Ministry for the Environment

Essential Freshwater Regulations – Industry Impact Analysis

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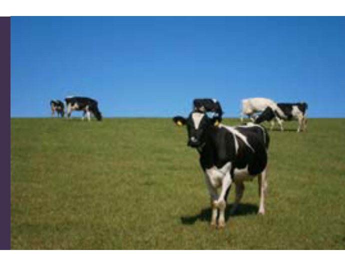


Acknowledgement

We would like to acknowledge the guidance and input from the multi-agency governance group that was convened by the Ministry for the Environment to oversee the preparation of the analysis contained in this report.

John Ballingall of Sense Partners, Adolf Stroombergen of Infometrics and Megan Star of Star Economics also peer-reviewed this report for the Ministry for the Environment. Their feedback on earlier drafts has been incorporated into the final version.

Contents

Executive Summary

The purpose of this report was to estimate the potential industry impact of the proposed Essential Freshwater Regulations (the Regulations) on a regional basis across New Zealand. The analysis undertaken for this report considered the direct agricultural industry impacts of the Regulations, the wider economic impacts are separately considered in other analysis commissioned by the Ministry for the Environment (MfE) as part of the wider work being undertaken in relation to the Regulations.[1]

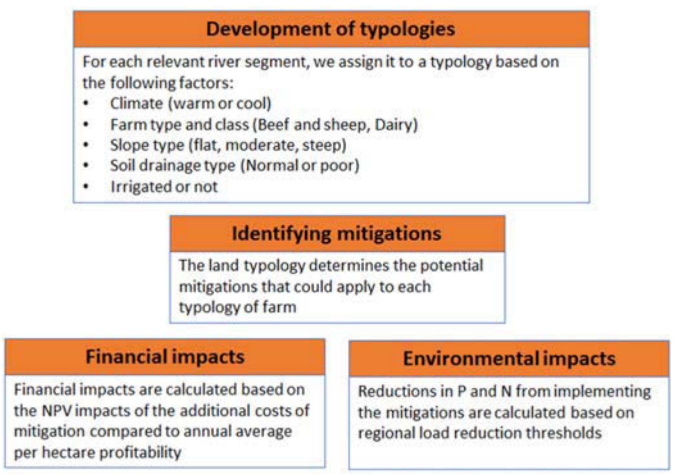
The approach adopted for assessing the industry impact was to estimate the cost of a range of identified mitigation options for reducing nitrogen and phosphate loads in waterways as required by the 2017 National Policy Statement for freshwater management (NPSFM 2017) and the 2020 Essential Freshwater package.

This report covers the Dairy and Beef and Sheep sectors which are the parts of the agriculture sector most impacted by the Regulations and also for which there was available data and information to estimate the potential industry impact.

Analytical framework

The analytical framework developed for the preparation of this report is illustrated in Figure E.1 below.

Figure E.1 Framework for estimating the industry impact



Methodology

Based on the framework above, the methodology for estimating the industry impact (as detailed in Chapter 2) incorporated the following steps:

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[1] Ministry for the Environment (2020), *Overview of the impact analysis undertaken to inform decisions on freshwater policy, with a focus on monetised costs*

- *Spatially allocate farms by sector* – based on spatial data and information from Agribase®, spatial allocation of individual farms by sector (Dairy and Beef and sheep) nationally across each of the 16 regional council areas in New Zealand
- *Assign farm areas to river catchments* – based on the River Environment Classification v2.0 (REC2), assignment of all farmland to its respective river catchment area
- *Assign physical properties* – assignment of the physical attributes of farmland within each catchment area (i.e., climate slope type, soil drainage type, irrigation and elevation)
- *Assignment to typologies* – based on their combination of physical attributes, farmland was then assigned to a typology based on its sector (Dairy typologies and Beef and sheep typologies). This allocation allowed for variability that exists across different farms including profitability and effectiveness of different mitigations
- *Assignment of profitability* – average profitability was then assigned to farmland: for dairy farms, profitability was based on its location; for beef and sheep farms, profitability was based on typology/farm class across regions
- *Calculation of total cost of mitigations and load reduction impacts* – based on the total areas assigned to each typology in each region, calculation of the potential load reduction impacts of each mitigation on Nitrogen (N) and Phosphorus (P) loads, and then consider the total cost of implementation of each mitigation
- *Development of lowest cost mitigation bundles* – based on the combination of average per hectare profitability, mitigation cost and efficiency of mitigations, the development of a set of mitigation bundles for each region that allows it to realise its load reduction targets (if possible) at the lowest cost (as outlined in section 4.3 of this report).
- *Development of scenarios* – four scenarios were agreed with MfE to test the sensitivity of mitigation and cost outcome impacts of particular mitigations, with lowest cost mitigation bundles developed for each scenario for N and P.

Modelling results

Based on applying all available mitigations in sequence starting with the most cost-effective, this indicates the potential to achieve 78.7% of the N load reduction target and 86.3% of the P load reduction target, at a total cost of $8.02B. Under this setting, most regions are able to realise their targets, both under the NPS (2017) and EFW (2020) policies. The exceptions tend to be regions with very large targets such as Canterbury in the case of N and Manawatu-Whanganui in the case of P.

Under the baseline scenario, the majority of N reductions are realised from the Dairy sector, which realises 69% of the reduction at an NPV cost of $6.2B, while the Beef and Sheep sector realises 31% of the reduction at an NPV cost of $817M. This is in part due to the fact that the majority of N load reductions can be realised by applying mitigations to the Dairy sector without a need to apply mitigations to the Beef and Sheep sector. Conversely, additional mitigations to reduce P following these mitigations generally occur through the Beef and Sheep sector, where mitigations tend to be more effective at reducing loads without a significant increase in price.

It is important to note that our analysis has been undertaken using regional averages. As such, variations in profitability and cost across farms by their type, sectors and regions are not specifically captured in the model developed for this report, beyond those used to classify Beef and Sheep farms. It is likely in practice, that the most appropriate set of mitigations will vary on a farm-by-farm basis, and it is also possible that individual farms may have already applied particular mitigations or have specific characteristics that yield higher reductions than what has been applied in our analysis. As such, the findings of this report provide an indication of where potential load reductions across sector and region could be realised, as well as highlighting how the potential costs may be distributed.

Results tables

Nitrogen reduction

Most regions realise their load reduction targets for N using the available suite of mitigations, and most are able to do so at a relatively low cost with the exceptions of Hawkes Bay, Canterbury and Southland. In addition, Canterbury, which also has the largest load reduction target, is unable to realise the required reductions despite the use of all mitigations.

Table E.1 Regional load reduction and cost impacts of applying lowest cost mitigation bundle for N[2]

Region	N target under NPS 2020 (t)	Total reduction achieved (t)	% of target load reduction achieved (%)	% reduction in average dairy farm profit from mitigation costs	% reduction in average beef and sheep farm profit from mitigation costs
Northland	124.0	124.0	100.0%	0.4%	0.0%
Auckland	168.8	168.8	100.0%	0.0%	0.3%
Waikato	3,808.5	3,808.5	100.0%	2.4%	0.4%
Bay of Plenty	299.6	299.6	100.0%	0.5%	0.0%
Gisborne	9.2	9.2	100.0%	2.2%	0.0%
Taranaki	1,696.5	1,696.5	100.0%	0.8%	1.3%
Manawatu-Whanganui	1,147.2	1,147.2	100.0%	2.4%	2.8%
Hawke's Bay	1,007.6	1,007.6	100.0%	51.1%	2.8%
Wellington	171.6	171.6	100.0%	1.1%	0.0%
Tasman	9.1	9.1	100.0%	0.1%	0.0%
Nelson	0.3	0.3	100.0%	0.0%	0.0%
Marlborough	14.7	14.7	100.0%	0.2%	0.0%
West Coast	21.9	21.9	100.0%	0.0%	0.1%
Canterbury	10,689.7	5,550.8	51.9%	38.4%	14.9%
Otago	680.4	680.4	100.0%	0.7%	6.5%
Southland	4,281.6	4,281.6	100.0%	40.0%	9.0%
TOTAL	24,130.6	18,991.7	78.7%	-	-

[2] Note that profit and cost estimates in results tables represent NPV values over 30 years

Phosphorus reduction

While the majority of regions are able to realise their P reduction targets, the distribution of different farms types means that Manawatu-Whanganui is unable to realise its load reduction targets, due to a relatively smaller proportion of farms where mitigations targeting P can be applied.

Table E.2 Load reduction impacts of applying lowest cost mitigation bundle for P

Region	P target under NPS 2020 (t)	Total achieved reduction in P (t)	% reduction in total P target
Northland	162.0	162.0	100.0%
Auckland	36.4	36.4	100.0%
Waikato	374.5	374.5	100.0%
Bay of Plenty	148.5	148.5	100.0%
Gisborne	20.2	20.2	100.0%
Taranaki	48.2	48.2	100.0%
Manawatu-Whanganui	333.1	139.3	41.8%
Hawke's Bay	114.0	114.0	100.0%
Wellington	36.4	36.4	100.0%
Tasman	5.0	5.0	100.0%
Nelson	0.4	0.4	100.0%
Marlborough	15.0	15.0	100.0%
West Coast	0.1	0.1	100.0%
Canterbury	23.2	23.2	100.0%
Otago	49.7	49.7	100.0%
Southland	50.3	50.3	100.0%
TOTAL	1416.8	1,223.0	86.3%

1. Introduction

1.1 Purpose

Sapere was engaged by the MfE to assist with the preparation of an estimate of the potential industry impact of the proposed Essential Freshwater Regulations (the Regulations).

This report considers the direct agricultural industry impact of the Regulations. The wider economic impacts are separately considered in other analysis commissioned by MfE as part of the wider work being undertaken in relation to the Regulations.[3]

1.2 Approach

The approach adopted for assessing the industry impact was to estimate the financial cost of a range of identified mitigation options for reducing nitrogen and phosphate loads in waterways as required by the 2017 National Policy Statement for freshwater management (NPSFM 2017) and the Essential Freshwater package.

