha	Flat to rolling			No	8-wire non-electric post and batten
		Steep				
	Sheep and beef - More than 10SU/ha	Flat to rolling				4-wire electric
		Steep				
	Dairy - More than 10SU/ha	Flat to rolling				2-wire electric
		Steep				
	Less than 10SU/ha	Flat to rolling	5m	Planted (1m spacing)	No	8-wire non-electric post and batten
		Steep				
	Sheep and beef - More than 10SU/ha	Flat to rolling				4-wire electric
		Steep				
	Less than 10SU/ha	Flat to rolling				8-wire non-electric post and batten
		Steep				
	Sheep and beef - More than 10SU/ha	Flat to rolling				4-wire electric
		Steep				
	Dairy - More than 10SU/ha	Flat to rolling				2-wire electric
		Steep				
	Less than 10SU/ha	Flat to rolling	5m	Rank grass	No	8-wire non-electric post and batten
		Steep				
	Sheep and beef - More than 10SU/ha	Flat to rolling				4-wire electric
		Steep				
	Less than 10SU/ha	Flat to rolling				8-wire non-electric post and batten
		Steep				
	Sheep and beef - More than 10SU/ha	Flat to rolling				4-wire electric
		Steep				
	Dairy - More than 10SU/ha	Flat to rolling				2-wire electric
		Steep				
Horticulture	Low & Medium Impact	Flat to rolling	5m	Rank grass	NA	NA
	High Impact	Flat to rolling				
	Low & Medium Impact	Flat to rolling	5m	Planted (1m spacing)	NA	NA
	High Impact	Flat to rolling				

1. Slope is split by 16 degrees, slope below 16 degrees is flat to rolling and slope between 16 and 28 degrees is steep slope.

Table 14: Dairy (>10SU/ha) – cost and efficacy summary (from Muller and Stephens, 2020)

Scenario description [2]	Costs[3]					Efficacy (% change)			
	Capital costs		Maintenance costs		Opportunity cost ($/buffer width m²/yr)	Nitrogen (TN)	Phosphorus (TP)	Sediment (TSS)	*E. coli*
	Fencing [1] ($/m)	Planting ($/buffer width m²)	Fencing ($/m/yr)	Planting ($/buffer width m²/yr)					
Fencing only 1m buffer width Rank grass Flat/rolling	Yr. 0: $5.40 Yr. 25: $5.40	-	$0.05	Yr. 1-50: $0.05	$0.06	-	-	-	-58%
Fencing only 1m buffer width Rank grass Steep	Yr. 0: $7.70 Yr. 25: $7.70	-	$0.11	Yr. 1-50: $0.05	$0.06	-	-	-	-58%
Riparian buffer 5m buffer width Rank grass Flat/rolling	Yr. 0: $5.40 Yr. 25: $5.40	-	$0.05	Yr. 1-50: $0.25	$0.32	-15%	-10%	-70%	-60%
Riparian buffer 5m buffer width Rank grass Steep	Yr. 0: $7.70 Yr. 25: $7.70	-	$0.11	Yr. 1-50: $0.25	$0.32	-15%	-10%	-70%	-60%
Riparian buffer 5m buffer width Riparian plants Flat/rolling	Yr. 0: $5.40 Yr. 25: $5.40	Yr. 0: $27.50 ($5.50/linear metre of fence)	$0.05	Yr. 1: $10.25 Yr. 2: $7.69 Yr. 3: $5.13 Yr. 4-50: $0.25	$0.32	-56%	-50%	-75%	-60%
Riparian buffer 5m buffer width Riparian plants Steep	Yr. 0: $7.70 Yr. 25: $7.70	Yr. 0: $27.50 ($5.50/linear metre of fence)	$0.11	Yr. 1: $10.25 Yr. 2: $7.69 Yr. 3: $5.13 Yr. 4-50: $0.25	$0.32	-56%	-50%	-75%	-60%

1. *Assumes 2-wire electric fencing for dairy farms*
2. *No difference in soil type considered*
3. *Where costs are $/buffer width m², this is $/5m² or $/1m² for the 5-metre setback and fence-only riparian management option*

Table 15: Sheep and beef (<10SU/ha) – cost and efficacy summary (from Muller and Stephens, 2020)

Scenario description [2]	Costs[3]					Efficacy (% change)			
	Capital costs		Maintenance costs		Opportunity cost ($/buffer width m^2/yr)	Nitrogen (TN)	Phosphorus (TP)	Sediment (TSS)	*E. coli*
	Fencing [1] ($/m)	Planting ($/buffer width m^2)	Fencing ($/m/yr)	Planting ($/buffer width m^2/yr)					
Fencing only 1m buffer width Rank grass Flat/rolling	Yr. 0: $16.10 Yr. 25: $16.10	-	$0.16	Yr. 1-50: $0.05	$0.02	-	-	-	-58%
Fencing only 1m buffer width Rank grass Steep	Yr. 0: $18.20 Yr. 25: $18.20	-	$0.32	Yr. 1-50: $0.05	$0.02				
Riparian buffer 5m buffer width Rank grass Flat/rolling	Yr. 0: $16.10 Yr. 25: $16.10	-	$0.16	Yr. 1-50: $0.25	$0.10	-5%	-5%	-70%	-60%
Riparian buffer 5m buffer width Rank grass Steep	Yr. 0: $18.20 Yr. 25: $18.20	-	$0.32	Yr. 1-50: $0.25	$0.10				
Riparian buffer 5m buffer width Riparian plants Flat/rolling	Yr. 0: $16.10 Yr. 25: $16.10	Yr. 0: $27.50 ($5.50/linear metre of fence)	$0.16	Yr. 1: $10.25 Yr. 2: $7.69 Yr. 3: $5.13 Yr. 4-50: $0.25	$0.10	-56%	-50%	-75%	-60%
Riparian buffer 5m buffer width Riparian plants Steep	Yr. 0: $18.20 Yr. 25: $18.20	Yr. 0: $27.50 ($5.50/linear metre of fence)	$0.32	Yr. 1: $10.25 Yr. 2: $7.69 Yr. 3: $5.13 Yr. 4-50: $0.25	$0.10				

1. *Assumes 8-wire non-electric post and batten fencing*
2. *No difference in soil type considered*
3. *Where costs are $/buffer width m^2, this is $/5$m^2$ or $/1$m^2$ for the 5-metre setback and fence-only riparian management options*

Table 16: Sheep and beef (<10SU/ha) – cost and efficacy summary (from Muller and Stephens, 2020)

Scenario description [2]	Costs[3]					Efficacy (% change)			
	Capital costs		Maintenance costs		Opportunity cost ($/buffer width m²/yr)	Nitrogen (TN)	Phosphorus (TP)	Sediment (TSS)	*E. coli*
	Fencing [1] ($/m)	Planting ($/buffer width m²)	Fencing ($/m/yr)	Planting ($/buffer width m²/yr)					
Fencing only 1m buffer width Rank grass Flat/rolling	Yr. 0: $8.40 Yr. 25: $8.40	-	$0.08	Yr. 1-50: $0.05	$0.03	-	-	-	-58%
Fencing only 1m buffer width Rank grass Steep	Yr. 0: $10.80 Yr. 25: $10.80	-	$0.17	Yr. 1-50: $0.05	$0.03				
Riparian buffer 5m buffer width Rank grass Flat/rolling	Yr. 0: $8.40 Yr. 25: $8.40	-	$0.08	Yr. 1-50: $0.25	$0.16	-15%	-10%	-70%	-60%
Riparian buffer 5m buffer width Rank grass Steep	Yr. 0: $10.80 Yr. 25: $10.80	-	$0.17	Yr. 1-50: $0.25	$0.16				
Riparian buffer 5m buffer width Riparian plants Flat/rolling	Yr. 0: $8.40 Yr. 25: $8.40	Yr. 0: $27.50 ($5.50/linear metre of fence)	$0.08	Yr. 1: $10.25 Yr. 2: $7.69 Yr. 3: $5.13 Yr. 4-50: $0.25	$0.16	-56%	-50%	-75%	-60%
Riparian buffer 5m buffer width Riparian plants Steep	Yr. 0: $10.80 Yr. 25: $10.80	Yr. 0: $27.50 ($5.50/linear metre of fence)	$0.17	Yr. 1: $10.25 Yr. 2: $7.69 Yr. 3: $5.13 Yr. 4-50: $0.25	$0.16				

1. *Assumes 4-wire electric fencing*
2. *No difference in soil type considered*
3. *Where costs are $/buffer width m², this is $/5m² or $/1m² for the 5-metre setback and fence-only riparian management options*

Table 17: Medium Impact Horticulture (arable, citrus, fodder, nuts, viticulture) & Low Impact Horticulture (orchards, idle & fallow) – cost and efficacy summary (from Muller and Stephens, 2020)

Scenario description [1, 2]	Costs[3]			Efficacy (% change)			
	Capital costs	Maintenance costs	Opportunity cost ($/buffer width m²/yr)	Nitrogen (TN)	Phosphorus (TP)	Sediment (TSS)	*E. coli*
	Planting ($/buffer width m²)	Planting ($/buffer width m²/yr)					
Riparian buffer 5m buffer width Rank grass	-	Yr. 1-50: $0.25	$0.58	-	-	-40%	-
Riparian buffer 5m buffer width Riparian plants	Yr. 0: $27.50 ($5.50/linear metre)	Yr. 1: $10.25 Yr. 2: $7.69 Yr. 3: $5.13 Yr. 4-50: $0.25	$0.58	-51%	-50%	-75%	-

1. *No difference in slope considered as no fencing costs included and no difference in benefits available*
2. *No difference in soil type considered*
3. *Where costs are $/buffer width m², this is $/5m² or $/1m² for the 5-metre setback and fence-only riparian management options*

Table 18: High Impact Horticulture (berryfruit, flowers, stonefruit, kiwifruit, nursery, pipfruit, fruit, vegetables, greenhouses) – cost and efficacy summary (from Muller and Stephens, 2020)

Scenario description [1, 2]	Costs[3]			Efficacy (% change)			
	Capital costs	Maintenance costs	Opportunity cost ($/buffer width m²/yr)	Nitrogen (TN)	Phosphorus (TP)	Sediment (TSS)	*E. coli*
	Planting ($/buffer width m²)	Planting ($/buffer width m²/yr)					
Riparian buffer 5m buffer width Rank grass	-	Yr. 1-50: $0.25	$0.97	-	-	-40%	-
Riparian buffer 5m buffer width Riparian plants	Yr. 0: $27.50 ($5.50/linear metre)	Yr. 1: $10.25 Yr. 2: $7.69 Yr. 3: $5.13 Yr. 4-50: $0.25	$0.97	-51%	-50%	-75%	-

1. *No difference in slope considered as no fencing costs included and no difference in benefits available*
2. *No difference in soil type considered*
3. *Where costs are $/buffer width m², this is $/5m² or $/1m² for the 5-metre setback and fence-only riparian management options*

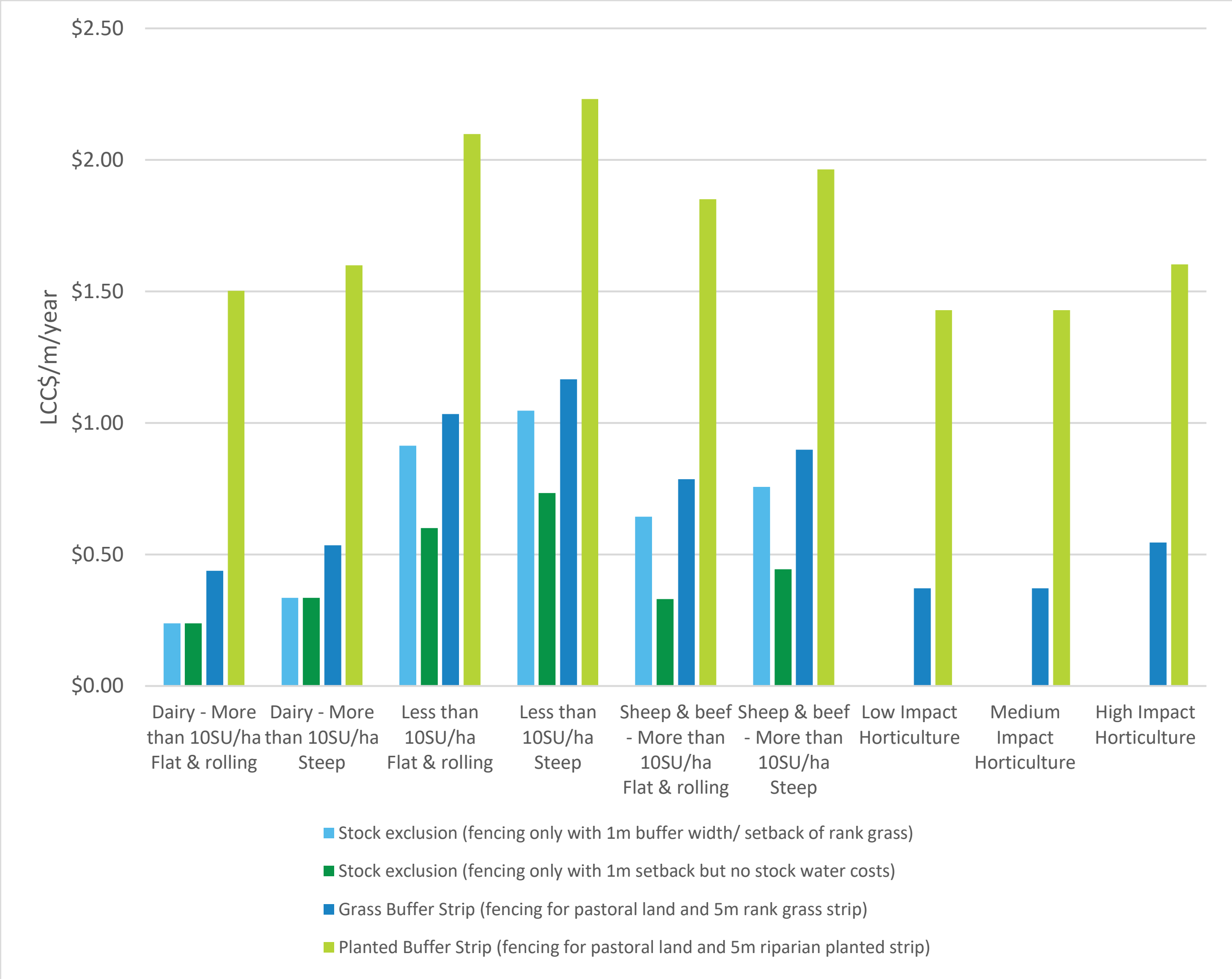

Figure 7: Riparian management scenarios $LCC/m/year (4% discount rate over 50 years)

3.2.3 EOF – Detainment bunds

For pastoral land uses the capital costs remain as per Muller et al. (2020) (in turn based on Doole, 2015). No lost opportunity cost is assumed for a detainment bund, even if the bunded area likely is otherwise sensitive to damage from stock during ponding. The LCC model has accounted for a full replacement cost at 25 years, with annual maintenance costs of $0.30 per ha (Doole, 2015). The benefits for pastoral land uses are predicated on Daigneault and Elliott (2017).