This report covers the Dairy and Beef and Sheep sectors which are the parts of the agriculture sector most impacted by the Regulations and also for which there was available data and information to estimate the potential industry impact. This report analyses these potential impacts over a 30-year period, from 2021 to 2050.

1.3 Structure of report

The structure of this report is the following:

- Section 2 outlines the methodology that was developed and applied for modelling the industry impact
- Section 3 describes the mitigations identified and how these were applied to each farming typology
- Section 4 presents the findings from load impact analysis and the cost modelling on a regional basis across New Zealand
- Section 5 outlines the limitations of the analysis of the report
- Section 6 outlines the conclusion from the analysis
- Attachment 1 details the key assumptions applied to the mitigation cost modelling
- Attachment 2 provides the distribution of farms by typology for each of the 16 regions across New Zealand

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[3] Ministry for the Environment (2020), *Overview of the impact analysis undertaken to inform decisions on freshwater policy, with a focus on monetised costs*

- Attachment 3 details the mitigations applied for the cost modelling
- Attachment 4 provides a bibliography and list of references.

2. Methodology

2.1 Information sources

The key information sources that underpin the cost modelling in this report are detailed in Table 2.1 below.

Table 2.1 Information sources and modelling assumptions

Information	Source
Location, type and area of farmland across NZ	Spatial data and information sourced from AgriBase®
River catchments	River Environment Classification v2.0 published by NIWA
Farm typologies	Provided by MfE
Nitrogen (N) & Phosphorus (P) loads by catchment	Provided by MfE from NIWA estimates of the average yields of kilograms of N and P per hectare in each catchment
Farm profitability	Dairy sector – *Dairy NZ Economic Survey* (2010-11 through to 2017-18) Beef and sheep sector – *Beef and Sheep NZ Financial Indicators* (2010-11 through to 2017-18)
Mitigation options	Provided by MfE based on: expert input from Professor Richard McDowell, Perrin Ag and published research
Mitigation costs	Provided by MfE based on: expert input from Professor Richard McDowell, Perrin Ag and published research
Mitigation effectiveness & efficiency	Provided by MfE based on expert input from Professor Richard McDowell, Perrin Ag and published research
Mitigation bundles	Provided by MfE based on expert input from Professor Richard McDowell, Perrin Ag and published research

The key steps in the methodology adopted for the preparation of this analysis are outlined below.

2.2 Spatially allocate farms by sector

Our first step was to spatially allocate the farmland by sector across each of the regional councils in New Zealand. The underlying data source for this was based on the use of the Agribase dataset, which provided highly granular allocations of farms by sector. For the purposes of this project, we focused on two sectors:

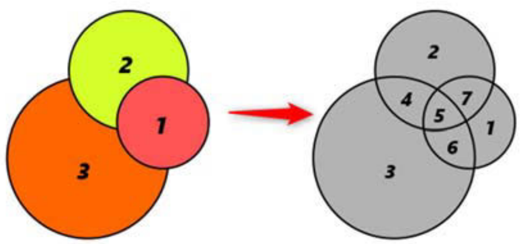
- **Dairy:** The Dairy sector included all farms in Agribase classified as either dairy sector farms (code DAI in Agribase) and dairy dry stock (DRY)
- **Beef and sheep sector:** The Beef and sheep sector included all farms in Agribase classified as either sheep farms (SHP), beef farms (BEF), sheep and beef farms (SNB) or grazing farms (GRA).

Using the QGIS software suite, maps were developed for each of these two sectors based on the data from Agribase.

2.3 Assign farm areas to river catchments

Following the allocation of farms by sector, we had to assign all farmland to their respective river catchment areas based on the River Environment Classification v 2.0 (REC2), which identifies 12,211 river catchments across New Zealand. Maps for each farmland sector and the river catchments were overlaid over each other using a *union* join, wherein the attributes of both maps, including boundaries of shapes, are retained. This is illustrated in Figure 2.1 below.

Figure 2.1 How a union join works



Objects 1, 2 and 3 on the left are all overlaid on top of each other under a union join. This produces 7 separate objects which retain all the attributes of their originating maps – for example, Object 7 will possess the attributes of both Object 1 and 2, while Object 4 possesses the attributes of Object 2 and 3. Object 5 will contain the attributes of all three of Objects 1, 2 and 3.

This results in a map where new objects are produced from the farmland map in situations where farms cross over multiple catchment areas. In such cases, the farm object is broken up into a number of smaller separate objects (called "fragments" henceforth), which represent the smallest unit used in the construction of the analysis.

2.4 Assign physical properties to each fragment

Upon the development of fragments which contain both farm sectoral information and river catchment information, we overlay a number of maps with the fragments to assign physical attributes to each fragment.[4] These included the following physical attributes and maps:

- **Climate (warm or cool)** – Fragments were classified as either warm or cool based on their climate classification from the REC2 river map

[4] In the case of the physical assignment, these were not overlaid using a union join, in the interest of efficiency of process. It is possible that the use of union joins with each of the physical attribute maps could result in some slightly different assignments for individual fragments, however given the size of the fragments relative to attribute objects, we consider it likely that the difference in result would be marginal and would not significantly impact the final results.

- **Slope type (flat, moderate or steep) –** Fragments were classified as either flat, moderate or steep based on the average slope across the fragment based on the 2012 NZ 8m Digital Elevation Model (DEM). The classification under this attribute was as follows:
    - Flat: An average slope of 7 degrees or flatter
    - Moderate: An average slope between 7 – 15 degrees
    - Steep: An average slope greater than 15 degrees
- **Soil drainage type (normal or poor) –** Fragments were classified as having either normal or poor drainage based on the New Zealand Fundamental Soil Layer Soil Drainage Class from the Land Resource Information System (LRIS). The classification under this attribute was as follows:
    - Normal: Soil Drainage Class of 4 or 5
    - Poor: Soil Drainage Class of 1, 2 or 3
- **Irrigation (irrigated or non-irrigated)** – Fragments were classified as either being on irrigated or non-irrigated land based on the Irrigated Land Area (2017) map from MfE
- **Elevation (high country or non-high country)** – Fragments were classified as high country if their elevation was 600m above sea level or higher, based on the DEM.

These attributes were used to then assign each fragment into one of the 15 defined typologies - eight Dairy typologies and seven Beef and Sheep typologies.

2.5 Assign fragments to typologies

Based on their combination of physical attributes, each fragment was assigned to a typology based on its sector. In the case of the dairy sector, farms were assigned based on their climate, slope, drainage and irrigation (see Table 2.2 below).

Table 2.2 Dairy typologies

Attributes	Typology ID
Warm-Flat-Poor	D1
Warm-Flat-Normal	D2
Warm-Moderate-Poor	D3
Warm-Moderate-Normal	D4
Cool-Flat-Poor	D5
Cool-Flat-Normal-Non-irrigated	D6
Cool-Flat-Normal-Irrigated	D7
Cool-Moderate	D8

In the case of the beef and sheep sector, farms typologies were designed to align as closely as possible with the farm classes used by Beef and Lamb NZ.[5] Assumptions were made to assign beef and sheep farms based on their physical attributes and their geographic location, combined with

[5] https://beeflambnz.com/data-tools/farm-classes

knowledge about the distribution of farm classes across the regions. These assumptions were as follows:

- All farms with an elevation above 600m were classified as 'High Country'
- All farms with 'moderate' slope were classified as Hill'
- All farms with 'steep' slope were classified as 'Hard Hill'
- All farms with a 'flat' slope were classified as 'Intensive Finishing' in the North Island and 'Mixed Finishing' in the South Island – the exception to this is 'flat' land in the Southland Region, which were all classified as 'Intensive Finishing' due to the prevalence of this type of farming in the region

Table 2.3 Beef and sheep typologies

Attributes	Typology ID
Hill, South Island	SB1
High Country, South Island	SB2
Hard Hill, North Island	SB3
Hill, North Island	SB4
Intensive Finishing, North Island	SB5
Intensive Finishing, South Island	SB6
Mixed Finishing, South Island	SB7

While this represents a simplification of the actual distribution of farms across region, this system of allocation allows us to capture some of the variability that exists across difference farm classes across sectors, including in profitability and effectiveness of different mitigations.

Once all fragments have been assigned to typologies, analysis can be undertaken to calculate the total area covered by each typology in each region. This forms the basis by which mitigation costs and load reduction impacts can be calculated.

2.6 Assign profitability to fragments

Average profitability values, based on farm profit before tax, are also assigned to each fragment based on its location in the case of dairy farms, and based on typology/farm class in the case of beef and sheep farms. This is based on two sources of information:

Dairy – We derive farm profit before tax through two figures provided in the Dairy NZ Economic Survey for the period 2010-11 to 2017-18.

1. We take the Operating Profit per hectare for Owner-Operators and 50:50 Sharemilkers from Dairy NZ Economic Survey 2010-11 to 2017-18.
2. We then calculate derived estimate of the average value of interest and rent based on the % of Gross Farm Revenue (which is a whole of industry figure) that accounts for interest and rent reported by Dairy NZ in the 2017-18 report. This figure is applied to the estimate of average gross farm revenue per hectare for each region for each year, with the result subtracted from the Operating Profit per hectare estimate.

This produces a derived estimate of farm profit before tax for each period.

- Covers 8 regions of Northland, Waikato, Bay of Plenty, Taranaki, Lower North Island, West Coast-Tasman, Marlborough-Canterbury, Otago-Southland (which are formed from aggregations of all regional councils) but data may be inconsistent across years.