For horticultural land uses the capital costs are based on Doole (2015) for a decanting earth bund in the Lower Waikato Region. No maintenance costs were provided and so none are included here. The pastoral maintenance costs are not assigned to horticultural land uses due to uncertainty around the cost components such as fencing that was included in the pastoral detainment bunds. The benefits for sediment traps on horticultural land are based on Doole (2015) who considered the benefit only on sediment. Daigneault and Elliott (2017) were not used as they did not consider sediment traps or detainment bunds on horticulture land. The addition of this EOF mitigation on horticulture land was not included in Muller et al. (2020).

Table 19 details the expected costs and benefits for detainment bunds and sediment traps. They are not differentiated by soil group, slope or intensity of land use. Instead, by pastoral and horticultural land use given differing studies and underlying costs. Both capital and maintenance costs are provided on a per hectare of drainage area. **An assumption will be needed on the areas of HRU draining to both detainment bunds and sediment traps.**

As per the LCC Model, costs are discounted at 2%, 4% and 6% across a 50-year time period and are reported as $/ha catchment area treated/ year (Appendix A). The full capital costs are incurred in Years 1 and 25, which is predicated on a 25-year life span for this intervention (i.e. a full replacement cost is therefore incurred in Year 25). It is **assumed there is no opportunity cost** for this mitigation as detainment bunds are likely to be located in areas which can be utilised when dry and which would suffer productive losses if stocked when wet (Levine, 2020). Maintenance costs occur annually for pastoral land uses and are based on Doole (2015). The costs and benefits for horticulture detainment bunds are based on Doole (2015), no maintenance costs were included. However, this was felt to be unrealistic and the maintenance costs from the pastoral detainment bunds were applied to the horticultural detainment bunds given the 50-year life-cycle basis of costing for the FWMT Stage 1.

Contaminant impacts of detainment bunds are **assumed to apply only to runoff contaminant loads,** unlike prior mitigations which apply to all HRU-loads independent of pathway. This corresponds with literature evidence of detainment bund efficacy being principally derived from interception and ponding of runoff (Levine, 2020). Detainment bunds are also **assumed limited to free-draining soils,** corresponding with literature evidence for contaminant attenuation efficacy being primarily through infiltration of ponded water (Levine et al., 2019; Paterson et al., 2020). Importantly, the actual potential for detainment bunds on pastoral land is governed by more than simply soil drainage class – flat to rolling topography (≤15°) is required of ponded areas (i.e., ensure more volume detained behind a bund of <2-3 m height to align with permitted activity rules in regional plans – Paterson et al., 2020). Equally, there is emerging evidence that the optimal upstream catchment size to be treated by individual detainment bunds is 40-50 ha (e.g., that wider catchments can be treated in sequential order, with areas of <50 ha per bund but larger collective areas treated by multiple detainment bunds – Levine, 2020). Hence, an **assumption will be required of the maximum potential for detainment bunds on free-draining and flat-to-rolling pastoral land within sub-catchments.**

For pastoral land uses the capital costs remain as per Muller et al. (2020) (in turn based on Doole, 2015). **No lost opportunity cost is assumed for a detainment bund**, even if the bunded area likely is otherwise sensitive to damage from stock during ponding. The LCC model has accounted for a full replacement cost at 25 years, with annual maintenance costs of $0.30 per ha of catchment (Doole, 2015). The benefits for pastoral land uses are predicated on Daigneault and Elliott (2017).

For horticultural land uses the capital costs are based on Doole (2015) for a decanting earth bund in the Lower Waikato Region. No maintenance costs were provided and so none are included here. The pastoral maintenance costs are not assigned to horticultural land uses due to uncertainty around the cost components such as fencing that was included in the pastoral detainment bunds. The benefits for sediment traps on horticultural land are based on Doole (2015) who considered the benefit only on sediment. Daigneault and Elliott (2017) were not used as they did not consider sediment traps or detainment bunds on horticulture land. The addition of this EOF mitigation on horticulture land was not included in Muller et al. (2020).

Detainment bunds LCC $/ha/ year are illustrated in Figure 8.

Table 19: Costs and benefit of detainment bunds/sediment traps, for all HRUs

Land cover	Soil group	Slope	Contaminant impact				Economic impact		
			N	P	Sediment	*E. coli*	Capital ($/ha catchment)[1]	Maintenance ($/ha catchment /yr)[1]	Opportunity cost ($/ha/yr)
Pastoral[2]	Free-draining	Flat-to-rolling	-0%	-15%	-80%	-50%	$250	$0.30	$0
Horticulture[3]	Free-draining	Flat-to-rolling	-	-	-88%	-	$130	$0.30	$0

1. *Catchment relates to area of land mitigated by the detainment bund*
2. *Benefits based on Daigneault and Elliott (2017) costs based on Doole (2015)*
3. *Based on Doole (2015)*

3.2.4 EOF – Space planting of erosion control trees

Table 20 highlights the costs and benefits of space planting of erosion control trees for pastoral HRU's, these are derived from Muller et al. (2020). These costs and benefits apply to all pastoral land uses and are not differentiated slope and soil type. Although as per Section 4.1, where this is considered as a mitigation is influenced by slope. Costs are provided on a per hectare basis. As per the LCC Model, costs are discounted at 2%, 4% and 6% across a 50-year time period and are reported as $/ha planted with poles/ year (Appendix A).

The full capital costs are incurred in Years 1 and 25, which is predicated on a 25-year life span for this intervention (i.e. a full replacement cost is therefore incurred in Year 25). This is a simplification of reality where maintenance is likely to occur in years 5 and 15 with a full replacement in about year 30, although it is likely that initial and replacement planting costs are likely to be staggered over a few years. Given likely diversity in farming practices, weather and soil structure on tree mortality a simplification of maintenance costs was made to incur a full replacement cost in year 25. Well managed poplars can recover their replacement costs through revenue from harvesting (e.g., covering the costs of harvest and replacement planting [Basher et al., 2016]). By including full replacement costs at year 25, the associated LCC includes additional costing for ongoing replacement during the 25 year life-cycle of the trees (e.g., accounts for trimming and thinning at years 5 and 15; accounts for some degree of sub-standard management resulting in lesser timber value). As with other EOF mitigations, marked variation can be expected in that reflecting the quality of pruning, growth form and access to space-planted erosion control trees. It is assumed there is no opportunity cost for this mitigation as it is expected farmers can still graze under the space planted trees.

Space planting of erosion control trees LCC $/ha/ year are illustrated in Figure 8.

Table 20: Costs and benefit of space planting of erosion control trees, for all pastoral land uses

HRU[1,2]	Contaminant impact[3]				Economic impact			Comments & explanation
	N	P	Sediment	*E. coli*	Capital ($/ha)[4]	Maintenance ($/ha/yr)	Opportunity cost ($/ha/yr)	
All pastoral land uses	0%	-20%	-70%	0%	$1,000	$0	$0	Shading impact of trees as they mature is expected to have limited impact on pasture production. Combined with the reduction in soil loss and positive impacts that shading will have on animal welfare, the net production impact on the farm system is considered negligible (e.g., zero).

1. *No differentiation in slope*
2. *No differentiation in soil type*
3. *Benefits based on Daigneault and Elliott (2017)*
4. *Based on Parminter et al. (2001) for approximately 70 stems per hectare*

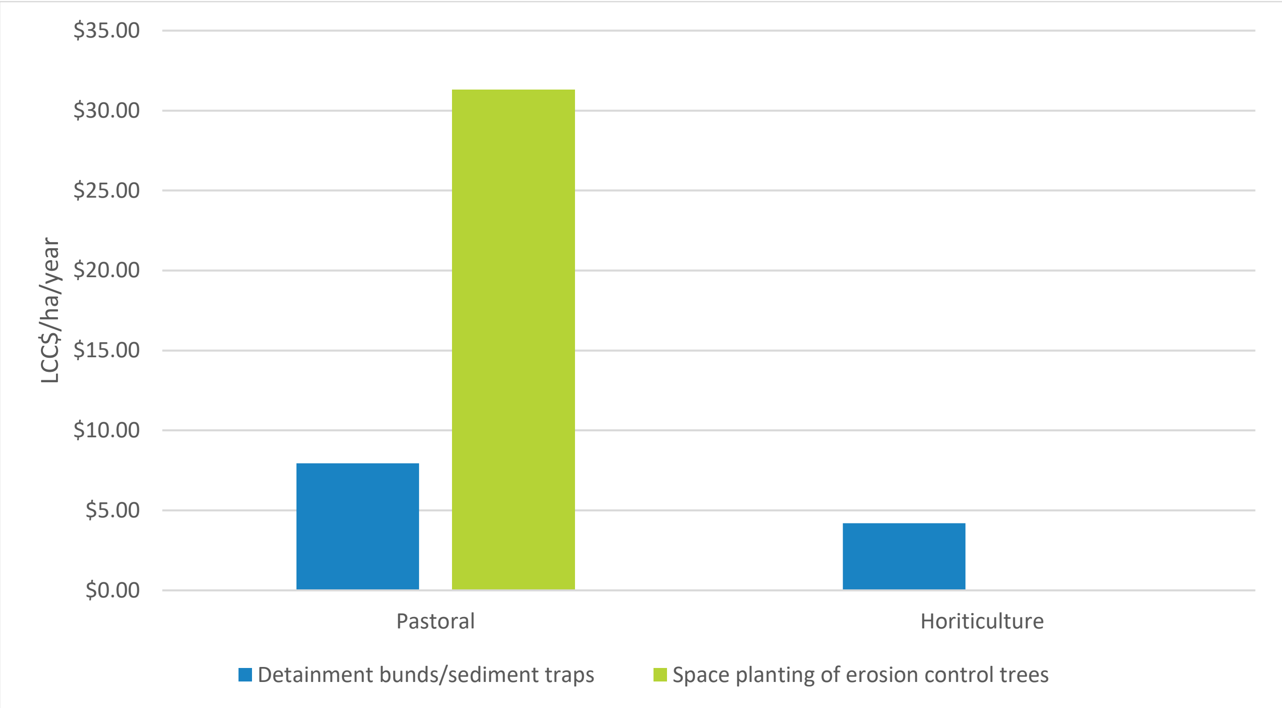

Figure 8: Detainment bund and Space Planting $LCC/ha/year (4% discount rate over 50 years)

3.3 Land retirement

For Stage 1 of the FWMT, only one land retirement option was included across all pastoral and horticultural HRU groups, permanent retirement to native bush without harvesting. The capital costs and annual opportunity costs are as per Muller et al. (2020) but the carbon income costs were revised to be provided in an annual form to fit the 50-year LCC model. The capital costs are a one-off cost incurred in Year 1 while opportunity costs are annual and based on the operating profit per total hectare of the prior land use, these are summarised in Table 21.

Capital costs include a subsidy for native planting and no salvage costs are assumed for the transition (e.g. removing fences). No maintenance costs are included, and capital costs are not staggered over multiple years. The costs of this mitigation can be applied to either whole farms or proportions of a farm. As mentioned in Section 2.1.2 the total acquisition cost portion includes an overhead and indirect cost factor of 17.5% of the construction cost (this accounts for time needed to plan, consent or implement potential mitigations, and associated contingencies, and is based on a likely overhead cost for urban interventions of 15% - 20%) (Ira and Simcock, 2019).

Table 21: Capital and annual opportunity costs of land retirement mitigations inputs for use in the FWMT stage 1

Land cover	Intensity	Capital cost ($/ha)[1]	Opportunity cost ($/total ha/yr)	Comments & explanation
Pastoral	Less than 10SU/ha	$15,000	$378	Establishment costs of $15,000/ha (including $4,000/ha[2] subsidy from Government). Assume no salvage value of farm (e.g. selling salvaged fencing) and no salvage cost (e.g. removing fences).
	Sheep and beef - More than 10SU/ha	$15,000	$646	
	Dairy - More than 10SU/ha	$15,000	$1,264	
Horticulture	Low Impact Horticulture & Medium Impact Horticulture - (Orchards, idle, fallow, arable, citrus, fodder, nuts, viticulture)	$15,000	$2,320	
	High Impact Horticulture - Berryfruit, flowers, stonefruit, kiwifruit, nursery, pipfruit, fruit, vegetables, greenhouses	$15,000	$3,880	

1. *Based on Douglas, Dodd & Power (2007)*
2. *Native planting grant from Te Uru Rakau (2020)*

In addition to the annual opportunity costs, annual carbon income and costs are included in the LCC Model for to allow for discounting. These costs are summarised in Table 22. The data for carbon stock is sourced from MPI (2017) for indigenous forest for post 1989 forest land. **The cost of filing a carbon return is assumed once every 5 years and is based on 1 hour of work** (MPI, 2019), with a carbon cost of $25/tonne is assumed.

Table 22: Carbon income and expenses

Year	Five yearly sum of carbon stock (t/ha)[1]	Return (carbon income – filing fee, $/ha)[2]
5	7.8	$95
10	32.4	$710
15	55.3	$1,283
20	63.2	$1,480
25	56.3	$1,308
30	42.5	$963
35	29	$625
40	18.6	$365
45	11.4	$185
50	6.9	$72

1. *MPI (2017)*
2. *MPI (2019) assuming 1 hour of work and a carbon price of $25/t*

As per the LCC Model, costs and carbon income are discounted at 2%, 4% and 6% across a 50-year time period and are reported as $/ha land retired/ year (Appendix A). Land retirement LCC $/ha/ year are illustrated in Figure 9.