Beef and Sheep – Farm Profit Before Tax per hectare is reported and taken from the Beef and Lamb NZ Financial Indicators from 2010-11 to 2017-18

- Covers 5 regions of Northland-Waikato-Bay of Plenty, Gisborne-Hawkes Bay-Wairarapa, Taranaki-Manawatu, Marlborough-Nelson-Canterbury and Otago-Southland
- Also covers 5 classes of Hard Hill, Hill, Intensive Finishing, Finishing Breeding and Mixed Finishing.

2.7 Calculate total load reduction impacts

Based on the total areas assigned to each typology in each region, we calculate the potential load reduction impacts of each mitigation on Nitrogen (N) and Phosphorus (P) loads and the total aggregate load reduction that can be realised in each region.

The total load reduction impact is based on estimates of the efficiency of mitigations on reduction of N and P loads, based on estimates provided by Perrin Ag based on work from Professor Richard McDowell and a review of the existing literature on the effectiveness of these measures.[6] These are calculated on a catchment level. These efficiency ratios are applied to each mitigation in each region, based on reported average yields of kilograms of N and P per hectare in each catchment from NIWA.

In calculating the load reduction impacts, we consider a situation where farms in a catchment will at most only mitigate to the extent that their catchment load reduction target is reached and no further. We calculate the total load reduction that arises in each catchment from the implementation of each mitigation individually under this system. Note that while they are important in understanding how the mitigations would work in practice, we do not incorporate any temporal element to the load reductions – we are only concerned with whether or not the load targets can be realised using the set of mitigations over the 30 year period.

2.8 Develop cost estimates for mitigations

The total cost of each mitigation is calculated based on the total area where the mitigation would apply in a region combined with the unit cost of applying that mitigation to a given catchment and sector, based on costings provided by Perrin Ag.[7] These costs are calculated and reported on a per hectare basis to allow for comparison with the profitability estimates.

In the case of financial costings, it is assumed all capital costs are borne in the first period (assumed to be 2020-21) based on the total applicable area of land and ongoing costs are then assumed to

[6] Perrin Ag (2020)
[7] Ibid

continue on an ongoing basis for 30 years (to 2050). In the case of some mitigations, such as switching to low water-soluble P fertiliser, a transition period is also incorporated over a number of years. We acknowledge that this will likely have an effect of underweighting the effect of mitigations which are able to act more quickly.

The NPV of this costing model is then calculated for each mitigation in each region at a discount rate of 3%. The NZ Treasury currently recommends use of a 6% default rate.[8] However, for sensitivity analysis they have used a 3% rate in their CBAx tool, which is a spreadsheet model that contains a database of values to help agencies measure impacts and undertake CBAs.[9] At the request of MfE and agreed upon by the steering committee, we have calculated the initial baseline estimates of the model under the 3% discount rate.

The NPV of the average profitability of farms based on their class applied over 30 years is also calculated at a discount rate of 3% for development of the lowest cost mitigation bundles in the next step.

Details of the mitigations included are provided in Chapter 3 and the assumptions in modelling total costs are provided in Attachment 1.

2.9 Develop estimates of cost-effectiveness of each mitigation across sectors

Following the calculation of per hectare mitigation costs, we then derive an estimate of the kg of load reduced in N and P per $ spent to determine the order in which mitigations should be applied so as to achieve the largest load reduction at the smallest cost.

This involves calculating the total cost of applying each mitigation across a specific farm typology in a region divided by the total achievable load reductions in N and P achieved by that mitigation for that given farm typology and region.

These cost-effectiveness metrics are summarised in Tables 2.4 and 2.5 below. Note that cost-effectiveness at a regional level is heavily impacted by the farm typology profile of each region, as mitigation effectiveness will be significantly higher for particular farm types, and completely ineffective for some other farm types. This variation in effectiveness can be seen in Chapter 3.

Table 2.4 Cost-effectiveness of mitigations applied to the dairy sector

	Mitigations targeting N			Mitigations targeting P			
Kg/$ '000	ENM1	ENM2	ENM3	Fencing (incl. VBS)	Optimal Olsen P	Low water-soluble P fertiliser	Wetlands
Northland	20.06	8.65	1.21	1.74	0.24	0.66	0.001
Auckland	33.79	16.33	1.78	0.00	0.38	1.07	0.002

[8] NZ Treasury (2019)
[9] ibid

Waikato	22.39	7.38	1.00	1.09	11.10	0.18	0.001
Bay of Plenty	44.15	16.89	1.84	1.59	0.15	0.39	0.001
Gisborne	36.12	19.14	1.57	1.10	0.05	0.53	0.002
Taranaki	70.91	31.58	2.78	0.00	0.03	0.32	0.001
Manawatu-Wanganui	21.47	5.02	0.96	7.59	0.02	0.16	0.000
Hawke's Bay	29.96	8.56	1.13	0.00	0.02	0.25	0.001
Wellington	31.46	7.20	1.42	0.00	0.06	0.25	0.000
Tasman	95.76	16.01	3.55	0.00	0.10	0.68	0.004
Nelson	0.00	0.00	0.00	0.00	0.00	0.00	0.000
Marlborough	55.12	10.07	1.86	0.00	0.23	1.62	0.005
West Coast	74.15	8.11	2.52	1.59	0.13	0.89	0.002
Canterbury	29.21	2.18	0.86	0.00	0.00	0.04	0.000
Otago	22.60	1.43	0.73	1.02	0.00	0.08	0.000
Southland	22.16	1.46	0.74	0.00	0.00	0.09	0.000

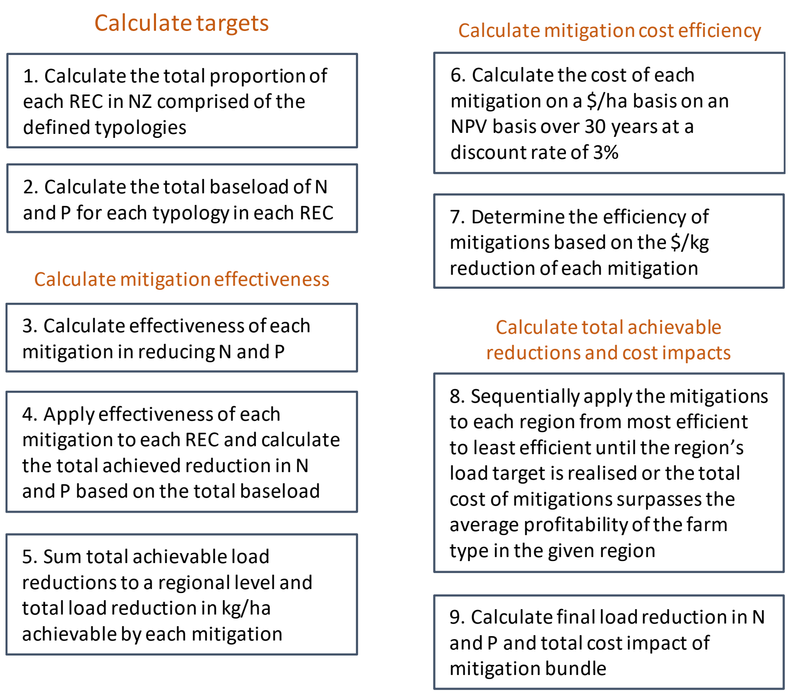
Table 2.5 Cost-effectiveness of mitigations applied to the beef and sheep sector

	Mitigations targeting N			Mitigations targeting P			
Kg/$ '000	ENM1	ENM2	ENM3	Fencing (incl. VBS)	Optimal Olsen P	Low water-soluble P fertiliser	Wetlands
Northland	264.9	351.5	221.4	98.89	2.86	6.68	0.036
Auckland	399.5	545.2	333.9	0.00	4.34	9.34	0.049
Waikato	115.6	102.5	96.6	15.45	0.44	0.83	0.007
Bay of Plenty	190.4	203.5	159.1	57.69	1.47	1.98	0.014
Gisborne	160.3	137.5	134.0	52.13	1.09	0.77	0.034
Taranaki	231.3	311.9	193.3	0.00	0.55	0.78	0.013
Manawatu-Wanganui	5.2	6.6	4.4	1.60	0.02	0.02	0.000
Hawke's Bay	14.8	14.0	12.3	0.00	0.46	0.19	0.002
Wellington	45.3	42.0	37.9	0.00	0.99	0.73	0.008
Tasman	220.4	173.6	184.3	0.00	1.46	8.98	0.019
Nelson	2,112.7	1,649.1	1,766.1	0.00	3.63	11.02	0.212
Marlborough	40.7	32.0	34.0	0.00	0.09	1.49	0.004
West Coast	156.7	123.8	131.0	77.16	1.19	6.54	0.006
Canterbury	4.3	3.4	3.6	0.00	0.01	0.03	0.000
Otago	3.0	2.4	2.5	0.88	0.00	0.04	0.000
Southland	6.4	12.8	5.4	0.00	0.00	0.16	0.000

2.10 Develop lowest cost mitigation bundles

Based on the combination of average per hectare profitability and mitigation cost-efficiency, we develop a set of mitigation bundles for each region that allows it to realise its load reduction targets (if possible) at the lowest cost. For the purpose of the bundle construction, N load reduction is prioritised, and as such, mitigations are applied first to realise the N load reduction target before applying the same process for P load reduction targets.

Figure 1.2 Key steps in calculating total load reductions and cost impacts



In order to construct the bundles, mitigations are applied sequentially following a set of rules:

1. The most cost-effective mitigation is applied first, and the total N load reduction impact from this mitigation is realised
2. If the N load reduction target is not achieved, then the next most cost-effective mitigation is applied
3. If at any point the target is reached, the last used mitigation is only applied to the minimum required proportion of farmland (the exception to this is Achieving Optimal Olsen P in regions where there would be cost savings from applying the mitigation to all areas)
4. Once the N load reduction target is reached, the total P load reduction impact of the already applied mitigations are calculated, and then if necessary, the lowest cost remaining mitigation is applied and the sequence is repeated

5. Mitigations are applied until, at any point, costs of the mitigation bundle equal average per hectare profitability.[10]

Note that standalone mitigations to N such as fencing and constructed wetlands are all contained in the Enhanced Nitrogen Management (ENM) bundles – as such, these standalone mitigations are not included to ensure there is no double counting of mitigation application.

[10] In practice, it is likely that farmers would require some form of profit margin to justify continuing their present operations but we have not incorporated that into the modelling, as no indication is given as to what that average profit margin would be

3. Mitigations

The mitigation options applied for the cost modelling undertaken for this report are outlined below along with the estimates of cost and effectiveness in achieving load reductions in N and P. These are based on an estimate of costs provided by Perrin Ag (2020).

Note that the costs associated with each mitigation do not include any transaction costs associated with the implementation of each mitigation. Additional ongoing costs, such as compliance and reporting costs are also not costed, as it is not clear at this juncture the form of the regulations will take and the requirements this will create. However, in a more detailed analysis, consideration would need to be given for the form of the regulation and the subsequent compliance costs industry would incur.

3.1 Enhanced Nitrogen Management (ENM)

ENM involves matching nitrogen-related on-farm practices to the characteristics of the soil and climate to minimise nitrogen loads entering waterways, while limiting impact on farm production. This practice could include the implementation of a range of mitigations, such as the following:

- Replacing (or removing altogether) high-nitrogen supplementary feeds (for example, palm oil extract)
- Replacing (or removing altogether) nitrogen fertiliser
- Reducing (or removing altogether) the practice of foraging on winter crops (for example, oats)
- Altering the type of crops that are planted (for example, greater use of mixed pasture swards)
- Targeting fertiliser applications to particular parts of the farm (dictated by soil conditions) or times of the year
- Targeted (variable rate) irrigation
- Reduced stock numbers
- Plant growth regulators (giberellic acid)
- Nitrogen inhibitors.

ENM bundles represent combinations of these mitigations tailored to the specific farm soil and climate circumstances. Ultimately, an ENM bundle will not necessarily include all of these practices, but rather include a mix that achieves a similar reduction in contaminants for a given annualised cost per ha.

To develop estimates for the ENM bundles, effectiveness assumptions were provided to the study team and MfE by AgResearch including assumed effectiveness rates for individual mitigation actions and for 'bundles' of actions.[11] Costs were supplied for a selection of individual measures by Perrin Ag Consultants. These cost estimates provided an initial dataset for model construction.

However, because they were limited in scope and number, an alternative source was used for the costs of bundles of measures, as is common in other studies. The AgResearch effectiveness numbers for specific land typologies were combined with cost and effectiveness estimates by Landcare

[11] Richard McDowell (personal communication); McDowall *et al* (in prep)

Research, Motu and NIWA.[12] Using these sources, MfE constructed assumptions for mitigation bundles, labelled M1, M2 and M3 (which can include some of the stand-alone mitigations in this section). The components of these bundles may vary but some of the potential mitigations to be included are summarised in Table 3.1 below.

Table 3.1 Mitigations included in ENM bundles

Bundle 1 (M1)	Bundle 2 (M2)	Bundle 3 (M3)
- Soil moisture monitoring and Variable Rate Irrigation (VRI) - Adjust cropping fertiliser rates - Stock exclusion/fencing - Limit each urea application - Variable Rate Fertiliser - Gibberellic acid instead of autumn/spring fertiliser - Apply nitrate inhibitors - Optimise stocking rates - Implement best practice for maintenance and infrastructure - Laneway runoff diversion - Effluent management	- Variable Rate Irrigation (VRI) - Variable rate application liquid urea - Wetlands and/or sediment traps - Tile drain amendments - Reduce nitrogen fertiliser - Enhance animal productivity via genetic selection - Dairy farms to install covered feed pads and effluent systems	- Further reduce nitrogen fertiliser - All cows wintered off paddock - Reduce stocking rates - Restricted grazing of pasture and cropland - Apply alum to pasture and crops - Increase effluent area - No winter feed crop yields

Unlike the other mitigations described further, the ENM mitigations have a sequential ordering that requires bundles to be applied in a particular order, with M1 a prerequisite for M2 and M2 a prerequisite for M3.

Cost estimates

Note that these ongoing costs do not include the opportunity cost of any land converted from productive use into land for mitigation purposes or any profits that would arise from alternative land use.

$/ha, annual	M1	M2	M3
Ongoing costs - Dairy	11	35	687
Ongoing costs – Beef and sheep	20	7	19

Source: MfE estimates

[12] Daigneault *et al* (2016)

Effectiveness estimates (% reduction in N loads)

Typology	M1	M2	M3
DAIRY			
D1	6%	8%	27%
D2	11%	-	27%
D3	5%	7%	22%
D4	9%	13%	22%
D5	17%	5%	38%
D6	12%	-	24%
D7	22%	-	37%
D8	13%	3%	28%
BEEF AND SHEEP			
SB1	19%	5%	15%
SB2	19%	2%	15%
SB3	19%	2%	15%
SB4	19%	4%	15%
SB5	19%	10%	15%
SB6	19%	19%	15%
SB7	19%	5%	15%

Source: MfE estimates

3.2 Fencing and riparian exclusions

Description

Livestock access to streams damages the stream bank and allows for the direct deposition of N and P contained in soil (via bank erosion) and excreta into streams. In addition to fencing stock out of waterways, the planting of riparian margins can provide a number of ancillary benefits that help to improve the ecological function of waterways. These include the provision of shade to minimise fluctuations in stream temperatures, stabilisation of stream banks and uptake of nutrients from riparian margins[13]

An additional important consideration for fencing and riparian exclusion is that some farms will already have streams fenced off. Based on this, we have constrained the proportion of total area where additive fencing could be added (see Table 3.2 below).

[13] Smith and Muirhead (2019)

Table 3.2 Percentage of area where new fencing could be added

	DAIRY (D1-D8)	SBHILL (SB1, SB3, SB4)	SBINTEN (SB5, SB6, SB7)	SBHIGH (SB2)
Northland	7.3%	39.9%	39.9%	39.9%
Auckland	0.0%	0.0%	0.0%	0.0%
Waikato	3.7%	32.4%	30.0%	29.0%
Bay of Plenty	3.8%	39.9%	39.9%	39.9%
Gisborne	24.9%	39.9%	39.9%	39.9%
Hawke's Bay	0.0%	0.0%	0.0%	0.0%
Taranaki	0.9%	52.5%	22.3%	30.5%
Manawatu-Wanganui	7.5%	55.8%	55.8%	55.8%
Wellington	0.0%	0.0%	0.0%	0.0%
Marlborough	0.0%	0.0%	0.0%	0.0%
West Coast	7.0%	50.8%	50.8%	50.8%
Canterbury	0.0%	0.0%	0.0%	0.0%
Otago	14.9%	50.8%	50.8%	50.8%
Southland	11.8%	50.8%	50.8%	50.8%
Tasman	6.6%	50.8%	50.8%	50.8%
Nelson	0.0%	0.0%	0.0%	0.0%

Source: Resource Economics analysis

Cost estimates

Capital costs	\$4.82-\$17.50 per metre
Maintenance costs (annual)	\$0.05-\$0.50 per metre
Land retirement costs	Based on typology profitability

Effectiveness estimates (% reduction in loads)

Nitrogen	10%
Phosphorus	54%

3.3 Vegetated buffer strips

Description

The installation of vegetated buffer strips can filter/attenuate P loss in surface runoff from sloping land. Vegetated buffer strips work to decrease P loss in surface runoff by a combination of filtration, deposition and improving infiltration.[14]

[14] Ibid

Note that the effectiveness of this mitigation is incorporated into the effectiveness of 3.1 Fencing and riparian exclusion.

Cost estimates[15]

Capital costs	\$3.70-\$6.40 per m^2
Maintenance costs (annual)[16]	\$1-\$1.87 m^2

Effectiveness estimates (% reduction in loads)

Nitrogen	N/A
Phosphorus	42%[17]

3.4 Achieving optimal Olsen P levels

Description

Farms vary in the extent to which their soil phosphorus levels deviate from the agronomic optimum level of Olsen P. The magnitude of P losses from soil via surface runoff or subsurface flow is generally proportional to soil P concentration. Therefore, maintaining a soil test P concentration in excess of the optimum for pasture production represents an unnecessary source of P loss. Achieving optimal soil test P concentration (e.g. Olsen P) can be done with nutrient budgeting software such as Overseer, although in practice, this would be applied on a farm level rather than across a catchment or region.[18]

Cost estimates

Under the current assumptions, cost savings can be realised from the movement towards optimal Olsen P level at an aggregated regional level. However, the achievement of this outcome would need to occur at a farm level rather than a catchment or region level, and it will not necessarily be the case that all farms in all regions will necessarily realise cost savings as a result of the implementation of this mitigation. As such, beyond the costs calculated here, there could also be a range of implementation costs associated with this mitigation that are required to encourage behavioural change in a region to the extent that these cost savings can be realised, rather than a uniform saving that could be realised from simply applying this mitigation.

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[15] Perrin Ag (2020), *Estimated on-farm economic impacts of selected mitigation options*
[16] Note these costs do not include any costs associated with additional costs that would be required for fence maintenance should the introduction of vegetated buffer strips increase this value in scenarios such as when fallen branches damage fences
[17] Smith and Muirhead (2019) *Implementations of mitigations contained in Mitigator*
[18] Ibid

Operating costs (annual)	Saving of $19-$54 per ha depending on current levels of Olsen P

Effectiveness estimates

Nitrogen	N/A
Phosphorus	23% for regions where current levels of Olsen P exceed optimal levels[19]

3.5 Switching to low water-soluble phosphorus fertiliser

Description

Use low water solubility P fertiliser to decrease loss after application. Low water solubility P fertilisers decrease P loss by maintaining a smaller pool of soluble P in soil solution soon after application than highly water-soluble P fertilisers, thereby minimising the potential for loss should runoff occur.[20]

Note that this mitigation assumes that farms have also transitioned to optimal Olsen P levels. Costs associated with any specialist to help with the implementation of a nutrient plan, such as an agronomist, have not been included in this cost.