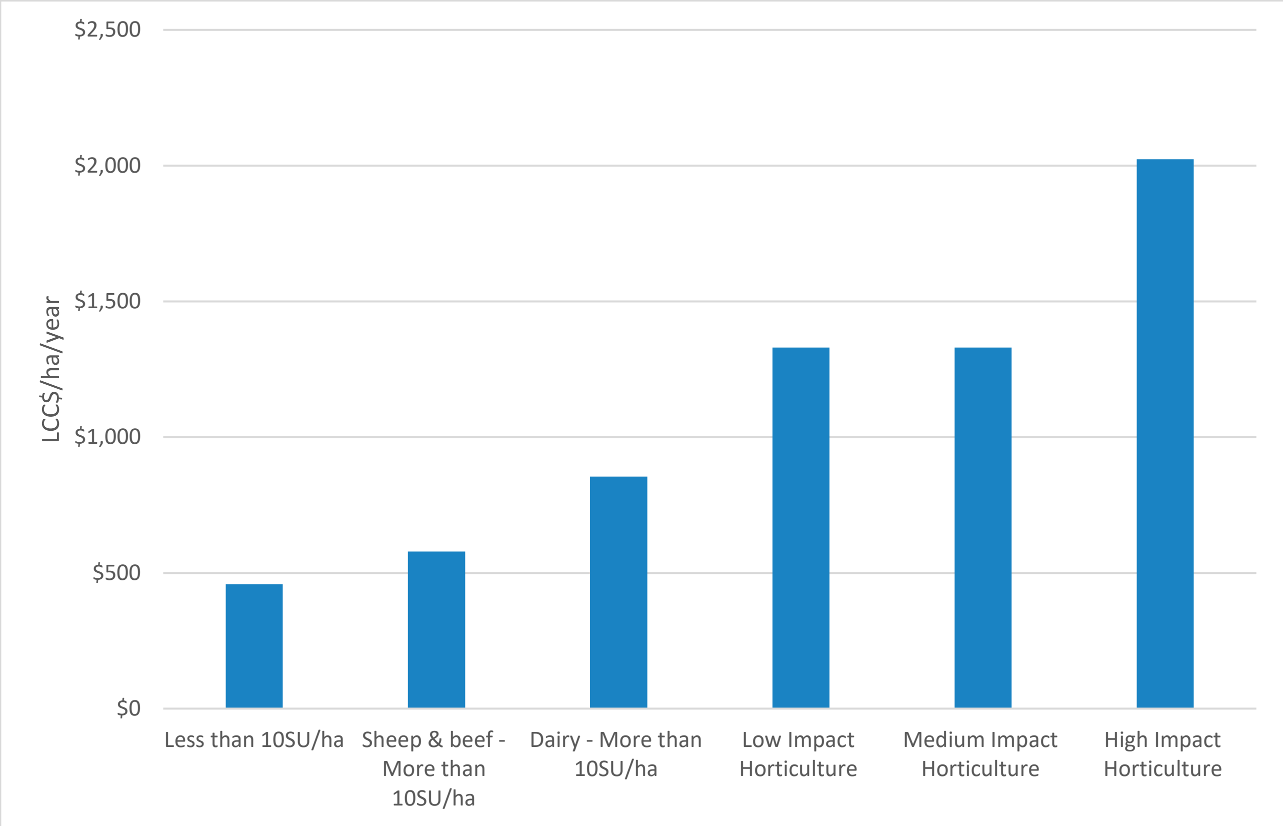

Figure 9: Land Retirement $LCC/ha/year (4% discount rate over 50 years)

4 Application of rural mitigation options to FWMT Stage 1

This section provides detail on how the mitigation options in Section 3 are applied to the FWMT Stage 1. Two key matters are considered. Firstly, how to align the mitigations in this report with the HRU framework (applicability) and then second, what information if any, is available on prior rates of adoption (relative to FWMT Stage 1 baseline period of 2013-2017). Applicability determines the potential maximum area that could be managed by a mitigation and adoption considers area already managed by a mitigation during baseline.

4.1 Applicability of the mitigations to the HRUs in the FWMT

4.1.1 Land use in the HRU framework

Muller et al. (2020), Muller and Stephens (2020) and this report **assume that pastoral land with more than 10SU/ha can be farmed for dairy or sheep and beef** (with differing mitigation costs, benefits and applicability). While the HRU framework does not explicitly discriminate between pastoral sectors, to enable differing sectoral costs, benefits and applicability to be represented in optimisation routines, an assumption about the proportion of High-Impact Pasture in dairying is needed (e.g., remainder being sheep & beef of >10SU/ha, as these are the two predominant land uses). For Stage 1 of the FWMT, the following approach is recommended:

- In the Auckland Region, over the baseline configuration period (2013-2017[6]) the annual average extent of effective dairying was 46,220 ha (DairyNZ & LIC, 2019).
- If the same assumption is used to translate effective to total hectares as for operating profit (i.e. dairy farms have approximately 5% ineffective land area), then approximately 48,530 ha of total dairying area existed in the Auckland Region.
- The HRU framework has approximately 224,970 ha of total pastoral HRU, of which 70,640 ha (31%) are High-Impact Pasture HRU (e.g., with more than 10SU/ha).
- If total dairying extent is accounted for, then approximately 22,110 ha (31%) of High Impact Pasture (10% of all Pasture) are likely sheep and beef farmland of >10SU/ha.

The approach above is defensibly simple, reflecting limited detailed and audited information on the extent and stocking rates of sheep and beef farming in the Auckland region (including deer, pigs and horses). Notably, by relying on dairy sector statistics that relate only to milking platforms and dairying herds, any remaining High-Impact Pasture described as of "sheep and beef" farmland could still be associated with the dairy sector (e.g., for wintering support of milking cattle) or alternative pastoral land uses with more than 10SU/ha.

An assumption is also required on the distribution of the 48,530 ha of total dairying area between watersheds to ensure dairy-specific mitigations are applied appropriately in the FWMT. We recommend for simplicity and limited spatial resolution of dairying information, to apply a consistent ratio to High Impact Pasture HRU extent in all sub-catchments (0.69) (e.g., that 69% of High Impact Pasture extent is dairying in all sub-catchments). For continuous improvement of FWMT scenario modelling, more detailed information on the extent of pastoral land use with more than 10SU/ha and variation in that across catchments would be valuable.

For horticulture, as previously discussed Low Impact Horticulture is combined with Medium Impact Horticulture in this report. In this report, Medium Impact Horticulture mitigation costs are based on

[6] Encompassing the dairy seasons 2013-14 to 2017-18

arable farming, while High Impact Horticulture is based on vegetable farming. These assumptions mean that some land uses are likely to be inaccurately reflected in these results (e.g. tree-based orchards). This should be revisited in future iterations of the FWMT.

4.1.2 Soil and slope in the HRU framework

FWMT Stage 1 land types are represented by HRU's that are stratified across various classes of hydrologic soil group (HSG) and slope. Five classes of HSG have been configured within the FWMT Stage 1 spanning a gradient of soil characteristics but particularly, effective infiltration rate – using the New Zealand Fundamental Soil Layer (see Bambic et al., 2020). HSG vary from A+ (lowest runoff potential – volcanic soils) through A, B, C and to D (highest runoff potential – clay and heavier clay-silt or clay-sand groups). HSG have been assigned regionwide to a $2m^2$ raster, intersected by land cover and use information, to generate HRU soil and land impact mixes for pasture (e.g., low and high impact variants of each of the five HSG classes) and horticulture (e.g., low, medium and high impact variants of each of the five HSG classes). In terms of regional spread, HSG-C is most extensive (39%), followed by HSG-B (31%), HSG-D (11%), HSG-A (9%) and HSG-A+ (6%). Notably, 80% (24,780 Ha) of HSG-A+ (free-draining volcanic soils) are found in the Manukau Harbour watershed, with 58% (3720 Ha) and 25% (1620 Ha) of HSG-A in the Kaipara and West Coast watersheds respectively. Rural mitigation options requiring free-draining soils are more likely suited to the Manukau, Kaipara and West Coast watersheds.

Of the EOF and mitigation bundles recommended here for the FWMT Stage 1, only the M1 pastoral bundle (dairy – 69% of High-Impact Pasture HRU extent) and EOF detainment bund options are to be limited by HSG (e.g., to HRU classes on basis of soil group). To guide that, Table 23 below links soil drainage class to HSG on the basis of descriptions in Milne et al. (1995) and Auckland Regional Council Technical Publication 108 (Auckland Council, 1999), in turn based on the US Natural Resource Conservation Service National Engineering Handbook (NRCS, 1997).

Table 23: Hydrologic Soil Group alignment to soil drainage class for application of M1 (dairy) and EOF detainment bund mitigations in the FWMT Stage 1

Hydrologic Soil Group	HSG Drainage Description	HSG Infiltration Rate (mm/hr)	HSG Description	Soil drainage class
A+	Very high infiltration	>12.7-25.3	Volcanic geology	Free draining
A	High infiltration	>7.6-12.7	Sand, Loamy Sand, Sandy Loam	
B	Moderate infiltration	>3.8-7.6	Silt, Silt Loam, Loam	Moderately draining
C	Low infiltration	>1.3-3.8	Sandy Clay Loam	Poorly drained
D	Very low infiltration	0-1.3	Clay loam, Silty Clay Loam, Sandy Clay, Silty Clay, Clay	

Whilst the slope of each sub-catchment is used to drive hydrological and contaminant processes within the FWMT Stage 1, variation in process responses to slope is configured in two regionalised relationships or classes (low and high; <10% and ≥10% slope – equivalent to a threshold of approximately 6 degrees). The 6 degree threshold of HRU group delineation does not align with the slope thresholds affecting costs or applicability of several rural mitigation options (e.g., EOF Wetlands, EOF Riparian management, EOF Detainment bund). For instance, fencing costs on steep pasture (>16 degrees) are more than double those on flat-to-rolling pasture (≤16 degrees) (across dairy, sheep & beef <10 SU/ha and sheep & beef >10 SU/ha). Detainment bunds are recommended to be limited to locations on flat-to-rolling land to ensure sufficient volume of stormwater detained behind "permitted" bunds to generate a 120:1 ratio of volume stored to area upstream (e.g., 120 m^3 per ha for bunds able to receive permitted activity status – see Paterson et al., 2020).

Further analysis will be needed on how best to apply the differing pastoral slope-based riparian costs to streams (e.g., proportion of pastoral streams on land >16 degrees). However, all pastoral Low-Slope HRU's (less than 6 degrees in the FWMT) should have flat-to-rolling riparian costs applied. The recommendation is made that rural scenario modelling by the FWMT consider an explicit approach, utilising information on actual slope of pastoral HRU's within a buffered distance of streams, to govern what proportion of High-Slope (greater than 6 degrees in the FWMT) Pasture borders streams subject to steep riparian costs[7] .

4.1.3 Applicability of bundled mitigations

All mitigation bundles (M1 to M3) apply to HRU pastoral and horticultural groups. There is no difference by slope and only M1- dairy has a difference by soil type. The applicability of the bundled mitigations is shown in Table 24. For instance, mitigation bundle M1 for sheep and beef land can be applied to all Low Impact Pasture HRU's (e.g., <10SU/ha), regardless of soil type or slope HRU class. The M1 mitigation bundle for dairy is differentiated by soil group but not slope type. To apply M1 to High Impact Pasture requires an assumption about the proportion thereof that is dairying, for each of free-draining, moderately-draining and poorly-drained pastoral HRU's. In absence of detailed dairying spatial information, a simplified approach is recommended where by the 69% of High-Impact Pasture is presumed to apply equivalently to all HSG classes (e.g., dairying represents 69% of High Impact Pasture on A+, A, B, C and D class soils).

[7] For instance, determining the proportion of streams on High-Slope High-Impact Pasture that over some buffered distance (e.g., 100m) exhibit an average slope >16 degrees. Of that, 69% of such streams would then have dairying riparian costs of steep land applied; the remainder having beef and sheep riparian costs of steep land applied. All streams on Low Slope-Low Impact pasture should have beef and sheep riparian costs of flat-to-rolling land applied.

Table 24: Applicability of bundled mitigation cost or benefit information to FWMT Stage 1. Noting M1 is the only bundle split by soil group, and only for dairy farming

Mitigation	Intensity	Soil group	Slope
M1	Less than 10SU/ha	All	All
	Sheep and beef - More than 10SU/ha	All	All
	Dairy - More than 10SU/ha	Free draining	All
		Moderately draining	
		Poorly drained	
	Low Impact Horticulture & Medium Impact Horticulture	All	All
	High Impact Horticulture	All	All
M2 (N or P variant for dairy)	Less than 10SU/ha	All	All
	Sheep and beef - More than 10SU/ha	All	All
	Dairy - More than 10SU/ha	All	All
	Low Impact Horticulture & Medium Impact Horticulture	All	All
	High Impact Horticulture	All	All
M3 (N or P variant for dairy)	Less than 10SU/ha	All	All
	Sheep and beef - More than 10SU/ha	All	All
	Dairy - More than 10SU/ha	All	All
	Low Impact Horticulture & Medium Impact Horticulture	All	All
	High Impact Horticulture	All	All

Notably, whereas M1 bundles include both N and P effects, mitigation bundles M2 and M3 for dairy are discriminated into separate variants for N or P (e.g., M2 N, M2 P, M3 N, M3 P). The choice of M2 N or M2 P limiting subsequent optimisation to M3 N or M3 P, respectively. This is because the literature for M2 N and M3 N is more robust in the Auckland region than the M2 P or M3 P mitigation study. The M2 P and M3 P mitigation is predicated on dairy farm modelling in Southland which has a different climate and likely differing dairy systems to Auckland (e.g., prevalence of winter cropping). As noted previously, M2 N and P mitigations can be combined (ensuring both the contaminant and profit impact are added to the M1 bundle). However, doing so adds considerable uncertainty to scenario outputs which should be treated with caution.

4.1.4 Applicability of EOF mitigations

This section considers which HRU groups EOF and land retirement mitigations are applicable to. It cannot describe where the FWMT will optimise mitigations. For example, while a particular EOF mitigation may be applicable across all slope classes, the FWMT may target steep sloping land only (e.g., if of lower cost per unit of contaminant reduced, if otherwise insufficient load cannot be reduced elsewhere or if more cost-effective options apply for flat-to-rolling land). The applicability of the EOF and land retirement mitigations, to guide optimisation in the FWMT Stage 1 is shown in Table 25.

Table 25: Applicability of EOF and land retirement mitigations

Mitigation	Intensity	Soil group	Slope
Small wetland	Less than 10SU/ha	All	All
	Sheep and beef - More than 10SU/ha	All	All
	Dairy - More than 10SU/ha	All	All
	Low & Medium Impact Horticulture	All	All
	High Impact Horticulture	All	All
Large wetland	Less than 10SU/ha	All	All
	Sheep and beef - More than 10SU/ha	All	All
	Dairy - More than 10SU/ha	All	All
	Low & Medium Impact Horticulture	All	All
	High Impact Horticulture	All	All
Riparian management[1] (various scenarios)	Various scenarios across all pastoral land uses	All	Various
	Various scenarios across all horticulture land uses	All	Various
Detainment bunds	All pastoral land uses	Free-draining	Flat-to-rolling
	All horticulture land uses	Free-draining	Flat-to-rolling
Space planting	All pastoral land uses	All	All
Land retirement	Less than 10SU/ha	All	All
	Sheep and beef - More than 10SU/ha	All	All
	Dairy - More than 10SU/ha	All	All
	Low & Medium Impact Horticulture	All	All
	High Impact Horticulture	All	All

1. The various riparian management scenarios are described in more detail in Table 13 due to the extent of scenarios considered.

4.2 Adoption of the mitigations in the FWMT

There is a notable lack of data on historic (baseline), ongoing or future rates of water quality mitigation adoption across Auckland and New Zealand (PCE, 2019). Surveyed farming data is often inconsistent between regions, land uses, mitigations and/or lacking in verification, if even available beyond localised areas (Daigneault and Elliot, 2017; Our Land and Water, 2019). For instance, in Larned et al. (2018) various environmental experts surveyed by the Ministry for Environment, concluded there was a lack of standardised procedures at regional and national scale, for data on rural mitigation adoption rates. The Parliamentary Commissioner for the Environment recently highlighted the lack of robust (verified and consistent) datasets on rural mitigation actions continues to constrain water quality management for throughout New Zealand (PCE, 2019). Other water quality modelling by regional councils, have tended to accommodate such uncertainty either in a conservative approach (assuming no prior adoption) or by developing typologies on existing farm systems (a "bottom-up" or farm system approach, contrasting with the "top-down" or environmental process-based approach of the FWMT) (Environment Southland, Bay of Plenty Regional Council, Waikato Regional Council Officers pers. comm., June 2020).