Cost estimates

Operating costs (annual)	$29-$200 per ha

Effectiveness estimates (% reduction in loads)

Nitrogen	N/A
Phosphorus	13%[21]

3.6 Construction of wetlands

Description

Constructed wetlands are designed to capture nutrients discharging from obvious discharge points such as tile drains, primarily focused in capturing nitrogen. Some excavation is usually required to create a wetland bed that can be planted with wetland plants to help disperse and decrease the velocity of water flowing through it. This also helps to promote the settling of particulate matter.[22]

[19] Ibid
[20] Ibid
[21] Ibid
[22] Ibid

Note that the total cost per hectare estimate of this mitigation includes the opportunity cost of land converted from productive land into wetlands.

Cost estimates[23]

Capital costs	$13-$20 per m^2
Maintenance costs (annual)	$50-$300 per ha
Land retirement costs (annual)	Based on typology profitability

Effectiveness estimates (% reduction in loads)

Nitrogen	25%[24]
Phosphorus	N/A

3.7 Stock reduction

A reduction in the total stock in a given herd of cattle will generally result in a reduction in the total volume of N produced as a result of livestock. For the purposes of our analysis, we have assumed this reduction only applies to dairy cattle, as estimates of the effectiveness for stock reduction in the Sheep and Beef sector could not be estimated[25]. The stock reduction mitigation applied involves a 10% reduction in stock numbers.

As a result of any stock reduction, it is assumed that farms receive revenue from the sale of cattle in the first year.

Cost estimates

Capital costs	$1,061 - $1,590 gained per head of cattle sold
Ongoing costs (annual)	Foregone profit based on typology profitability

Effectiveness estimates (% reduction in loads)

Nitrogen	25%
Phosphorus	N/A

[23] Perrin Ag (2020)
[24] Smith and Muirhead (2019)
[25] Perrin Ag (2020)

3.8 Land use change

While in practice land use change could represent a potential option for load reductions, due to the inability to fully incorporate all potential mitigations, we have opted not to include it as a potential mitigation. Unlike other mitigations, land use change could involve a significant change to the ongoing management and purpose of the land in question, beyond the extent to changes required by other mitigations. However, given we are unable to ascertain the cost and effectiveness of other mitigations not included this report or the basis on which farmers would make a choice to change land use (and to what land use they would change to), our modelling does not provide any insight on the proportion of farms that would pursue this pathway. As such, land use change has not been considered amongst the mitigations for load reduction - however, we acknowledge that it is likely that may ultimately feature as part of an overall package to help meet the targets of the policy.

4. Results

4.1 Load reduction impacts

To determine the potential impacts on industry, we must first consider which mitigations will be applied in each region to achieve the load reduction targets. To do this, we consider the maximum potential reduction that could be realised for N and P under each mitigation, and the maximum potential load reduction that could be realised across all mitigations. Note that this initial analysis does not consider cost of the mitigations, which will take place in the next stage of the analysis – in this section, we are only considering the potential to realise the load reduction targets in each region.

4.1.1 Load reduction impacts – Nitrogen

The load reduction impact targets for Nitrogen have varying levels of success based on the farm composition (and thus applicable mitigations) across regions. Of the costed mitigations impacting N, Enhanced Nitrogen Management (ENM) – Bundle 3 is typically able to realise the largest N reductions under current parameters. This is directly proportional to the intensity of the dairy sector in regions such as Waikato, Taranaki, Canterbury and Southland.

Table 4.1 Estimated load reduction impacts from implementation of identified mitigations - N

Region		Maximum potential N reduction (t)			Maximum potential achievable target reduction (%)
	N target under NPS 2020 (including EFW) (t)	Enhanced Nitrogen Management - Bundle 1	Enhanced Nitrogen Management - Bundle 2	Enhanced Nitrogen Management - Bundle 3	
Northland	124.0	124.0	124.0	124.0	100.0%
Auckland	168.8	168.8	168.8	168.8	100.0%
Waikato	3,808.5	3,808.5	2,969.5	3,808.5	100.0%
Bay of Plenty	299.6	299.6	299.6	299.6	100.0%
Gisborne	9.2	9.2	9.2	9.2	100.0%
Taranaki	1,696.5	1,696.5	782.3	1,696.5	100.0%
Manawatu-Whanganui	1,147.2	794.7	370.5	1,147.2	100.0%
Hawke's Bay	1,007.6	750.8	252.7	743.9	100.0%
Wellington	171.6	171.6	171.6	171.6	100.0%
Tasman	9.1	9.1	9.1	9.1	100.0%
Nelson	0.3	0.3	0.3	0.3	100.0%
Marlborough	14.7	14.7	14.7	14.7	100.0%
West Coast	21.9	21.9	21.9	21.9	100.0%
Canterbury	10,689.7	2,116.1	238.8	3,195.9	51.9%
Otago	680.4	680.4	195.4	680.4	100.0%
Southland	4,281.6	1,616.6	679.4	2,329.6	100.0%

TOTAL	24,130.6	12,282.7	6,307.8	14,421.1	78.7%

4.1.2 Load reduction impacts – Phosphorus

The load reduction impact targets for Phosphorus have varying levels of success, driven by the different sectoral compositions of each region and the proportion of farmland that is considered eligible for application of mitigations. All the regions with the exception of Manawatu-Whanganui have the potential to realise full load reductions, in part due to this reason – relative to other regions, the model identifies relatively fewer eligible areas where load reductions can be realised. Of the four mitigations impacting P, low water-soluble P fertiliser is able to realise the largest P reductions under our current parameters.

Table 4.2 Estimated load reduction impacts from implementation of identified mitigations - P

		Maximum potential P reduction (t)				
Region	P target under NPS 2020 (including EFW) (t)	Fencing (including vegetated buffer strips)	Constructed wetlands	Achieving optimal Olsen P levels	Low water-soluble P fertiliser	Maximum potential achievable target reduction (%)
Northland	162.0	162.0	8.5	162.0	162.0	100.0%
Auckland	36.4	0.0	2.8	36.4	36.4	100.0%
Waikato	374.5	263.0	4.5	374.5	306.7	100.0%
Bay of Plenty	148.5	143.0	1.8	148.5	113.8	100.0%
Gisborne	20.2	20.2	1.8	20.2	20.2	100.0%
Taranaki	48.2	33.9	0.7	48.2	48.2	100.0%
Manawatu-Whanganui	333.1	30.2	0.4	69.4	39.3	41.8%
Hawke’s Bay	114.0	0.0	1.0	98.4	55.6	100.0%
Wellington	36.4	0.0	1.3	36.4	36.4	100.0%
Tasman	5.0	5.0	0.3	5.0	5.0	100.0%
Nelson	0.4	0.0	0.0	0.4	0.4	100.0%
Marlborough	15.0	0.0	0.3	15.0	15.0	100.0%
West Coast	0.1	0.1	0.1	0.1	0.1	100.0%
Canterbury	23.2	0.0	0.2	22.6	23.2	100.0%
Otago	49.7	38.0	0.2	30.1	25.6	100.0%
Southland	50.3	50.3	0.4	50.3	50.3	100.0%
TOTAL	1,416.8	745.6	24.3	1,117.4	938.0	86.3%

4.2 Costs of mitigations

Section 4.1 indicates the potential for the identified mitigations to help farms in each region to realise their required load reduction targets. This section summarises the per hectare cost of each mitigation, calculated on an NPV basis, to evaluate a potential strategy for application of the mitigations that will allow the realisation of the load reduction target at lowest cost.

Detailed breakdowns of the cost of mitigations under the scenario for the dairy and beef and sheep sectors are provided on the following pages. The assumptions underpinning the calculation of these costs (some of which also applied to calculating the load reduction impacts are found in Attachment 1).

In calculating NPV values, we have assumed a 3% discount rate.

Table 4.3 Estimated cost of mitigations for the dairy sector

Region	**Average NPV profit ($/ha)**	**NPV cost of mitigation ($/ha)**								
		Fencing	Vegetated buffer strips	Achieving optimal Olsen P	Low water-soluble phosphorous fertiliser	Constructed wetlands	Stock reduction	Enhanced Nitrogen Management – Bundle 1	Enhanced Nitrogen Management – Bundle 2	Enhanced Nitrogen Management – Bundle 3
Northland	17,047	12	440	207	838	3,559	1,303	145	512	10,996
Auckland	17,047	0	0	207	838	3,559	647	163	347	10,996
Waikato	21,992	11	386	-2	1,173	3,653	1,820	153	368	10,996
Bay of Plenty	21,970	18	627	-272	1,173	3,653	1,540	146	325	10,996
Gisborne	21,970	47	1,523	1,082	1,173	3,653	1,401	94	379	10,996
Taranaki	21,400	0	0	1,218	1,173	3,642	1,449	175	154	10,996
Manawatu-Whanganui	22,346	12	416	1,082	1,173	3,660	1,908	159	381	10,996
Hawke's Bay	22,346	17	571	1,082	1,173	3,660	1,695	142	291	10,996
Wellington	22,346	0	0	302	838	3,660	1,591	161	359	10,996
Tasman	13,666	0	0	-518	838	3,495	960	58	366	10,996
Nelson	-	-	-		-	-		-		-
Marlborough	29,399	0	0	-518	838	3,794	1,626	97	229	10,996
West Coast	13,666	13	524	-518	838	3,495	1,005	156	278	10,996
Canterbury	29,399	15	444	0	1,340	3,794	2,444	168	132	10,996
Otago	23,772	10	332	0	1,173	3,687	1,986	176	452	10,996
Southland	23,772	0	0	0	1,173	3,687	1,946	179	533	10,996

Table 4.4 Estimated cost of mitigations for the beef and sheep sector

Region	**Average NPV profit ($/ha)**	**NPV cost of mitigation ($/ha)**								
		Fencing	Vegetated buffer strips	Achieving optimal Olsen P	Low water-soluble phosphorous fertiliser	Constructed wetlands	Stock reduction	Enhanced Nitrogen Management – Bundle 1	Enhanced Nitrogen Management – Bundle 2	Enhanced Nitrogen Management – Bundle 3
Northland	5,215	72	123	-285	838	3,350	-	190	63	180
Auckland	5,625	-	-	-257	838	3,363	-	189	63	178
Waikato	5,162	80	184	-280	1,173	3,359	-	146	49	138
Bay of Plenty	5,754	54	168	-192	1,173	3,373	-	172	57	163
Gisborne	3,596	104	26	-108	1,173	3,332	-	29	10	27
Taranaki	3,570	-	-	-185	1,173	3,342	-	67	22	64
Manawatu-Whanganui	3,606	55	10	-142	1,173	3,337	-	80	27	75
Hawke's Bay	4,054	97	15	-60	1,173	3,333	-	116	39	109
Wellington	4,114	-	-	-108	838	3,336	-	115	38	108
Tasman	1,655	-	-	-117	838	3,286	-	75	25	71
Nelson	1,635	94	0	-99	-	3,278	-	15	5	14
Marlborough	1,242	-	-	-206	838	3,302	-	38	13	36
West Coast	3,607	69	608	164	838	3,313	-	262	87	248
Canterbury	1,853	44	127	-119	1,340	3,302	-	122	41	115
Otago	1,335	30	9	-185	1,173	3,273	-	147	49	139
Southland	6,172	-	-	77	1,173	3,385	-	244	81	231

4.3 Lowest cost mitigation bundles

By combining the per hectare estimates of profitability, costs of mitigations and efficiency of mitigations, we produced a set of mitigation bundles for each region. As described in Chapter 2, mitigations are applied sequentially following a set of rules:

1. The cost-efficiency of bundles are calculated for both dairy and beef and sheep sector mitigations and ranked from most cost-efficient to least cost efficient
2. For a given region, the most cost-efficient mitigation is applied first, and the total N load reduction impact from this mitigation is realised
3. If the N load reduction target is not achieved, then the next most cost-effective mitigation is applied
4. If at any point the target is reached, the last used mitigation is only applied to the minimum required proportion of farmland. Similarly, if the total cost of mitigations exceeds the average profit of farms in the region, then the last used mitigation is only applied to the extent that total cost is equal to total profit
5. Priority is given to reducing N load in the first instance – reduction in P is only considered after all bundles for N have been applied (see Section 4.3.2).

Sensitivity testing

In order to test the sensitivity of the results of our modelling, we have modelled the results for a number of different scenarios. The scenarios agreed with MfE were the following:

1. Periphyton 20%, Dissolved Inorganic Nitrogen (DIN) 1.0, all ENM bundles
2. Periphyton 20%, DIN 1.0, only M2 and M3 (assumes M1 has already been applied across farms)
3. Periphyton 20%, DIN 1.0, only M1 and M2 (tests sensitivity of impacts to removal of most expensive measure)
4. Periphyton 20%, DIN 1.0, all ENM bundles but targets are only the required marginal improvements from the EFW policy.

Each scenario is considered in the following sections before being compared against each other in the final section of the chapter.

4.3.1 Scenario 1 – Periphyton 20%, DIN 1.0, all ENM bundles

4.3.1.1 Nitrogen – lowest cost mitigation bundle

Table 4.5 below summarises the results from the application of the lowest cost bundles (detailed in Attachment 3) to each region on the following pages where all three ENM bundles are available to be applied.

Under the lowest cost mitigation bundle, there is an achievement of 78.7% of the required target of N load reductions under the NPS 2020 policy. Every region is able to achieve its load reduction targets with the exception of Canterbury, which has the largest target of all regions.

As shown in Table 4.6, cost impacts also vary significantly between regions and sectors, with some regions being able to realise their reductions through applying mitigations to a single sector. For the dairy sector, Canterbury and Southland bear the most significant costs from implementing mitigations, while in the beef and sheep sector, the Canterbury, Otago, Southland and Manawatu-Whanganui all have the largest reduction in profits.

Table 4.5 Lowest cost mitigation bundles for N – effectiveness and cost

Region	N target under NPS 2020 (t)	Total reduction achieved (t)	% of target load reduction achieved (%)	Average dairy farm profit ($/ha)	Costs of dairy mitigations bundle ($/ha)	% reduction in average dairy farm profit from mitigation costs	Average beef and sheep farm profit ($/ha)	Costs of beef and sheep mitigations bundle ($/ha)	% reduction in average beef and sheep farm profit from mitigation costs
Northland	124.0	124.0	100.0%	17,047	60.9	0.4%	5,215	0.0	0.0%
Auckland	168.8	168.8	100.0%	17,047	0.0	0.0%	5,625	15.3	0.3%
Waikato	3,808.5	3,808.5	100.0%	21,992	520.7	2.4%	5,162	18.5	0.4%
Bay of Plenty	299.6	299.6	100.0%	21,970	108.8	0.5%	5,754	0.0	0.0%
Gisborne	9.2	9.2	100.0%	21,970	473.1	2.2%	3,596	0.1	0.0%
Taranaki	1,696.5	1,696.5	100.0%	21,400	175.2	0.8%	3,570	47.1	1.3%
Manawatu-Whanganui	1,147.2	1,147.2	100.0%	22,346	539.9	2.4%	3,606	102.4	2.8%
Hawke's Bay	1,007.6	1,007.6	100.0%	22,346	11,428.8	51.1%	4,054	112.1	2.8%
Wellington	171.6	171.6	100.0%	22,346	254.4	1.1%	4,114	0.0	0.0%
Tasman	9.1	9.1	100.0%	13,666	7.1	0.1%	1,655	0.0	0.0%
Nelson	0.3	0.3	100.0%	-	0.0	0.0%	1,635	0.4	0.0%
Marlborough	14.7	14.7	100.0%	29,399	59.5	0.2%	1,242	0.0	0.0%
West Coast	21.9	21.9	100.0%	13,666	0.0	0.0%	3,607	4.0	0.1%
Canterbury	10,689.7	5,550.8	51.9%	29,399	11,295.4	38.4%	1,853	277.0	14.9%
Otago	680.4	680.4	100.0%	23,772	176.5	0.7%	1,335	87.4	6.5%
Southland	4,281.6	4,281.6	100.0%	23,772	9,505.0	40.0%	6,172	556.7	9.0%
TOTAL	24,130.6	18,991.7	78.7%	-					

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Table 4.6 Regional cost distribution under lowest cost mitigation bundles for N

	DAIRY			BEEF AND SHEEP			TOTAL
Region	**Total applicable area (ha)**	**Bundle cost per hectare ($/ha)**	**Total bundle cost ($)**	**Total applicable area (ha)**	**Bundle cost per hectare ($/ha)**	**Total bundle cost ($)**	**Total cost ($)**
Northland	101,518	60.9	6,181,426	1,131,444,666	0.0	0	6,181,426
Auckland	14,499	0.0	0	276,792,514	15.3	422,655	422,655
Waikato	534,504	520.7	278,316,786	3,472,633,430	18.5	6,413,303	284,730,089
Bay of Plenty	62,360	108.8	6,785,154	632,614,668	0.0	0	6,785,154
Gisborne	764	473.1	361,586	1,798,578,008	0.1	22,947	384,534
Taranaki	95,211	175.2	16,676,909	472,123,357	47.1	2,222,405	18,899,314
Manawatu-Whanganui	146,849	539.9	79,287,418	7,024,992,480	102.4	71,930,114	151,217,531
Hawke's Bay	23,652	11,428.8	270,313,376	3,808,255,773	112.1	42,705,261	313,018,637
Wellington	30,356	254.4	7,721,552	1,401,749,213	0.0	0	7,721,552
Tasman	13,350	7.1	95,156	184,303,466	0.0	0	95,156
Nelson	0	0.0	0	2,672,550	0.4	118	118
Marlborough	4,481	59.5	266,485	1,325,645,297	0.0	0	266,485
West Coast	65,272	0.0	0	351,119,833	4.0	139,404	139,404
Canterbury	310,858	11,295.4	3,511,274,910	11,434,391,713	277.0	316,679,818	3,827,954,728
Otago	93,869	176.5	16,564,899	11,730,554,068	87.4	102,475,762	119,040,661
Southland	211,885	9,505.0	2,013,965,872	4,931,636,594	556.7	274,550,466	2,288,516,338
TOTAL	1,709,426	3,631.5	6,207,811,529	49,979,507,631	163.6	817,562,254	7,025,373,783

Under the lowest cost mitigation bundles, the majority of reduction is achieved by the dairy sector, accounting for 69% of the total reduction under the scenario. However, it does this by accounting for a total cost over 7.5 times greater than the cost of mitigations applied to the beef and sheep sector, largely in part due to the significant cost disparity between the two sectors for the Enhanced Nitrogen Management – Bundle 3.

Table 4.7 Sectoral impacts of lowest cost mitigation bundle for N

	Total N reduction (t)	Total cost ($)
Dairy	13,090.5	6,207,811,529
Beef and sheep	5,901.1	817,562,254
TOTAL	18,991.7	7,025,373,783

4.3.1.2 Phosphorus – lowest cost mitigation bundle

After the application of the mitigation bundles for N, we also consider the potential additional mitigations that would be required to meet the P load reduction targets under NPS 2020 (including the EFW policy). Two of the mitigations applied for N under the ENM bundles, fencing (including vegetated buffer strips) under M1 and wetlands under M2 also have impacts on P load reduction. We apply these reductions in the first instance, and then consider the remaining mitigations to be applied to target P load reductions.