A strong recommendation must be made here now: that the FWMT would be improved markedly for scenario and ongoing accounting exercises through robust surveying of implementation of mitigation options on horticultural and pastoral land. Notably, any such surveys require consistent terminology linked to the FWMT mitigation library, geospatial information on the areas of farmland treated by bundles and EOF devices, dates of adoption and ongoing maintenance activity – all classified consistently over time and region. The review that follows, identifies that national surveys are often inconsistent or too coarse (or non-existent) for numerous mitigation options included in the FWMT Stage 1. There are also no Auckland region surveys of verified status (independently audited). A further recommendation is to engage industry sectoral bodies with the latter to inform baseline and maximum probable assumptions for scenarios.

Potential sources of information on the adoption of rural mitigations exist, including: the Survey of Rural Decision Makers (MWLR, 2018, 2020); Sustainable Dairy Water Accord (SDWA, 2014-2018); and reporting for the Ministry for Environment (Graham et al., 2020). However, all are weakly assured (i.e., involving limited if any auditing, low resolution of results and/or lack of independent peer-review). For instance, the Survey of Rural Decision Makers (MWLR, 2018, 2020) provides national data on a limited range of mitigation options. It is not independently audited or verified for accuracy, whilst results offer limited coverage by sector. In addition, some results seem inconsistent with other data sources and it is not always clear on what each question or metric means.

In recent national mitigation modelling Graham et al. (2020) applied mitigations based on farm typology without prior adoption accounted for (i.e. any mitigations that were considered appropriate to a range of farm types were applied in order of cost-effectiveness). Presumably, due to lack of robust data on historic or ongoing mitigation adoption. Graham et al. (2020) developed outputs to inform the total scale of mitigation required to achieve targeted load reductions rather than the impact of additional adoption of certain mitigations relative to an existing baseline. Their exception to accounting for prior adoption was in relation to fencing where prior adoption was considered regionally.

The following section details the few data sources possibly useful in determining historic (baseline), current and potential future levels of adoption of the mitigation options in the FWMT Stage 1. It also highlights what data sources may be explored to improve future iterations of the FWMT.

4.2.1 Bundled mitigations

The bundled mitigations in this report are based on an assessment of existing farming mitigation literature, recognising that a wide diversity of actions are available to farm systems for reduced contaminant loss and that these are best simplified in “bundled” mitigations - noting this inherently limits scenario outputs to be generalised changes (e.g., unable to be tied explicitly as described to any one farm but rather held as a general targeted change across numerous farms).

In other regions where this literature is drawn from, such as the Waikato, Southland and Bay of Plenty regions, bundled mitigations are typically designed from case study farms based on their actual on-farm practices and current levels of mitigation options. Farms are separated into typologies (often based on farm system differences as well as biophysical features), with a case study farm being representative of a typology. For each case study farm, a selected base year of farm data is collected and mitigations appropriate to each farm type are then designed and applied. Because this method utilises actual farm data, the assumption is that only mitigations which are not yet adopted are applied, meaning prior adoption is zero for new mitigations applied to each farm type.

The case-study typology approach taken in other regions has meant that existing (baseline) mitigation adoption is assumed to be nil (i.e., mitigations are designed for the representative farm type as in addition to baseline). In contrast, the FWMT Stage 1 is based on existing literature from other regions and applied to HRUs from a 2013-17 baseline. This means that mitigations are not tailored to farms in the Auckland region, nor for their baseline or pre-existing farm setup. Whilst the HRU framework recognises for the fundamental differences in soil and slope of farmland to sub-catchment level, it generalises farm system parameters such as cropping rotations or stock mixes. From this, the FWMT puts more emphasis on climatic-driven differences in contaminant footprints with a large diversity of varying footprints available for any one of the 50 pastoral or horticultural HRU's. Configuring those HRU responses enables a process-based understanding of the causes in spatial variation of baseline water quality. However, compared to other approaches that often utilise less diverse biophysical typologies and resolve lesser variation of footprint within any type, the FWMT Stage 1 is limited by the lack of understanding of baseline farm system typologies (i.e. within each intensity class) and mitigation adoption. That limitation is the consequence of no comprehensive reasonably assured information on the current farm practices across the Auckland region (e.g., verified, independently audited, resolved to HRU group across horticultural and pastoral sectors).

To improve Stage 1 scenarios and future FWMT iterations, robust information on the baseline, ongoing and future mitigation options adopted by pastoral and horticultural farms is required. Most notably, some of this can be gathered through a Farm Environment Plan programme, as required under the revised NPS-FM to enable freshwater accounting by Auckland Council (e.g., MfE, 2020). In the absence of such information, we recommend simulating rural mitigation options from a conservative approach assuming no prior adoption (i.e. applying bundles M1, M2 and M3 to all applicable HRU areas). Naturally, sensitivity testing whereby some prior baseline adoption is assumed, will help identify how the quantum of potential change in future water quality will reduce if existing adoption is better.

4.2.2 EOF – Wetlands

Two types of EOF wetlands are recommended for application to pastoral and horticultural farms in this report, as life-cycle costs vary in relation to the size of natural wetlands (Kadlec & Wallace, 2009). Accessing information on the current extent of wetlands across the region and the extent of wetlands in the baseline period is much like information on the adoption of bundled mitigations, challenging. There is limited assured data on the extent of remaining wetland within sub-catchments in the Auckland region, with no national inventory yet available but required of regional authorities under the revised NPS-FM (e.g., MfE, 2020).

Graham et al. (2020) have suggested that that 2% of all hectares (assuming hectares in agricultural land) that is 'flat' or 'moderate' (i.e. up to 15 degrees in slope) and with a 'poor' drainage class (soil drainage class of 1, 2 or 3 from the NZ Fundamental Soil Layer Soil Drainage Class) could be used for constructed wetlands. Whilst this offers a reasonable upper limit on the maximum extent of wetland to optimise to in FWMT scenarios, the prior baseline extent remains poorly quantified[8] .

Historic wetland loss has been marked in New Zealand, with over 90% by area having been drained or converted since human migration to New Zealand, including of ~95% by area in the Auckland region (Ausseil et al., 2008). Despite a diversity of wetland types, each has been heavily affected by drainage, creating that overall pattern of extreme loss throughout New Zealand (e.g., between 40-95% of loss in pre-human extent across seven wetland types – swamp, marsh, pakihi-gumland, inland saline, fen, bog and seepage [Ausseil et al., 2008; StatsNZ, 2018]). Recent research suggests continued loss of wetland extent nationally, including within the Auckland region (Belliss et al., 2017). Combined, there is little evidence to suggest all but a very minor extent of remaining wetland on pastoral and horticultural land in the Auckland region (e.g., <860 ha – Ausseil et al., 2008). For instance, from the likely current extent in Ausseil et al. (2008), over half of remaining regional wetland extent (2,639 ha) are occupied by features of <5 ha in size. So, at least 264 wetland features are likely distributed over the 5,465 sub-

[8] Another maximum opportunity estimate for wetland regeneration in the FWMT is the prehistoric regional extent of 57,851 ha (Ausseil et al., 2008).

catchments and 490,000 ha of the Auckland Region (e.g., occupying ~5% of no more than 1 in 20 sub-catchments).

In the absence of a robust regional or national wetland inventory, assuming no prior adoption of small and medium wetlands on existing horticultural and pastoral farmland offers both a conservative and reasonable approach to scenario modelling in the FWMT Stage 1. Note that the FWMT delineation of land cover with LCDB4 is also likely to have captured any modest-sized wetlands and excluded those from pastoral or horticultural HRUs.

4.2.3 EOF – Riparian management

Riparian options recommended for the FWMT Stage 1 are relatively diverse, varying in cost and benefit for equivalent option across HRU groups (e.g., by setback and management). Our recommendation is to ensure reasonably assured variation across pastoral and horticultural sectors, of a rural mitigation option now mandated nationally across agricultural streams (e.g., MfE, 2020). Any associated baseline information would preferably include both size (order, width) and management of waterways (e.g. stock exclusion only, 5-metre setbacks with planting or not). However, baseline adoption information on riparian options is limited much like that for EOF – Wetlands, with a lack of consistency on baseline adoption, auditing and resolution across dairy, sheep and beef and horticultural sectors.

The Sustainable Dairy Water Accord (SDWA, 2018; 2017; 2016; 2015; 2014) is arguably, the most informative source of baseline dairy stock exclusion (fence only) information. SDWA information is also audited, albeit of Accord waterways only (e.g., permanent, metre or more wide). However, SDWA reporting is not available regionally or by varying stream type (e.g., size, order, slope). In addition, SDWA reporting lacks information on setback distance or vegetation cover. Whilst being assured, the data is nonetheless of low resolution and limited diversity preventing much use (see Table 26).

If used, SDWA information could inform fence only riparian options of one metre or greater width, on the 69% of high impact pasture presumed to be of total dairying area in the FWMT Stage 1. Average dairy cattle exclusion of such streams over the baseline period is 97%, suggesting all such streams could be assumed already subject to "fence only" riparian options. However, caution would be needed to determine what length of streams are represented by "Accord waterways" (e.g., permanent, 1m wide, 30 cm deep) but equally, that many might well also have some setback and/or planting unaccounted for. Ultimately, any use of SDWA reporting should consider that ~3% of the nation's dairy farms were located in the Auckland region (StatsNZ, 2017). So, little of the 24,000 km of stock excluded Accord streams are likely present in the region (e.g., 3% thereof equates to 720 km of "fence only" mitigated permanent stream on dairying, with over 16,650 km of permanent streams in Auckland [Storey and Wadhwa, 2009]).

Table 26: Stock exclusion on dairy farms according to the Sustainable Dairy Water Accord

Season	% of Accord waterways with stock exclusion	Km of stock exclusion	Length of stream considered Accord waterway
2013-14	94%	24,000 km	
2014-15	95.6%	25,657 km	26,700 km
2015-16	97.2%	26,197 km	26,953 km
2016-17	97.5%	24,744 km	25,359 km
2017-18	98.3%	23,837 km	24,249 km

The Survey of Rural Decision Makers (MWLR, 2018) data set offers an alternative source of baseline riparian management information. Comparison to the MWLR (2020) dataset could highlight any degree of change more recently. However, both MWLR (2018 and 2020) are hindered by limited number of respondent in the Auckland region, results being presented as number of respondents, not by area or stream length, lack of verification or auditing of respondent answers, and inconsistent terminology over surveys. As with the SDWA, responses do not highlight the setback distance, even if otherwise informed by questions on vegetation cover thereof. Collectively, there is more assurance of SDWA data, suggesting limited value of MWLR (2018, 2020) datasets to the FWMT.

In 2017 and nationally, 62% of pastoral respondents with streams and wetlands on their property excluded stock from “major waterways” and 49% from “minor waterways” (MWLR, 2018); there is no definition of both waterway types, nor any assurance that respondents are clear of differences in waterway type when providing responses (e.g., of width, stream order, land slope) and there is no indication of how the number or respondents translates to length of waterways. Across Auckland in 2017 and among those who fence “major waterways”, on average 86% of large streams are apparently fenced and among those who fence “minor waterways” on average 71% of small streams are fenced. Amongst respondents who fence major (minor) waterways, the national average percentage of large streams fenced on sheep and beef farms was 68% (57%). Equivalent percentages on dairy farms are 92% (82%). Again, considerable uncertainty surrounds MWLR survey data, precluding their direct use in the FWMT. For instance, there are 16,650 km of permanent stream distributed in Auckland (Storey & Wadhwa, 2009). If permanent waterways are equivalent to “major waterways” and evenly distributed (e.g., independent of land cover) then with 47% of the Auckland region covered in pasture, approximately 7,830 km of pastoral “major waterways” exist in Auckland (and 1,670 km of dairying “major waterway” – e.g., 61% of High Impact Pasture assumed to be dairy). Applying Auckland major waterway stock exclusion estimates of 86%, would result in 13,460 km of fencing (e.g., on both sides of 7,830 km). Applying the SDWA estimates of 97% stock exclusion to “major waterways” on dairying HRU’s would result in 3,350 km of stock exclusion (i.e., ~14% of all SDWA stock exclusion over the past decade in a region with 3% of the nation’s dairy farms). The examples are less to dispute MWLR findings as much as to recognise that without verification and from limited respondents, the scalability of such data is highly uncertain.

Despite their uncertainty, MWLR datasets might indicate that stock exclusion on streams on sheep and beef land area should be acknowledged in baseline adoption rates. However, again the lack of assured Government, industry or researcher information precludes anything but a conservative approach assuming no such fencing exists. If so, caution should be exercised in FWMT Stage 1 scenario outputs as these will then likely over-estimate the maximum potential effects of riparian management options on sheep and beef farmland (e.g., 100% Low Impact Pasture, 31% of High Impact Pasture).

Another source of information on baseline riparian management adoption is Graham et al. (2020) who undertook some underlying analysis for the Ministry of Environment and Essential Freshwater: Healthy Allocation revisions to the NPS-FM, though not of the final proposed policy. Graham et al. (2020) considered the required extent of fencing required for agricultural land uses on flat to moderate land (< 15 degrees). They came to the conclusion that that there are no additional fencing requirements in the Auckland region of waterways. There is no information on what waterways were required to be fenced nor on how the costs, which were on a dollars per hectare basis, relate to kilometres of fencing. Given the absence of detail behind such conclusions, and their seeming to be at odds with even the generous MWLR (2018) data, this source is of little use given a lack of information on how to translate it to kilometres of existing fencing in the Auckland region by land use and waterway type.

Overall, any recommendation about the extent of riparian management adopted during the FWMT Stage 1 baseline period cannot be reasonably assured. Consequently, our recommendation is to presume limited such adoption across pastoral and horticultural HRU's even if otherwise a conservative assumption. A consequence is that FWMT scenario outputs will likely over-estimate the degree of water quality improvement from implementation of riparian management options, and that outputs are more valuable indications of the "quantum of change" potentially supported by widespread riparian management adoption, than of absolute changes in water quality expected.

It should also be noted that there is no information on how much stock water reticulation will be needed per length of stock exclusion. However, it is reasonable to assume that given dairy farms have largely fenced Accord waterways they are unlikely to need stock water reticulation, while some sheep and beef farms will. Given the lack of information in the FWMT Stage 1, stock water reticulation is incorporated as a sensitivity analysis whereby all sheep and beef farms need it, or none need it.

4.2.4 EOF – Detainment bunds

Detainment bunds are applicable for pastoral and horticultural land uses. The costs and benefits are not considered to be different across soil and slope types, the FWMT will decide where to apply this EOF mitigation based on relative costs and benefits.

In terms of baseline adoption, no peer-reviewed or independently audited dataset exists for detainment bunds or sediment traps on pasture or horticulture, nationally or in the Auckland region. The only dataset available is that from the Survey of Rural Decision Makers (MWLR, 2018). The latter is not verified or audited, and as above, might not represent sectoral activity in the Auckland region. Nonetheless, responses in 2017 (with 2019 equivalent responses in brackets) indicate only 1 in 4 farmers possessed a sediment trap. Among those respondents managing erosion, 5% (17%) maintain sediment traps to a "low" extent, 9% (34%) to a "medium" extent, 7% (33%) to a "high" extent and 4% (16%) to the "fullest" extent possible – noting the lack of definition and therefore consistency about low, medium, high or fullest forms of maintenance. Respondents are not segregated into pastoral or horticultural farmers, nor too is the area of farm treated understood (e.g., unclear what area of farm is upstream and how to modify recommended benefits here to reflect the four tiers of sediment trap management).

4.2.5 EOF –Space planting of erosion control trees

Space planting of erosion control trees is applicable only to pastoral HRUs, with costs and benefits that do not differ across soil, slope or pastoral types (e.g., there is no opportunity cost). Space planting and hill country stabilisation have been practised across the North Island hill country (>15 degree slope) since the 1940s following increased storm-related erosion (e.g., Soil Conservation and Rivers Control Act, 1941). Despite considerable effort researching changes to erosion rate, limited evidence exists for adoption (e.g., Basher et al., 2008, 2016; Douglas et al., 2009). As with many other rural EOF mitigations, there is no independently audited dataset for space planting of trees during the baseline period.

The MWLR (2018) dataset reports that amongst sheep and/or beef or deer farmer respondents who manage erosion (e.g., unquantified proportion of sector, unqualified term): 30% have no trees planted on slopes; 18% have a "low" extent of trees planted on slopes; 29% have a "medium" extent of trees planted on slopes; 18% have a "high" extent of trees planted on slopes; and 5% have planted trees on slope to the "fullest" extent possible. As with other questions asked in the Survey of Rural Decision Makers, there is little clarity on how the various extents of planted trees differed (i.e., how to link that to the rural space planting option for the FWMT Stage 1). Equally, the lack of quantification of respondents to regional level could readily mean responses offered are not relevant to Auckland. For instance, a recent review of space-planting by Cameron (2019) identified that approximately 85% of all North Island poplars are planted in Taranaki, Horizons, Wellington, Hawkes Bay and Gisborne. Auckland is one of three North Island regions to lack a Council-sponsored poplar nursery programme and the only to lack a land or farm management programme (e.g., supporting soil conservation measures on-farm) (Cameron, 2019). Consequently, as with other rural mitigation bundles or EOF options lacking assured information, a conservative recommendation is made to presume limited if any implementation of the rural mitigation across pastoral HRU's in the FWMT Stage 1.

As with all rural mitigations lacking assured datasets on baseline adoption, further sensitivity testing in FWMT Stage 1 scenarios is recommended to ensure that any "quantum of change" outputs can be compared for say 5%, 10% and 25% adoption.

4.2.6 Land retirement

Land retirement from existing pasture and horticulture to native vegetation is accounted for in the FWMT Stage 1. Effectively either of minor paddock areas or entire paddocks – both able to be costed on a per area basis for LCC.

The baseline data for the FWMT Stage 1 includes land cover databases (LCDB4, Agribase). Any modest area (>5 ha) of native vegetation is presumed to have been captured by the latter and delineated in the configuration of the HRU raster (i.e., excluded from pastoral and horticultural HRU area).

In earlier rural option development for the FWMT Stage 1 (Section 3.1), varying levels of ineffective area were assumed in baseline farming HRU's ranging from 3% for all horticulture (across all Horticultural Impact classes of HRU), 5% for all dairying and intensive beef (High Impact Pasture) and 10% for extensive beef and/or sheep farming (Low Impact Pasture). This ineffective area is not necessarily native vegetation, and includes tracks and buildings. These assumptions should limit the probable maximum adoption of the land retirement option (e.g., limiting maximum application to 97% of horticultural HRUs, 95% of High Impact Pasture and 90% of Low Impact Pasture). Though if the maximum area possible was converted to native bush these ineffective areas remaining would not constitute a farm or productive land area.

5 Summary and recommendations

This report documents recommendations about a suite of rural mitigation options to include in Auckland Council's freshwater quality accounting framework, the FWMT- Stage 1. Rural mitigation options have been developed from an extensive literature review and tested for reasonable assurance.

Rural mitigation options span bundled farm practice and system changes (M1, M2, M3 in order of increasing cost and severity of change) to EOF mitigation (wetlands [small, large], riparian management [horticulture, dairying, beef, sheep & beef; 1m setback, 5m setback; grassed, planted], detainment bunds, space-planted erosion control trees and land retirement).

Rural mitigation options have been applied to the underlying typology of land used by the FWMT (Hydrological Response Unit; HRU). Rural mitigation costs and benefits are provided for HRU groups, whilst recognising for variation of those with differences in sector, soil group or slope class. Collectively, a diversity of rural water quality management options are quantified for life-cycle[9] cost-optimised contaminant modelling within the FWMT Stage 1 (e.g., for water quality grading, contaminant concentration or load-based outcomes).

In all options there is limited if any assured data available on adoption rate during the FWMT baseline period (2013-2017) – the only exceptions being in the extent of likely "fence only" mitigation of permanent dairying streams and native land retirement across systems. Although dairy industry reporting suggests 96% of permanent streams are stock-excluded (SDWA, 2020), sufficient uncertainty exists about whether that is the case in Auckland or if that applies to all permanent streams of 1m width on total dairy land. Baseline land retirement was informed by the underlying land cover databases used to create the HRU framework. Theoretically, land retirement could be extended to cover the effective area of all pastoral and horticultural land uses, though this is unlikely given the relative efficacy of other mitigations.

Due to assured data on baseline adoption rates being so limited, scenario output from the FWMT Stage 1 should be cautiously used and preferably, supported by sensitivity testing of varying prior adoption (e.g., 1%, 5%, 10% and 25% of applicable farms having adopted mitigation during the baseline period).

Other recommendations to consider in the development of LCC estimates to inform the FWMT Stage 1 and to ensure continued improvement of water quality scenario modelling, include:

- Revising bundled mitigations to reflect some period when opportunity or profitability lost from baseline should no longer be accounted for (e.g., that managing for future a water quality target is business as usual). Subsequent LCC modelling will consider a 50-year adoption period and apply loss in operating profit (from bundled mitigations) or opportunity cost (of retiring land out of production) throughout.
- Changes to operating profit are accounted for but impacts on farm tax, debt repayments and interest are not included. Some mitigations, or combinations of mitigations, reduce operating profit by more than 100%. No consideration has been given here on what degree of reduced profit is unsustainable and hence, rural scenarios will need to assign this as a limit for any rural mitigation option.

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[9] Lifecycle costing (LCC) is excluded from this report and addressed in wider FWMT reporting. Instead the report presents the base units of cost associated with outlay, maintenance and replacement.

- Mitigation costs and benefits are robust if literature-based, meaning variation should be expected in these when applied to the range of farms in the FWMT. FWMT Stage 1 scenario outputs should be viewed as generalised and therefore, of increasing associated error in cost and benefit with finer spatial scale.
- Many assured literature studies were conducted on one or only a few mitigation options. There is a likelihood that reported benefits and costs are not cumulative as required to be assumed here. Hence, targeted research in Auckland farms is highly recommended to better resolve cumulative effects[10]. In addition, because the mitigation bundles are from other literature sources some of them include some of the EOF mitigations there is the possibility that when mitigations are applied cumulatively in the FWMT Stage 1 there is some duplication In future iterations of the FWMT a better separation between bundled and EOF mitigations should be considered.
- Literature studies also limit M2 and M3 bundles to either total nitrogen (TN) or total phosphorus (TP) targeted bundles (M2N, M2P, M3N, M3P) for dairy farms. Hence, FWMT scenarios will need to determine whether TN-loss or TP-loss is being prioritised for dairy farms before application of M2 and M3 bundles. Further farm-system modelling of Auckland could be targeted at the wider contaminants of interest.
- A marked lack of national or regional baseline information on rural mitigation adoption has been noted here and more recently in MfE (2020) (e.g., requirements of regulatory authorities to undertake annual surveys of rural wetland extent and quality >500m^2; regular certified auditing of Farm Environment Plan actions). It is strongly recommended that Auckland Council develop geospatial datasets of rural mitigation options, to inform future re-configuration of the FWMT Stage 2 (e.g., Baseline 2) as well as ongoing freshwater quality accounting by the FWMT (e.g., effects of Auckland Unitary Plan and NPS-FM implementation).
- All EOF and land retirement mitigations include a Total Acquisition Cost (TAC). TAC includes an overhead and indirect cost of 17.5% of the construction cost (this accounts for time needed to plan, consent or implement potential mitigations, and associated contingencies, and is based on a likely overhead cost for urban interventions of 15% - 20% [Ira and Simcock, 2019]). Whether that is appropriate for rural mitigation options is uncertain, though is recommended here to ensure consistency between urban and rural choices within the FWMT Stage 1.
- Mitigation bundles may need to be refined further by farm typology, e.g. land uses not considered here, or more refined types of farm systems (e.g. separate costs and benefits for different horticultural rotations).

[10] A further report proceeds this and proposes an approach for farm-system modelling of representative pastoral and horticultural HRUs. Farm-system baseline and mitigation modelling is recommended to help inform literature-based cost and benefit estimates, as well as better inform the Stage 2 HRU-framework (e.g., configuration of variation in profit, environmental processes and mitigation opportunities of Auckland pastoral and horticultural sectors).

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7 Appendices

7.1 Rural Mitigation Annualised Life Cycle Costs

7.1.1 50-year Life Cycle Costs – 2% Discount Rate (base date 2019)

MITIGATION BUNDLES - M1

				LCCL* NZ DOLLARS (loss of profit)	CONTAMINANT IMPACT			
Land cover	Intensity	Soil group	Unit	2% DR	N	P	Sediment	*E. coli*
Pastoral	Less than 10SU/ha		$/ha/yr LCCL	$90	-2%	-9%		
	Sheep & beef - More than 10SU/ha		$/ha/yr LCCL	$335	-1%	-18%		
	Dairy - More than 10SU/ha	Free draining	$/ha/yr LCCL	$162	-16%	-75%	-15%	-79%
		Moderately draining	$/ha/yr LCCL	$73	-17%	-68%	-15%	-62%
		Poorly drained	$/ha/yr LCCL	-$16	-17%	-61%	-15%	-45%
Horticulture	Low Impact Horticulture - Orchards & idle fallow		$/ha/yr LCCL	$104	-9%	-1%		
	Medium Impact Horticulture - Arable, citrus, fodder, nuts & viticulture		$/ha/yr LCCL	$104	-9%	-1%		
	High Impact Horticulture - Berryfruit, flowers, stonefruit, kiwifruit, nursery, pipfruit, fruit, vegetables, greenhouses		$/ha/yr LCCL	$0	-2%			

*Life Cycle Cost (Loss)

MITIGATION BUNDLES - M2

				LCCL* NZ DOLLARS (loss of profit)	CONTAMINANT IMPACT			
Land cover	Intensity	Contaminant	Unit	2% DR	N	P	Sediment	Ecoli
Pastoral	Less than 10SU/ha		$/ha/yr LCCL	$119	-4%	-9%		
	Sheep & beef - More than 10SU/ha		$/ha/yr LCCL	$646	-25%	-38%		
	Dairy - More than 10SU/ha	Nitrogen	$/ha/yr LCCL	$121	-36%	-68%	-15%	-62%
		Phosophorus	$/ha/yr LCCL	$194	-17%	-78%	-15%	-62%
		Combined	$/ha/yr LCCL	$243	-36%	-78%	-15%	-62%
Horticulture	Low Impact Horticulture - Orchards & idle fallow		$/ha/yr LCCL	$627	-15%	-1%		
	Medium Impact Horticulture - Arable, citrus, fodder, nuts & viticulture		$/ha/yr LCCL	$627	-15%	-1%		
	High Impact Horticulture - Berryfruit, flowers, stonefruit, kiwifruit, nursery, pipfruit, fruit, vegetables, greenhouses		$/ha/yr LCCL	$1,492	-10%			

MITIGATION BUNDLES - M3				LCCL* NZ DOLLARS (loss of profit)	CONTAMINANT IMPACT			
Land cover	Intensity	Contaminant	Unit	2% DR	N	P	Sediment	Ecoli
Pastoral	Less than 10SU/ha		$/ha/yr LCCL	$143	-14%	-10%		
	Sheep & beef - More than 10SU/ha		$/ha/yr LCCL	$762	-31%	-38%		
	Dairy - More than 10SU/ha	Nitrogen	$/ha/yr LCCL	$194	-61%	-68%	-15%	-62%
		Phosophorus	$/ha/yr LCCL	$397	-17%	-93%	-15%	-62%
		Combined	$/ha/yr LCCL	$518	-61%	-93%	-15%	-62%
Horticulture	Low Impact Horticulture - Orchards & idle fallow		$/ha/yr LCCL	$1,492	-21%	-1%		
	Medium Impact Horticulture - Arable, citrus, fodder, nuts & viticulture		$/ha/yr LCCL	$1,492	-21%	-1%		
	High Impact Horticulture - Berryfruit, flowers, stonefruit, kiwifruit, nursery, pipfruit, fruit, vegetables, greenhouses		$/ha/yr LCCL	$3,010	-14%			

LAND RETIREMENT			LCC NZ DOLLARS	CONTAMINANT IMPACT			
Land cover	Intensity	Unit	2% DR	N	P	Sediment	*E. coli*
Pastoral	Less than 10SU/ha	LCC/ha/yr	$502				
	Sheep & beef - More than 10SU/ha	LCC/ha/yr	$674				
	Dairy - More than 10SU/ha	LCC/ha/yr	$1,070				
Horticulture	Low Impact Horticulture - Orchards & idle fallow	LCC/ha/yr	$1,753				
	Medium Impact Horticulture - Arable, citrus, fodder, nuts & viticulture	LCC/ha/yr	$1,753				
	High Impact Horticulture - Berryfruit, flowers, stonefruit, kiwifruit, nursery, pipfruit, fruit, vegetables, greenhouses	LCC/ha/yr	$2,747				

EDGE OF FIELD MITIGATIONS				ANNUALISED LCC NZ DOLLARS	TAC PERCENTAGES	CONTAMINANT IMPACT			
Mitigation Type	**Rural Landuse Type**	**Description**	**Unit**	**2% DR**	**2% DR**	**N**	**P**	**Sediment**	***E. coli***
Small wetland (<1ha)	Pastoral	Less than 10SU/ha	LCC/m^2/yr	$0.52	84%	-10%	-45%	-65%	-55%
	Pastoral	Sheep & beef - More than 10SU/ha	LCC/m^2/yr	$0.48	87%	-10%	-45%	-65%	-55%
	Pastoral	Dairy - More than 10SU/ha	LCC/m^2/yr	$0.47	86%	-10%	-45%	-65%	-55%
	Horticulture	Low Impact Horticulture - Orchards & idle fallow	LCC/m^2/yr	$0.47	83%	-10%	-45%	-65%	-55%
	Horticulture	Medium Impact Horticulture - Arable, citrus, fodder, nuts & viticulture	LCC/m^2/yr	$0.47	83%	-10%	-45%	-65%	-55%
	Horticulture	High Impact Horticulture - Berryfruit, flowers, stonefruit, kiwifruit, nursery, pipfruit, fruit, vegetables, greenhouses	LCC/m^2/yr	$0.52	75%	-10%	-45%	-65%	-55%
Large wetland (>1 ha)	Pastoral	Less than 10SU/ha	LCC/m^2/yr	$0.44	80%	-10%	-45%	-65%	-55%
	Pastoral	Sheep & beef - More than 10SU/ha	LCC/m^2/yr	$0.39	83%	-10%	-45%	-65%	-55%
	Pastoral	Dairy - More than 10SU/ha	LCC/m^2/yr	$0.39	81%	-10%	-45%	-65%	-55%
	Horticulture	Low Impact Horticulture - Orchards & idle fallow	LCC/m^2/yr	$0.39	77%	-10%	-45%	-65%	-55%
	Horticulture	Medium Impact Horticulture - Arable, citrus, fodder, nuts & viticulture	LCC/m^2/yr	$0.39	77%	-10%	-45%	-65%	-55%
	Horticulture	High Impact Horticulture - Berryfruit, flowers, stonefruit, kiwifruit, nursery, pipfruit, fruit, vegetables, greenhouses	LCC/m^2/yr	$0.44	69%	-10%	-45%	-65%	-55%
Detainment bunds/sediment traps	Pastoral	All	LCC/ha/yr	$9.17	64%	0%	-15%	-80%	-50%
Detainment bunds/sediment traps	Horiticulture	All	LCC/ha/yr	$4.85	63%			-88%	
Space planting of erosion control trees	Pastoral	All	LCC/ha/yr	$35.93	65%	0%	-20%	-70%	0%