Under the lowest cost mitigation bundle, there is an achievement of 86.3% of the required target of P load reductions under the NPS 2020 policy. This is driven by an inability to realise the P load reduction target in Manawatu-Whanganui, in part due to a comparatively smaller proportion of farmland located in areas where mitigations could be applied. Nelson also fails to realise its load reduction, but does so from a small base, and as such, could represent the absence of eligible farms in the model.

Table 4.8 Lowest cost mitigation bundle for P - impacts

Region	P target under NPS 2020 (t)	P Reduction from implemented N mitigations (t)	Remaining P target	Potential additional reduction achievable (t)	Total achieved reduction in P (t)	% reduction in total P target
Northland	162.0	852.4	0.0	904.5	162.0	100.0%
Auckland	36.4	2.8	33.6	333.0	36.4	100.0%
Waikato	374.5	267.5	107.0	542.6	374.5	100.0%
Bay of Plenty	148.5	144.8	3.6	201.3	148.5	100.0%
Gisborne	20.2	0.2	20.0	166.4	20.2	100.0%
Taranaki	48.2	34.6	13.5	106.9	48.2	100.0%
Manawatu-Whanganui	333.1	30.6	302.5	108.7	139.3	41.8%
Hawke's Bay	114.0	1.0	113.1	113.1	114.0	100.0%
Wellington	36.4	1.3	35.0	133.8	36.4	100.0%
Tasman	5.0	126.8	0.0	118.8	5.0	100.0%

Nelson	0.4	0.0	0.4	2.0	0.4	100.0%
Marlborough	15.0	0.0	15.0	134.9	15.0	100.0%
West Coast	0.1	255.5	0.0	86.2	0.1	100.0%
Canterbury	23.2	0.2	23.0	23.0	23.2	100.0%
Otago	49.7	38.1	11.6	38.7	49.7	100.0%
Southland	50.3	97.6	0.0	0.0	50.3	100.0%
TOTAL	1416.8	1,853.5	678.3	3,013.9	1,223.0	86.3%

The cost impacts of the additional P focused mitigations have the largest reduction in average farm profit in Manawatu-Whanganui and Hawke's Bay, driven by the need to apply the full suite of mitigations to maximise load reduction. In contrast, some regions are able to realise cost savings through achieving regional adoption of optimal levels of Olsen P, but note that this represents an overall improvement across the region when Optimal Olsen P is realised across the region. In practice, there may be costs or barriers associated with getting to this state, which would need to be taken into account (which have not been costed in this instance).

Table 4.9 Lowest cost mitigation bundles for P – sector impacts

	DAIRY			BEEF AND SHEEP		
Region	Average farm profit ($/ha)	Cost of additional P mitigations applied($/ha)[26]	Reduction in average farm profit	Average farm profit ($/ha)	Cost of additional P mitigations applied($/ha)	Reduction in average farm profit
Northland	17,047	0.0	0.0%	5,215	-285.5	-5.5%
Auckland	17,047	206.7	1.2%	5,625	-256.5	-4.6%
Waikato	21,992	-1.7	0.0%	5,162	-280.2	-5.4%
Bay of Plenty	21,970	-271.7	-1.2%	5,754	-192.3	-3.3%
Gisborne	21,970	1,082.2	4.9%	3,596	-107.6	-3.0%
Taranaki	21,400	1,218.4	5.7%	3,570	-185.0	-5.2%
Manawatu-Whanganui	22,346	2,255.0	10.1%	3,606	1,030.5	28.6%
Hawke's Bay	22,346	2,255.0	10.1%	4,054	125.6	3.1%
Wellington	22,346	302.0	1.4%	4,114	-107.6	-2.6%
Tasman	13,666	-518.1	-3.8%	1,655	-116.9	-7.1%
Nelson	-	0.0	0.0%	1,635	-99.3	-6.1%
Marlborough	29,399	-518.1	-1.8%	1,242	-206.3	-16.6%
West Coast	13,666	-518.1	-3.8%	3,607	0.0	0.0%
Canterbury	29,399	30.7	0.1%	1,853	-118.7	-6.4%
Otago	23,772	1,172.8	4.9%	1,335	-184.8	-13.8%
Southland	23,772	0.0	0.0%	6,172	0.0	0.0%

[26] Negative cost values indicate cost savings that could be potentially be realised

Table 4.10 Regional cost distribution under lowest cost mitigation bundles for P

	DAIRY			BEEF AND SHEEP			TOTAL
Region	**Total applicable area (ha)**	**Bundle cost per hectare ($/ha)**	**Total bundle cost ($ NPV)**	**Total applicable area (ha)**	**Bundle cost per hectare ($/ha)**	**Total bundle cost ($ NPV)**	**Total cost ($ NPV)**
Northland	101,518	0.0	0	113,144	-285.5	-32,301,835	-32,301,835
Auckland	14,499	206.7	2,997,641	27,679	-256.5	-7,099,994	-4,102,353
Waikato	534,504	-1.7	-884,199	347,263	-280.2	-97,307,287	-98,191,486
Bay of Plenty	62,360	-271.7	-16,944,004	63,261	-192.3	-12,163,022	-29,107,026
Gisborne	764	1,082.2	826,772	179,858	-107.6	-19,348,063	-18,521,291
Taranaki	95,211	1,218.4	116,002,407	47,212	-185.0	-8,736,379	107,266,027
Manawatu-Whanganui	146,849	2,255.0	331,140,209	702,499	1,030.5	723,901,447	1,055,041,656
Hawke's Bay	23,652	2,255.0	53,334,570	380,826	125.6	47,839,248	101,173,817
Wellington	30,356	302.0	9,166,004	140,175	-107.6	-15,079,200	-5,913,196
Tasman	13,350	-518.1	-6,916,198	18,430	-116.9	-2,153,990	-9,070,188
Nelson	0	0.0	0	267	-99.3	-26,523	-26,523
Marlborough	4,481	-518.1	-2,321,459	132,565	-206.3	-27,351,020	-29,672,479
West Coast	65,272	-518.1	-33,815,286	35,112	0.0	0	-33,815,286
Canterbury	310,858	30.7	9,546,430	1,143,439	-118.7	-135,704,166	-126,157,737
Otago	93,869	1,172.8	110,090,385	1,173,055	-184.8	-216,813,803	-106,723,418
Southland	211,885	0.0	0	493,164	0.0	0	0
TOTAL	1,709,428	334.7	572,223,270	4,997,949	39.5	197,655,413	769,878,683

Substantial reductions to P are already realised from mitigations that would be applied under the ENM mitigation bundles, and so in some regions, there are no additional P specific reductions applied to particular sectors (such as Dairy in Northland, Nelson and Southland). Once these mitigations are taken into account, the majority of additional P reduction are largely driven from the beef and sheep sector, which accounts for 78% of the total additional reductions under the scenario, but does so at a significantly lower cost. This is largely due to the high cost associated with some of the measures applied to the Dairy sector.

Table 4.11 Sectoral impacts of additional cost mitigation bundle for P

	Load reductions from previously applied mitigations (t)	Total additional P reduction realised (t)	Total additional cost ($)
Dairy	116.33	677.6	572,223,270
Beef and Sheep	1737.2	2452.7	197,655,413
TOTAL	1853.5	3130.2	769,878,683

4.3.2 Scenario 2 – Periphyton 20%, DIN 1.0, M2 and M3 only

This scenario assumes a situation where the majority of mitigations in ENM1 have already been applied, and thus load reductions for N can only be realised through the more expensive M2 and M3 bundles.

4.3.2.1 Nitrogen – lowest cost mitigation bundle

Table 4.12 below summarises the results from the application of the lowest cost bundles to each region on the following pages under the scenario constraint of no M1 bundle.

Under the constraint, there is an achievement of 64.6% of the required target of N load reductions under the NPS 2020 policy. All regions are able to meet their load reduction targets with the exception of Canterbury, Southland and Hawke's Bay.

As shown in Table 4.13, cost impacts also vary significantly between regions and sectors, with some regions being able to realise their reductions through applying mitigations to a single sector. For the dairy sector, Canterbury, Southland and Waikato bear significant costs from implementing mitigations, while in the beef and sheep sector, the Canterbury, Otago and Hawke's Bay regions have the largest reduction in profits.

Table 4.12 Lowest cost mitigation bundles for N – effectiveness and cost

Region	N target under NPS 2020 (t)	Total reduction achieved (t)	% of target load reduction achieved (%)	Average dairy farm profit ($/ha)	Costs of dairy mitigations bundle ($/ha)	% reduction in average dairy farm profit from mitigation costs	Average beef and sheep farm profit ($/ha)	Costs of beef and sheep mitigations bundle ($/ha)	% reduction in average beef and sheep farm profit from mitigation costs
Northland	124.0	124.0	100.0%	17,047	0.0	0.0%	5,215	3.1	0.1%
Auckland	168.8	168.8	100.0%	17,047	0.0	0.0%	5,625	11.2	0.2%
Waikato	3,808.5	3,808.5	100.0%	21,992	0.0	0.0%	5,162	110.5	2.1%
Bay of Plenty	299.6	299.6	100.0%	21,970	0.0	0.0%	5,754	23.3	0.4%
Gisborne	9.2	9.2	100.0%	21,970	0.0	0.0%	3,596	0.4	0.0%
Taranaki	1,696.5	1,696.5	100.0%	21,400	1,448.7	6.8%	3,570	86.2	2.4%
Manawatu-Whanganui	1,147.2	1,147.2	100.0%	22,346	4,775.6	21.4%	3,606	101.9	2.8%
Hawke's Bay	1,007.6	996.7	98.9%	22,346	11,287.2	50.5%	4,054	147.8	3.6%
Wellington	171.6	171.6	100.0%	22,346	0.0	0.0%	4,114	29.2	0.7%
Tasman	9.1	9.1	100.0%	13,666	0.0	0.0%	1,655	2.8	0.2%
Nelson	0.3	0.3	100.0%	-	0.0	0.0%	1,635	0.6	0.0%
Marlborough	14.7	14.7	100.0%	29,399	0.0	0.0%	1,242	3.5	0.3%
West Coast	21.9	21.9	100.0%	13,666	0.0	0.0%	3,607	5.0	0.1%
Canterbury	10,689.7	3,434.7	32.1%	29,399	11,127.5	37.8%	1,853	155.4	8.4%
Otago	680.4	680.4	100.0%	23,772	1,613.6	6.8%	1,335	234.9	17.6%
Southland	4,281.6	3,009.0	70.3%	23,772	11,528.6	48.5%	6,172	312.3	5.1%
TOTAL	24,130.6	15,592.1	64.6%	-					