EDGE OF FIELD MITIGATIONS - FENCING AND BUFFER STRIPS

Mitigation Type	Rural Landuse Type	Description	Unit	ANNUALISED LCC NZ DOLLARS	TAC PERCENTAGES	% Annual BUFFER LCC RELATING TO FENCING	% Annual BUFFER LCC RELATING TO FENCING & STOCKWATER RETICULATION	CONTAMINANT IMPACT			
				2% DR	2% DR			N	P	Sediment	*E. coli*
Stock exclusion - Fencing (with 1m buffer width/ setback of rank grass and including stock water costs for sheep and beef)	Pastoral	Dairy - More than 10SU/ha Flat & rolling	LCC/m/yr	$0.29	44%						-58%
	Pastoral	Dairy - More than 10SU/ha Steep	LCC/m/yr	$0.41	44%						
	Pastoral	Less than 10SU/ha Flat & rolling	LCC/m/yr	$1.08	57%						-58%
	Pastoral	Less than 10SU/ha Steep	LCC/m/yr	$1.25	53%						
	Pastoral	Sheep & beef - More than 10SU/ha Flat & rolling	LCC/m/yr	$0.76	57%						-58%
	Pastoral	Sheep & beef - More than 10SU/ha Steep	LCC/m/yr	$0.90	54%						
Stock exclusion - Fencing (as above but **no stock water reticulation costs**)	Pastoral	Less than 10SU/ha Flat & rolling	LCC/m/yr	$0.72	57%						-58%
	Pastoral	Less than 10SU/ha Steep	LCC/m/yr	$0.89	48%						
	Pastoral	Sheep & beef - More than 10SU/ha Flat & rolling	LCC/m/yr	$0.40	49%						-58%
	Pastoral	Sheep & beef - More than 10SU/ha Steep	LCC/m/yr	$0.54	47%						

EDGE OF FIELD MITIGATIONS - FENCING AND BUFFER STRIPS				ANNUALISED LCC NZ DOLLARS	TAC PERCENTAGES	% Annual BUFFER LCC RELATING TO FENCING	% Annual BUFFER LCC RELATING TO FENCING & STOCKWATER RETICULATION	CONTAMINANT IMPACT			
Mitigation Type	Rural Landuse Type	Description	Unit	2% DR	2% DR			N	P	Sediment	*E. coli*
Grass Buffer Strip (fencing for pastoral land and 5m rank grass strip; stock water for sheep and beef)	Pastoral	Dairy - More than 10SU/ha Flat & rolling	LCC/m/yr	$0.58	23%	50%	N/A	-15%	-10%	-70%	-60%
	Pastoral	Dairy - More than 10SU/ha Steep	LCC/m/yr	$0.70	27%	59%	N/A				
	Pastoral	Less than 10SU/ha Flat & rolling	LCC/m/yr	$1.25	49%	57%	86%	-5%	-5%	-70%	-60%
	Pastoral	Less than 10SU/ha Steep	LCC/m/yr	$1.42	47%	63%	88%				
	Pastoral	Sheep & beef - More than 10SU/ha Flat & rolling	LCC/m/yr	$0.96	45%	41%	79%	-15%	-10%	-70%	-60%
	Pastoral	Sheep & beef - More than 10SU/ha Steep	LCC/m/yr	$1.11	45%	49%	81%				
	Horticulture	Low Impact Horticulture - Orchards & idle fallow	LCC/m/yr	$0.53	N/A	N/A	N/A			-40%	
	Horticulture	Medium Impact Horticulture - Arable, citrus, fodder, nuts & viticulture	LCC/m/yr	$0.53	N/A	N/A	N/A			-40%	
	Horticulture	High Impact Horticulture - Berryfruit, flowers, stonefruit, kiwifruit, nursery, pipfruit, fruit, vegetables, greenhouses	LCC/m/yr	$0.78	N/A	N/A	N/A			-40%	

EDGE OF FIELD MITIGATIONS - FENCING AND BUFFER STRIPS				ANNUALISED LCC NZ DOLLARS	TAC PERCENTAGES	% Annual BUFFER LCC RELATING TO FENCING	% Annual BUFFER LCC RELATING TO FENCING & STOCKWATER RETICULATION	CONTAMINANT IMPACT			
Mitigation Type	Rural Landuse Type	Description	Unit	2% DR	2% DR			N	P	Sediment	*E. coli*
Planted Buffer Strip (fencing for pastoral land and 5m riparian planted strip; stock water for sheep and beef)	Pastoral	Dairy - More than 10SU/ha Flat & rolling	LCC/m/yr	$1.66	47%	18%	N/A	-56%	-50%	-75%	-60%
	Pastoral	Dairy - More than 10SU/ha Steep	LCC/m/yr	$1.78	47%	23%	N/A				
	Pastoral	Less than 10SU/ha Flat & rolling	LCC/m/yr	$2.33	54%	31%	46%	-56%	-50%	-75%	-60%
	Pastoral	Less than 10SU/ha Steep	LCC/m/yr	$2.50	52%	36%	50%				
	Pastoral	Sheep & beef - More than 10SU/ha Flat & rolling	LCC/m/yr	$2.05	53%	20%	37%	-56%	-50%	-75%	-60%
	Pastoral	Sheep & beef - More than 10SU/ha Steep	LCC/m/yr	$2.19	52%	25%	41%				
	Horticulture	Low Impact Horticulture - Orchards & idle fallow	LCC/m/yr	$1.60	41%	N/A	N/A	-51%	-50%	-75%	
	Horticulture	Medium Impact Horticulture - Arable, citrus, fodder, nuts & viticulture	LCC/m/yr	$1.60	41%	N/A	N/A	-51%	-50%	-75%	
	Horticulture	High Impact Horticulture - Berryfruit, flowers, stonefruit, kiwifruit, nursery, pipfruit, fruit, vegetables, greenhouses	LCC/m/yr	$1.85	36%	N/A	N/A	-51%	-50%	-75%	

EDGE OF FIELD MITIGATIONS - FENCING AND BUFFER STRIPS				ANNUALISED LCC NZ DOLLARS
Mitigation Type	**Rural Landuse Type**	**Description**	**Unit**	**2% DR**
Grass Buffer Strip (**No fencing** for pastoral land; 5m rank grass strip)	Pastoral	Dairy - More than 10SU/ha Flat & rolling	LCC/m/yr	$0.29
	Pastoral	Dairy - More than 10SU/ha Steep	LCC/m/yr	$0.29
	Pastoral	Less than 10SU/ha Flat & rolling	LCC/m/yr	$0.53
	Pastoral	Less than 10SU/ha Steep	LCC/m/yr	$0.53
	Pastoral	Sheep & beef - More than 10SU/ha Flat & rolling	LCC/m/yr	$0.56
	Pastoral	Sheep & beef - More than 10SU/ha Steep	LCC/m/yr	$0.56
Planted Buffer Strip (**No fencing** for pastoral land; 5m riparian planted strip)	Pastoral	Dairy - More than 10SU/ha Flat & rolling	LCC/m/yr	$1.37
	Pastoral	Dairy - More than 10SU/ha Steep	LCC/m/yr	$1.37
	Pastoral	Less than 10SU/ha (sheep & beef): Flat & rolling	LCC/m/yr	$1.61
	Pastoral	Less than 10SU/ha (sheep & beef): Steep	LCC/m/yr	$1.61
	Pastoral	More than 10SU/ha (sheep & beef): Flat & rolling	LCC/m/yr	$1.64
	Pastoral	More than 10SU/ha (sheep & beef): Steep	LCC/m/yr	$1.64
Grass Buffer Strip (**No fencing or stock water reticulation** for pastoral land; 5m rank grass strip)	Pastoral	Less than 10SU/ha Flat & rolling	LCC/m/yr	$0.17
	Pastoral	Less than 10SU/ha Steep	LCC/m/yr	$0.17
	Pastoral	Sheep & beef - More than 10SU/ha Flat & rolling	LCC/m/yr	$0.21
	Pastoral	Sheep & beef - More than 10SU/ha Steep	LCC/m/yr	$0.21
Planted Buffer Strip (**No fencing or stock water reticulation** for pastoral land; 5m riparian planted strip)	Pastoral	Less than 10SU/ha Flat & rolling	LCC/m/yr	$1.25
	Pastoral	Less than 10SU/ha Steep	LCC/m/yr	$1.25
	Pastoral	Sheep & beef - More than 10SU/ha Flat & rolling	LCC/m/yr	$1.29
	Pastoral	Sheep & beef - More than 10SU/ha Steep	LCC/m/yr	$1.29

EDGE OF FIELD MITIGATIONS - BUFFER STRIPS				ANNUALISED LCC NZ DOLLARS	TAC PERCENTAGES
Mitigation Type	**Rural Landuse Type**	**Description**	**Unit**	**2% DR**	**2% DR**
Grass Buffer Strip (planting, plant maintenance and opportunity costs only) - based on 5m2 buffer strip	Pastoral	Dairy - More than 10SU/ha	LCC/m^2/yr	$0.07	2%
	Pastoral	Less than 10SU/ha	LCC/m^2/yr	$0.04	1%
	Pastoral	Sheep & beef - More than 10SU/ha	LCC/m^2/yr	$0.05	1%
	Horticulture	Low Impact Horticulture - Orchards & idle fallow	LCC/m^2/yr	$0.11	3%
	Horticulture	Medium Impact Horticulture - Arable, citrus, fodder, nuts & viticulture	LCC/m^2/yr	$0.11	3%
	Horticulture	High Impact Horticulture - Berryfruit, flowers, stonefruit, kiwifruit, nursery, pipfruit, fruit, vegetables, greenhouses	LCC/m^2/yr	$0.16	3%
Planted Buffer Strip (planting, plant maintenance and opportunity costs only) - based on 5m2 buffer strip	Pastoral	Dairy - More than 10SU/ha	LCC/m^2/yr	$0.29	45%
	Pastoral	Less than 10SU/ha	LCC/m^2/yr	$0.26	50%
	Pastoral	Sheep & beef - More than 10SU/ha	LCC/m^2/yr	$0.27	49%
	Horticulture	Low Impact Horticulture - Orchards & idle fallow	LCC/m^2/yr	$0.32	41%
	Horticulture	Medium Impact Horticulture - Arable, citrus, fodder, nuts & viticulture	LCC/m^2/yr	$0.32	41%
	Horticulture	High Impact Horticulture - Berryfruit, flowers, stonefruit, kiwifruit, nursery, pipfruit, fruit, vegetables, greenhouses	LCC/m^2/yr	$0.37	36%

7.1.2 50-year Life Cycle Costs – 4% Discount Rate (base date 2019)

MITIGATION BUNDLES - M1				LCCL* NZ DOLLARS (loss of profit)	CONTAMINANT IMPACT			
Land cover	Intensity	Soil group	Unit	4% DR	N	P	Sediment	*E. coli*
Pastoral	Less than 10SU/ha		$/ha/yr LCCL	$62	-2%	-9%		
	Sheep & beef - More than 10SU/ha		$/ha/yr LCCL	$234	-1%	-18%		
	Dairy - More than 10SU/ha	Free draining	$/ha/yr LCCL	$113	-16%	-75%	-15%	-79%
		Moderately draining	$/ha/yr LCCL	$51	-17%	-68%	-15%	-62%
		Poorly drained	$/ha/yr LCCL	-$11	-17%	-61%	-15%	-45%
Horticulture	Low Impact Horticulture - Orchards & idle fallow		$/ha/yr LCCL	$73	-9%	-1%		
	Medium Impact Horticulture - Arable, citrus, fodder, nuts & viticulture		$/ha/yr LCCL	$73	-9%	-1%		
	High Impact Horticulture - Berryfruit, flowers, stonefruit, kiwifruit, nursery, pipfruit, fruit, vegetables, greenhouses		$/ha/yr LCCL	$0	-2%			

*Life Cycle Cost (Loss)

MITIGATION BUNDLES - M2				LCCL* NZ DOLLARS (loss of profit)	CONTAMINANT IMPACT			
Land cover	Intensity	Contaminant	Unit	4% DR	N	P	Sediment	Ecoli
Pastoral	Less than 10SU/ha		$/ha/yr LCCL	$83	-4%	-9%		
	Sheep & beef - More than 10SU/ha		$/ha/yr LCCL	$450	-25%	-38%		
	Dairy - More than 10SU/ha	Nitrogen	$/ha/yr LCCL	$85	-36%	-68%	-15%	-62%
		Phosophorus	$/ha/yr LCCL	$135	-17%	-78%	-15%	-62%
		Combined	$/ha/yr LCCL	$169	-36%	-78%	-15%	-62%
Horticulture	Low Impact Horticulture - Orchards & idle fallow		$/ha/yr LCCL	$437	-15%	-1%		
	Medium Impact Horticulture - Arable, citrus, fodder, nuts & viticulture		$/ha/yr LCCL	$437	-15%	-1%		
	High Impact Horticulture - Berryfruit, flowers, stonefruit, kiwifruit, nursery, pipfruit, fruit, vegetables, greenhouses		$/ha/yr LCCL	$1,040	-10%			

MITIGATION BUNDLES - M3				LCCL* NZ DOLLARS (loss of profit)	CONTAMINANT IMPACT			
Land cover	Intensity	Contaminant	Unit	4% DR	N	P	Sediment	Ecoli
Pastoral	Less than 10SU/ha		$/ha/yr LCCL	$100	-14%	-10%		
	Sheep & beef - More than 10SU/ha		$/ha/yr LCCL	$531	-31%	-38%		
	Dairy - More than 10SU/ha	Nitrogen	$/ha/yr LCCL	$135	-61%	-68%	-15%	-62%
		Phosophorus	$/ha/yr LCCL	$277	-17%	-93%	-15%	-62%
		Combined	$/ha/yr LCCL	$361	-61%	-93%	-15%	-62%
Horticulture	Low Impact Horticulture - Orchards & idle fallow		$/ha/yr LCCL	$1,040	-21%	-1%		
	Medium Impact Horticulture - Arable, citrus, fodder, nuts & viticulture		$/ha/yr LCCL	$1,040	-21%	-1%		
	High Impact Horticulture - Berryfruit, flowers, stonefruit, kiwifruit, nursery, pipfruit, fruit, vegetables, greenhouses		$/ha/yr LCCL	$2,098	-14%			

LAND RETIREMENT			LCC NZ DOLLARS	CONTAMINANT IMPACT			
Land cover	Intensity	Unit	4% DR	N	P	Sediment	*E. coli*
Pastoral	Less than 10SU/ha	LCC/ha/yr	$459				
	Sheep & beef - More than 10SU/ha	LCC/ha/yr	$579				
	Dairy - More than 10SU/ha	LCC/ha/yr	$855				
Horticulture	Low Impact Horticulture - Orchards & idle fallow	LCC/ha/yr	$1,330				
	Medium Impact Horticulture - Arable, citrus, fodder, nuts & viticulture	LCC/ha/yr	$1,330				
	High Impact Horticulture - Berryfruit, flowers, stonefruit, kiwifruit, nursery, pipfruit, fruit, vegetables, greenhouses	LCC/ha/yr	$2,024				

EDGE OF FIELD MITIGATIONS				ANNUALISED LCC NZ DOLLARS	TAC PERCENTAGES	CONTAMINANT IMPACT			
Mitigation Type	**Rural Landuse Type**	**Description**	**Unit**	**4% DR**	**4% DR**	**N**	**P**	**Sediment**	***E. coli***
Small wetland (<1ha)	Pastoral	Less than 10SU/ha	LCC/m^2/yr	$0.49	90%	-10%	-45%	-65%	-55%
	Pastoral	Sheep & beef - More than 10SU/ha	LCC/m^2/yr	$0.45	92%	-10%	-45%	-65%	-55%
	Pastoral	Dairy - More than 10SU/ha	LCC/m^2/yr	$0.45	90%	-10%	-45%	-65%	-55%
	Horticulture	Low Impact Horticulture - Orchards & idle fallow	LCC/m^2/yr	$0.44	88%	-10%	-45%	-65%	-55%
	Horticulture	Medium Impact Horticulture - Arable, citrus, fodder, nuts & viticulture	LCC/m^2/yr	$0.44	88%	-10%	-45%	-65%	-55%
	Horticulture	High Impact Horticulture - Berryfruit, flowers, stonefruit, kiwifruit, nursery, pipfruit, fruit, vegetables, greenhouses	LCC/m^2/yr	$0.48	82%	-10%	-45%	-65%	-55%
Large wetland (>1 ha)	Pastoral	Less than 10SU/ha	LCC/m^2/yr	$0.41	87%	-10%	-45%	-65%	-55%
	Pastoral	Sheep & beef - More than 10SU/ha	LCC/m^2/yr	$0.37	88%	-10%	-45%	-65%	-55%
	Pastoral	Dairy - More than 10SU/ha	LCC/m^2/yr	$0.37	86%	-10%	-45%	-65%	-55%
	Horticulture	Low Impact Horticulture - Orchards & idle fallow	LCC/m^2/yr	$0.36	83%	-10%	-45%	-65%	-55%
	Horticulture	Medium Impact Horticulture - Arable, citrus, fodder, nuts & viticulture	LCC/m^2/yr	$0.36	83%	-10%	-45%	-65%	-55%
	Horticulture	High Impact Horticulture - Berryfruit, flowers, stonefruit, kiwifruit, nursery, pipfruit, fruit, vegetables, greenhouses	LCC/m^2/yr	$0.39	76%	-10%	-45%	-65%	-55%
Detainment bunds/sediment traps	Pastoral	All	LCC/ha/yr	$7.95	74%	0%	-15%	-80%	-50%
Detainment bunds/sediment traps	Horiticulture	All	LCC/ha/yr	$4.20	73%			-88%	
Space planting of erosion control trees	Pastoral	All	LCC/ha/yr	$31.30	75%	0%	-20%	-70%	0%

EDGE OF FIELD MITIGATIONS - FENCING AND BUFFER STRIPS				ANNUALISED LCC NZ DOLLARS	TAC PERCENTAGES	% Annual BUFFER LCC RELATING TO FENCING	% Annual BUFFER LCC RELATING TO FENCING & STOCKWATER RETICULATION	CONTAMINANT IMPACT			
Mitigation Type	Rural Landuse Type	Description	Unit	4% DR	4% DR			N	P	Sediment	*E. coli*
Stock exclusion - Fencing (with 1m buffer width/ setback of rank grass and including stock water costs for sheep and beef)	Pastoral	Dairy - More than 10SU/ha Flat & rolling	LCC/m/yr	$0.24	54%						-58%
	Pastoral	Dairy - More than 10SU/ha Steep	LCC/m/yr	$0.33	54%						
	Pastoral	Less than 10SU/ha Flat & rolling	LCC/m/yr	$0.91	67%						-58%
	Pastoral	Less than 10SU/ha Steep	LCC/m/yr	$1.05	63%						
	Pastoral	Sheep & beef - More than 10SU/ha Flat & rolling	LCC/m/yr	$0.64	67%						-58%
	Pastoral	Sheep & beef - More than 10SU/ha Steep	LCC/m/yr	$0.76	65%						
Stock exclusion - Fencing (as above but **no stock water reticulation costs**)	Pastoral	Less than 10SU/ha Flat & rolling	LCC/m/yr	$0.60	67%						-58%
	Pastoral	Less than 10SU/ha Steep	LCC/m/yr	$0.73	58%						
	Pastoral	Sheep & beef - More than 10SU/ha Flat & rolling	LCC/m/yr	$0.33	60%						-58%
	Pastoral	Sheep & beef - More than 10SU/ha Steep	LCC/m/yr	$0.44	57%						

EDGE OF FIELD MITIGATIONS - FENCING AND BUFFER STRIPS				ANNUALISED LCC NZ DOLLARS	TAC PERCENTAGES	% Annual BUFFER LCC RELATING TO FENCING	% Annual BUFFER LCC RELATING TO FENCING & STOCKWATER RETICULATION	CONTAMINANT IMPACT			
Mitigation Type	Rural Landuse Type	Description	Unit	4% DR	4% DR			N	P	Sediment	*E. coli*
Grass Buffer Strip (fencing for pastoral land and 5m rank grass strip; stock water for sheep and beef)	Pastoral	Dairy - More than 10SU/ha Flat & rolling	LCC/m/yr	$0.44	30%	54%	N/A	-15%	-10%	-70%	-60%
	Pastoral	Dairy - More than 10SU/ha Steep	LCC/m/yr	$0.53	35%	63%	N/A				
	Pastoral	Less than 10SU/ha Flat & rolling	LCC/m/yr	$1.03	60%	58%	88%	-5%	-5%	-70%	-60%
	Pastoral	Less than 10SU/ha Steep	LCC/m/yr	$1.17	57%	63%	90%				
	Pastoral	Sheep & beef - More than 10SU/ha Flat & rolling	LCC/m/yr	$0.79	55%	42%	82%	-15%	-10%	-70%	-60%
	Pastoral	Sheep & beef - More than 10SU/ha Steep	LCC/m/yr	$0.90	55%	49%	84%				
	Horticulture	Low Impact Horticulture - Orchards & idle fallow	LCC/m/yr	$0.37	N/A	N/A	N/A			-40%	
	Horticulture	Medium Impact Horticulture - Arable, citrus, fodder, nuts & viticulture	LCC/m/yr	$0.37	N/A	N/A	N/A			-40%	
	Horticulture	High Impact Horticulture - Berryfruit, flowers, stonefruit, kiwifruit, nursery, pipfruit, fruit, vegetables, greenhouses	LCC/m/yr	$0.55	N/A	N/A	N/A			-40%	

EDGE OF FIELD MITIGATIONS - FENCING AND BUFFER STRIPS				ANNUALISED LCC NZ DOLLARS	TAC PERCENTAGES	% Annual BUFFER LCC RELATING TO FENCING	% Annual BUFFER LCC RELATING TO FENCING & STOCKWATER RETICULATION	CONTAMINANT IMPACT			
Mitigation Type	Rural Landuse Type	Description	Unit	4% DR	4% DR			N	P	Sediment	*E. coli*
Planted Buffer Strip (fencing for pastoral land and 5m riparian planted strip; stock water for sheep and beef)	Pastoral	Dairy - More than 10SU/ha Flat & rolling	LCC/m/yr	$1.50	52%	16%	N/A	-56%	-50%	-75%	-60%
	Pastoral	Dairy - More than 10SU/ha Steep	LCC/m/yr	$1.60	52%	21%	N/A				
	Pastoral	Less than 10SU/ha Flat & rolling	LCC/m/yr	$2.10	60%	29%	44%	-56%	-50%	-75%	-60%
	Pastoral	Less than 10SU/ha Steep	LCC/m/yr	$2.23	59%	33%	47%				
	Pastoral	Sheep & beef - More than 10SU/ha Flat & rolling	LCC/m/yr	$1.85	58%	18%	35%	-56%	-50%	-75%	-60%
	Pastoral	Sheep & beef - More than 10SU/ha Steep	LCC/m/yr	$1.96	58%	23%	39%				
	Horticulture	Low Impact Horticulture - Orchards & idle fallow	LCC/m/yr	$1.43	46%	N/A	N/A	-51%	-50%	-75%	
	Horticulture	Medium Impact Horticulture - Arable, citrus, fodder, nuts & viticulture	LCC/m/yr	$1.43	46%	N/A	N/A	-51%	-50%	-75%	
	Horticulture	High Impact Horticulture - Berryfruit, flowers, stonefruit, kiwifruit, nursery, pipfruit, fruit, vegetables, greenhouses	LCC/m/yr	$1.60	42%	N/A	N/A	-51%	-50%	-75%	

EDGE OF FIELD MITIGATIONS - FENCING AND BUFFER STRIPS				ANNUALISED LCC NZ DOLLARS
Mitigation Type	**Rural Landuse Type**	**Description**	**Unit**	**4% DR**
Grass Buffer Strip (**No fencing** for pastoral land; 5m rank grass strip)	Pastoral	Dairy - More than 10SU/ha Flat & rolling	LCC/m/yr	$0.20
	Pastoral	Dairy - More than 10SU/ha Steep	LCC/m/yr	$0.20
	Pastoral	Less than 10SU/ha Flat & rolling	LCC/m/yr	$0.43
	Pastoral	Less than 10SU/ha Steep	LCC/m/yr	$0.43
	Pastoral	Sheep & beef - More than 10SU/ha Flat & rolling	LCC/m/yr	$0.45
	Pastoral	Sheep & beef - More than 10SU/ha Steep	LCC/m/yr	$0.45
Planted Buffer Strip (**No fencing** for pastoral land; 5m riparian planted strip)	Pastoral	Dairy - More than 10SU/ha Flat & rolling	LCC/m/yr	$1.26
	Pastoral	Dairy - More than 10SU/ha Steep	LCC/m/yr	$1.26
	Pastoral	Less than 10SU/ha (sheep & beef): Flat & rolling	LCC/m/yr	$1.50
	Pastoral	Less than 10SU/ha (sheep & beef): Steep	LCC/m/yr	$1.50
	Pastoral	More than 10SU/ha (sheep & beef): Flat & rolling	LCC/m/yr	$1.52
	Pastoral	More than 10SU/ha (sheep & beef): Steep	LCC/m/yr	$1.52
Grass Buffer Strip (**No fencing or stock water reticulation** for pastoral land; 5m rank grass strip)	Pastoral	Less than 10SU/ha Flat & rolling	LCC/m/yr	$0.12
	Pastoral	Less than 10SU/ha Steep	LCC/m/yr	$0.12
	Pastoral	Sheep & beef - More than 10SU/ha Flat & rolling	LCC/m/yr	$0.14
	Pastoral	Sheep & beef - More than 10SU/ha Steep	LCC/m/yr	$0.14
Planted Buffer Strip (**No fencing or stock water reticulation** for pastoral land; 5m riparian planted strip)	Pastoral	Less than 10SU/ha Flat & rolling	LCC/m/yr	$1.18
	Pastoral	Less than 10SU/ha Steep	LCC/m/yr	$1.18
	Pastoral	Sheep & beef - More than 10SU/ha Flat & rolling	LCC/m/yr	$1.21
	Pastoral	Sheep & beef - More than 10SU/ha Steep	LCC/m/yr	$1.21

EDGE OF FIELD MITIGATIONS - BUFFER STRIPS				ANNUALISED LCC NZ DOLLARS	TAC PERCENTAGES
Mitigation Type	**Rural Landuse Type**	**Description**	**Unit**	**4% DR**	**4% DR**
Grass Buffer Strip (planting, plant maintenance and opportunity costs only) - based on 5m2 buffer strip	Pastoral	Dairy - More than 10SU/ha	LCC/m^2/yr	$0.05	3%
	Pastoral	Less than 10SU/ha	LCC/m^2/yr	$0.03	1%
	Pastoral	Sheep & beef - More than 10SU/ha	LCC/m^2/yr	$0.04	2%
	Horticulture	Low Impact Horticulture - Orchards & idle fallow	LCC/m^2/yr	$0.07	4%
	Horticulture	Medium Impact Horticulture - Arable, citrus, fodder, nuts & viticulture	LCC/m^2/yr	$0.07	4%
	Horticulture	High Impact Horticulture - Berryfruit, flowers, stonefruit, kiwifruit, nursery, pipfruit, fruit, vegetables, greenhouses	LCC/m^2/yr	$0.11	4%
Planted Buffer Strip (planting, plant maintenance and opportunity costs only) - based on 5m2 buffer strip	Pastoral	Dairy - More than 10SU/ha	LCC/m^2/yr	$0.26	50%
	Pastoral	Less than 10SU/ha	LCC/m^2/yr	$0.24	53%
	Pastoral	Sheep & beef - More than 10SU/ha	LCC/m^2/yr	$0.25	52%
	Horticulture	Low Impact Horticulture - Orchards & idle fallow	LCC/m^2/yr	$0.29	46%
	Horticulture	Medium Impact Horticulture - Arable, citrus, fodder, nuts & viticulture	LCC/m^2/yr	$0.29	46%
	Horticulture	High Impact Horticulture - Berryfruit, flowers, stonefruit, kiwifruit, nursery, pipfruit, fruit, vegetables, greenhouses	LCC/m^2/yr	$0.32	42%

7.1.3 50-year Life Cycle Costs – 6% Discount Rate (base date 2019)

MITIGATION BUNDLES - M1

Land cover	Intensity	Soil group	Unit	LCCL* NZ DOLLARS (loss of profit) 6% DR	CONTAMINANT IMPACT N	P	Sediment	*E. coli*
Pastoral	Less than 10SU/ha		$/ha/yr LCCL	$47	-2%	-9%		
	Sheep & beef - More than 10SU/ha		$/ha/yr LCCL	$175	-1%	-18%		
	Dairy - More than 10SU/ha	Free draining	$/ha/yr LCCL	$84	-16%	-75%	-15%	-79%
		Moderately draining	$/ha/yr LCCL	$38	-17%	-68%	-15%	-62%
		Poorly drained	$/ha/yr LCCL	-$8	-17%	-61%	-15%	-45%
Horticulture	Low Impact Horticulture - Orchards & idle fallow		$/ha/yr LCCL	$54	-9%	-1%		
	Medium Impact Horticulture - Arable, citrus, fodder, nuts & viticulture		$/ha/yr LCCL	$54	-9%	-1%		
	High Impact Horticulture - Berryfruit, flowers, stonefruit, kiwifruit, nursery, pipfruit, fruit, vegetables, greenhouses		$/ha/yr LCCL	$0	-2%			

*Life Cycle Cost (Loss)

MITIGATION BUNDLES - M2

Land cover	Intensity	Contaminant	Unit	LCCL* NZ DOLLARS (loss of profit) 6% DR	CONTAMINANT IMPACT N	P	Sediment	Ecoli
Pastoral	Less than 10SU/ha		$/ha/yr LCCL	$62	-4%	-9%		
	Sheep & beef - More than 10SU/ha		$/ha/yr LCCL	$337	-25%	-38%		
	Dairy - More than 10SU/ha	Nitrogen	$/ha/yr LCCL	$63	-36%	-68%	-15%	-62%
		Phosophorus	$/ha/yr LCCL	$101	-17%	-78%	-15%	-62%
		Combined	$/ha/yr LCCL	$127	-36%	-78%	-15%	-62%
Horticulture	Low Impact Horticulture - Orchards & idle fallow		$/ha/yr LCCL	$327	-15%	-1%		
	Medium Impact Horticulture - Arable, citrus, fodder, nuts & viticulture		$/ha/yr LCCL	$327	-15%	-1%		
	High Impact Horticulture - Berryfruit, flowers, stonefruit, kiwifruit, nursery, pipfruit, fruit, vegetables, greenhouses		$/ha/yr LCCL	$778	-10%			

MITIGATION BUNDLES - M3				LCCL* NZ DOLLARS (loss of profit)	CONTAMINANT IMPACT			
Land cover	Intensity	Contaminant	Unit	6% DR	N	P	Sediment	Ecoli
Pastoral	Less than 10SU/ha		$/ha/yr LCCL	$75	-14%	-10%		
	Sheep & beef - More than 10SU/ha		$/ha/yr LCCL	$397	-31%	-38%		
	Dairy - More than 10SU/ha	Nitrogen	$/ha/yr LCCL	$101	-61%	-68%	-15%	-62%
		Phosophorus	$/ha/yr LCCL	$207	-17%	-93%	-15%	-62%
		Combined	$/ha/yr LCCL	$270	-61%	-93%	-15%	-62%
Horticulture	Low Impact Horticulture - Orchards & idle fallow		$/ha/yr LCCL	$778	-21%	-1%		
	Medium Impact Horticulture - Arable, citrus, fodder, nuts & viticulture		$/ha/yr LCCL	$778	-21%	-1%		
	High Impact Horticulture - Berryfruit, flowers, stonefruit, kiwifruit, nursery, pipfruit, fruit, vegetables, greenhouses		$/ha/yr LCCL	$1,569	-14%			

LAND RETIREMENT			LCC NZ DOLLARS	CONTAMINANT IMPACT			
Land cover	Intensity	Unit	6% DR	N	P	Sediment	*E. coli*
Pastoral	Less than 10SU/ha	LCC/ha/yr	$435				
	Sheep & beef - More than 10SU/ha	LCC/ha/yr	$524				
	Dairy - More than 10SU/ha	LCC/ha/yr	$731				
Horticulture	Low Impact Horticulture - Orchards & idle fallow	LCC/ha/yr	$1,087				
	Medium Impact Horticulture - Arable, citrus, fodder, nuts & viticulture	LCC/ha/yr	$1,087				
	High Impact Horticulture - Berryfruit, flowers, stonefruit, kiwifruit, nursery, pipfruit, fruit, vegetables, greenhouses	LCC/ha/yr	$1,605				

EDGE OF FIELD MITIGATIONS

Mitigation Type	Rural Landuse Type	Description	Unit	ANNUALISED LCC NZ DOLLARS	TAC PERCENTAGES	CONTAMINANT IMPACT			
				6% DR	6% DR	N	P	Sediment	*E. coli*
Small wetland (<1ha)	Pastoral	Less than 10SU/ha	LCC/m²/yr	$0.47	93%	-10%	-45%	-65%	-55%
	Pastoral	Sheep & beef - More than 10SU/ha	LCC/m²/yr	$0.44	94%	-10%	-45%	-65%	-55%
	Pastoral	Dairy - More than 10SU/ha	LCC/m²/yr	$0.44	93%	-10%	-45%	-65%	-55%
	Horticulture	Low Impact Horticulture - Orchards & idle fallow	LCC/m²/yr	$0.43	91%	-10%	-45%	-65%	-55%
	Horticulture	Medium Impact Horticulture - Arable, citrus, fodder, nuts & viticulture	LCC/m²/yr	$0.43	91%	-10%	-45%	-65%	-55%
	Horticulture	High Impact Horticulture - Berryfruit, flowers, stonefruit, kiwifruit, nursery, pipfruit, fruit, vegetables, greenhouses	LCC/m²/yr	$0.45	86%	-10%	-45%	-65%	-55%
Large wetland (>1 ha)	Pastoral	Less than 10SU/ha	LCC/m²/yr	$0.39	91%	-10%	-45%	-65%	-55%
	Pastoral	Sheep & beef - More than 10SU/ha	LCC/m²/yr	$0.36	92%	-10%	-45%	-65%	-55%
	Pastoral	Dairy - More than 10SU/ha	LCC/m²/yr	$0.35	90%	-10%	-45%	-65%	-55%
	Horticulture	Low Impact Horticulture - Orchards & idle fallow	LCC/m²/yr	$0.34	87%	-10%	-45%	-65%	-55%
	Horticulture	Medium Impact Horticulture - Arable, citrus, fodder, nuts & viticulture	LCC/m²/yr	$0.34	87%	-10%	-45%	-65%	-55%
	Horticulture	High Impact Horticulture - Berryfruit, flowers, stonefruit, kiwifruit, nursery, pipfruit, fruit, vegetables, greenhouses	LCC/m²/yr	$0.37	81%	-10%	-45%	-65%	-55%
Detainment bunds/sediment traps	Pastoral	All	LCC/ha/yr	$7.20	82%	0%	-15%	-80%	-50%
Detainment bunds/sediment traps	Horiticulture	All	LCC/ha/yr	$3.79	81%			-88%	
Space planting of erosion control trees	Pastoral	All	LCC/ha/yr	$28.44	83%	0%	-20%	-70%	0%

EDGE OF FIELD MITIGATIONS - FENCING AND BUFFER STRIPS

Mitigation Type	Rural Landuse Type	Description	Unit	ANNUALISED LCC NZ DOLLARS 6% DR	TAC PERCENTAGES 6% DR	% Annual BUFFER LCC RELATING TO FENCING	% Annual BUFFER LCC RELATING TO FENCING & STOCKWATER RETICULATION	CONTAMINANT IMPACT N	P	Sediment	*E. coli*
Stock exclusion - Fencing (with 1m buffer width/ setback of rank grass and including stock water costs for sheep and beef)	Pastoral	Dairy - More than 10SU/ha Flat & rolling	LCC/m/yr	$0.20	63%						-58%
	Pastoral	Dairy - More than 10SU/ha Steep	LCC/m/yr	$0.29	63%						
	Pastoral	Less than 10SU/ha Flat & rolling	LCC/m/yr	$0.81	75%						-58%
	Pastoral	Less than 10SU/ha Steep	LCC/m/yr	$0.92	72%						
	Pastoral	Sheep & beef - More than 10SU/ha Flat & rolling	LCC/m/yr	$0.57	75%						-58%
	Pastoral	Sheep & beef - More than 10SU/ha Steep	LCC/m/yr	$0.67	73%						
Stock exclusion - Fencing (as above but **no stock water reticulation costs**)	Pastoral	Less than 10SU/ha Flat & rolling	LCC/m/yr	$0.53	75%						-58%
	Pastoral	Less than 10SU/ha Steep	LCC/m/yr	$0.64	67%						
	Pastoral	Sheep & beef - More than 10SU/ha Flat & rolling	LCC/m/yr	$0.29	68%						-58%
	Pastoral	Sheep & beef - More than 10SU/ha Steep	LCC/m/yr	$0.39	66%						

EDGE OF FIELD MITIGATIONS - FENCING AND BUFFER STRIPS				ANNUALISED LCC NZ DOLLARS	TAC PERCENTAGES	% Annual BUFFER LCC RELATING TO FENCING	% Annual BUFFER LCC RELATING TO FENCING & STOCKWATER RETICULATION	CONTAMINANT IMPACT			
Mitigation Type	Rural Landuse Type	Description	Unit	6% DR	6% DR			N	P	Sediment	*E. coli*
Grass Buffer Strip (fencing for pastoral land and 5m rank grass strip; stock water for sheep and beef)	Pastoral	Dairy - More than 10SU/ha Flat & rolling	LCC/m/yr	$0.35	38%	58%	N/A	-15%	-10%	-70%	-60%
	Pastoral	Dairy - More than 10SU/ha Steep	LCC/m/yr	$0.44	43%	66%	N/A				
	Pastoral	Less than 10SU/ha Flat & rolling	LCC/m/yr	$0.90	68%	59%	90%	-5%	-5%	-70%	-60%
	Pastoral	Less than 10SU/ha Steep	LCC/m/yr	$1.01	66%	63%	91%				
	Pastoral	Sheep & beef - More than 10SU/ha Flat & rolling	LCC/m/yr	$0.68	64%	43%	84%	-15%	-10%	-70%	-60%
	Pastoral	Sheep & beef - More than 10SU/ha Steep	LCC/m/yr	$0.77	63%	50%	86%				
	Horticulture	Low Impact Horticulture - Orchards & idle fallow	LCC/m/yr	$0.28	N/A	N/A	N/A			-40%	
	Horticulture	Medium Impact Horticulture - Arable, citrus, fodder, nuts & viticulture	LCC/m/yr	$0.28	N/A	N/A	N/A			-40%	
	Horticulture	High Impact Horticulture - Berryfruit, flowers, stonefruit, kiwifruit, nursery, pipfruit, fruit, vegetables, greenhouses	LCC/m/yr	$0.41	N/A	N/A	N/A			-40%	

EDGE OF FIELD MITIGATIONS - FENCING AND BUFFER STRIPS				ANNUALISED LCC NZ DOLLARS
Mitigation Type	**Rural Landuse Type**	**Description**	**Unit**	**6% DR**
Grass Buffer Strip (**No fencing** for pastoral land; 5m rank grass strip)	Pastoral	Dairy - More than 10SU/ha Flat & rolling	LCC/m/yr	$0.15
	Pastoral	Dairy - More than 10SU/ha Steep	LCC/m/yr	$0.15
	Pastoral	Less than 10SU/ha Flat & rolling	LCC/m/yr	$0.37
	Pastoral	Less than 10SU/ha Steep	LCC/m/yr	$0.37
	Pastoral	Sheep & beef - More than 10SU/ha Flat & rolling	LCC/m/yr	$0.39
	Pastoral	Sheep & beef - More than 10SU/ha Steep	LCC/m/yr	$0.39
Planted Buffer Strip (**No fencing** for pastoral land; 5m riparian planted strip)	Pastoral	Dairy - More than 10SU/ha Flat & rolling	LCC/m/yr	$1.20
	Pastoral	Dairy - More than 10SU/ha Steep	LCC/m/yr	$1.20
	Pastoral	Less than 10SU/ha (sheep & beef): Flat & rolling	LCC/m/yr	$1.42
	Pastoral	Less than 10SU/ha (sheep & beef): Steep	LCC/m/yr	$1.42
	Pastoral	More than 10SU/ha (sheep & beef): Flat & rolling	LCC/m/yr	$1.44
	Pastoral	More than 10SU/ha (sheep & beef): Steep	LCC/m/yr	$1.44
Grass Buffer Strip (**No fencing or stock water reticulation** for pastoral land; 5m rank grass strip)	Pastoral	Less than 10SU/ha Flat & rolling	LCC/m/yr	$0.09
	Pastoral	Less than 10SU/ha Steep	LCC/m/yr	$0.09
	Pastoral	Sheep & beef - More than 10SU/ha Flat & rolling	LCC/m/yr	$0.11
	Pastoral	Sheep & beef - More than 10SU/ha Steep	LCC/m/yr	$0.11
Planted Buffer Strip (**No fencing or stock water reticulation** for pastoral land; 5m riparian planted strip)	Pastoral	Less than 10SU/ha Flat & rolling	LCC/m/yr	$1.14
	Pastoral	Less than 10SU/ha Steep	LCC/m/yr	$1.14
	Pastoral	Sheep & beef - More than 10SU/ha Flat & rolling	LCC/m/yr	$1.16
	Pastoral	Sheep & beef - More than 10SU/ha Steep	LCC/m/yr	$1.16

EDGE OF FIELD MITIGATIONS - BUFFER STRIPS				ANNUALISED LCC NZ DOLLARS	TAC PERCENTAGES
Mitigation Type	**Rural Landuse Type**	**Description**	**Unit**	**6% DR**	**6% DR**
Grass Buffer Strip (planting, plant maintenance and opportunity costs only) - based on 5m2 buffer strip	Pastoral	Dairy - More than 10SU/ha	LCC/m^2/yr	$0.04	3%
	Pastoral	Less than 10SU/ha	LCC/m^2/yr	$0.02	2%
	Pastoral	Sheep & beef - More than 10SU/ha	LCC/m^2/yr	$0.03	2%
	Horticulture	Low Impact Horticulture - Orchards & idle fallow	LCC/m^2/yr	$0.06	6%
	Horticulture	Medium Impact Horticulture - Arable, citrus, fodder, nuts & viticulture	LCC/m^2/yr	$0.06	6%
	Horticulture	High Impact Horticulture - Berryfruit, flowers, stonefruit, kiwifruit, nursery, pipfruit, fruit, vegetables, greenhouses	LCC/m^2/yr	$0.08	6%
Planted Buffer Strip (planting, plant maintenance and opportunity costs only) - based on 5m2 buffer strip	Pastoral	Dairy - More than 10SU/ha	LCC/m^2/yr	$0.25	53%
	Pastoral	Less than 10SU/ha	LCC/m^2/yr	$0.23	56%
	Pastoral	Sheep & beef - More than 10SU/ha	LCC/m^2/yr	$0.24	55%
	Horticulture	Low Impact Horticulture - Orchards & idle fallow	LCC/m^2/yr	$0.26	50%
	Horticulture	Medium Impact Horticulture - Arable, citrus, fodder, nuts & viticulture	LCC/m^2/yr	$0.26	50%
	Horticulture	High Impact Horticulture - Berryfruit, flowers, stonefruit, kiwifruit, nursery, pipfruit, fruit, vegetables, greenhouses	LCC/m^2/yr	$0.29	46%

Find out more: fwmt@aucklandcouncil.govt.nz

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Te Kaunihera o Tāmaki Makaurau