Table 4.13 Regional cost distribution under lowest cost mitigation bundles for N

	DAIRY			BEEF AND SHEEP			TOTAL
Region	**Total applicable area (ha)**	**Bundle cost per hectare ($/ha)**	**Total bundle cost ($)**	**Total applicable area (ha)**	**Bundle cost per hectare ($/ha)**	**Total bundle cost ($)**	**Total cost ($)**
Northland	101,518	0.0	0	1,131,444,666	3.1	352,653	352,653
Auckland	14,499	0.0	0	276,792,514	11.2	309,697	309,697
Waikato	534,504	0.0	0	3,472,633,430	110.5	38,388,863	38,388,863
Bay of Plenty	62,360	0.0	0	632,614,668	23.3	1,472,421	1,472,421
Gisborne	764	0.0	0	1,798,578,008	0.4	66,822	66,822
Taranaki	95,211	1,448.7	137,936,479	472,123,357	86.2	4,068,464	142,004,944
Manawatu-Whanganui	146,849	4,775.6	701,294,455	7,024,992,480	101.9	71,564,005	772,858,460
Hawke's Bay	23,652	11,287.2	266,963,715	3,808,255,773	147.8	56,299,541	323,263,256
Wellington	30,356	0.0	0	1,401,749,213	29.2	4,087,706	4,087,706
Tasman	13,350	0.0	0	184,303,466	2.8	52,495	52,495
Nelson	0	0.0	0	2,672,550	0.6	152	152
Marlborough	4,481	0.0	0	1,325,645,297	3.5	458,910	458,910
West Coast	65,272	0.0	0	351,119,833	5.0	176,529	176,529
Canterbury	310,858	11,127.5	3,459,080,737	11,434,391,713	155.4	177,649,654	3,636,730,391
Otago	93,869	1,613.6	151,464,096	11,730,554,068	234.9	275,567,241	427,031,337
Southland	211,885	11,528.6	2,442,724,166	4,931,636,594	312.3	154,016,115	2,596,740,281
TOTAL	1,709,426	4,188.2	7,159,463,649	49,979,507,631	157.0	784,531,267	7,943,994,917

Under the lowest cost mitigation bundles, the majority of reduction is achieved by the beef and sheep sector, which accounts for 56% of the total reduction under the scenario. Moreover, it does this at little over 10% of the cost of mitigations applied to the dairy sector, largely in part due to the significant cost disparity between the two sectors for the Enhanced Nitrogen Management – Bundle 3.

Table 4.14 Sectoral impacts of lowest cost mitigation bundle for N

	Total N reduction (t)	Total cost ($)
Dairy	6,684.75	7,159,463,649
Beef and Sheep	9,044.51	784,531,267
TOTAL	15,729.26	7,943,994,916

4.3.2.2 Phosphorus – lowest cost mitigation bundle

After the application of the mitigation bundles for N, we also consider the potential additional mitigations that would be required to meet the P load reduction targets under NPS 2020 (including the EFW policy) and under the constraint. Under the constraint, wetlands are previously applied under M2 which has an impacts on P load reduction, and fencing is assumed to already have been applied. We apply this reduction in the first instance, and then consider the remaining mitigations to be applied to target P load reductions.

Under the lowest cost mitigation bundle, there is an achievement of 84.0% of the required target of P load reductions under the NPS 2020 policy. This is driven by a majority of farms their load reductions, with the exception being farms in Manawatu-Whanganui. Tasman notably fails to reduce its load, but this is likely a result of a small number of farms being identified as eligible under the model.

Table 4.15 Lowest cost mitigation bundle for P - impacts

Region	P target under NPS 2020 (t)	P Reduction from implemented N mitigations (t)	Remaining P target	Potential additional reduction achievable (t)	Total achieved reduction in P (t)	% reduction in total P target
Northland	162.0	0.4	161.6	161.6	162.0	100.0%
Auckland	36.4	0.0	36.4	36.4	36.4	100.0%
Waikato	374.5	0.9	373.6	373.6	374.5	100.0%
Bay of Plenty	148.5	0.2	148.3	148.3	148.5	100.0%
Gisborne	20.2	0.0	20.2	20.2	20.2	100.0%
Taranaki	48.2	0.3	47.9	47.9	48.2	100.0%
Manawatu-Whanganui	333.1	0.2	332.8	108.7	108.9	32.7%
Hawke's Bay	114.0	0.1	114.0	114.0	114.0	100.0%
Wellington	36.4	0.0	36.3	36.3	36.4	100.0%
Tasman	5.0	0.1	0.0	0.0	0.1	1.2%
Nelson	0.4	0.0	0.4	0.4	0.4	100.0%
Marlborough	15.0	0.0	15.0	15.0	15.0	100.0%
West Coast	0.1	0.4	0.0	0.0	0.1	100.0%

Canterbury	23.2	0.1	23.0	23.0	23.2	100.0%
Otago	49.7	0.1	49.7	49.7	49.7	100.0%
Southland	50.3	0.3	49.9	49.9	50.3	100.0%
TOTAL	1416.8	3.1	1,409.1	1,184.9	1,187.7	84.0%

In the dairy sector, the cost impacts of the additional P focused mitigations have the largest reduction in average farm profit in Manawatu-Whanganui and Hawke's Bay. In the beef and sheep sector, Otago, Canterbury, Manawatu-Whanganui and Hawke's Bay are most heavily impacted by P mitigations. Otago is notable in that under the base scenario, it is able to achieve its mitigations at low cost – when the M1 reductions (notably fencing) are not available, then it requires the application of more expensive mitigations.

Table 4.16 Lowest cost mitigation bundles for P – sector impacts

	DAIRY			**BEEF AND SHEEP**		
Region	Average farm profit ($/ha)	Cost of additional P mitigations applied($/ha)[27]	Reduction in average farm profit	Average farm profit ($/ha)	Cost of additional P mitigations applied($/ha)	Reduction in average farm profit
Northland	17,047	0.0	0.0%	5,215	-285.5	-5.5%
Auckland	17,047	0.0	0.0%	5,625	-256.5	-4.6%
Waikato	21,992	-1.7	0.0%	5,162	-280.2	-5.4%
Bay of Plenty	21,970	0.0	0.0%	5,754	-192.3	-3.3%
Gisborne	21,970	0.0	0.0%	3,596	-13.1	-0.4%
Taranaki	21,400	77.3	0.4%	3,570	-185.0	-5.2%
Manawatu-Whanganui	22,346	2,255.0	10.1%	3,606	1,030.5	28.6%
Hawke's Bay	22,346	2,255.0	10.1%	4,054	147.4	3.6%
Wellington	22,346	0.0	0.0%	4,114	-107.6	-2.6%
Tasman	13,666	0.0	0.0%	1,655	-5.5	-0.3%
Nelson	-	0.0	0.0%	1,635	-99.3	-6.1%
Marlborough	29,399	-518.1	-1.8%	1,242	-206.3	-16.6%
West Coast	13,666	-518.1	-3.8%	3,607	0.0	0.0%
Canterbury	29,399	36.5	0.1%	1,853	-118.7	-6.4%
Otago	23,772	1,172.8	4.9%	1,335	574.9	43.1%
Southland	23,772	0.0	0.0%	6,172	51.2	0.8%

[27] Negative cost values indicate cost savings realised

Table 4.17 Regional cost distribution under lowest cost mitigation bundles for P

	DAIRY			BEEF AND SHEEP			TOTAL
Region	**Total applicable area (ha)**	**Bundle cost per hectare ($/ha)**	**Total bundle cost ($ NPV)**	**Total applicable area (ha)**	**Bundle cost per hectare ($/ha)**	**Total bundle cost ($ NPV)**	**Total cost ($ NPV)**
Northland	101,518	0.0	0	113,144	-285.5	-32,301,835	-32,301,835
Auckland	14,499	0.0	0	27,679	-256.5	-7,099,994	-7,099,994
Waikato	534,504	-1.7	-884,199	347,263	-280.2	-97,307,287	-98,191,486
Bay of Plenty	62,360	0.0	0	63,261	-192.3	-12,163,022	-12,163,022
Gisborne	764	0.0	0	179,858	-13.1	-2,354,460	-2,354,460
Taranaki	95,211	77.3	7,359,671	47,212	-185.0	-8,736,379	-1,376,708
Manawatu-Whanganui	146,849	2,255.0	331,140,209	702,499	1,030.5	723,901,447	1,055,041,656
Hawke's Bay	23,652	2,255.0	53,334,570	380,826	147.4	56,149,140	109,483,710
Wellington	30,356	0.0	0	140,175	-107.6	-15,079,200	-15,079,200
Tasman	13,350	0.0	0	18,430	-5.5	-100,686	-100,686
Nelson	0	0.0	0	267	-99.3	-26,523	-26,523
Marlborough	4,481	-518.1	-2,321,459	132,565	-206.3	-27,351,020	-29,672,479
West Coast	65,272	-518.1	-33,815,286	35,112	0.0	0	-33,815,286
Canterbury	310,858	36.5	11,333,293	1,143,439	-118.7	-135,704,166	-124,370,873
Otago	93,869	1,172.8	110,090,385	1,173,055	574.9	674,384,460	784,474,845
Southland	211,885	0.0	0	493,164	51.2	25,264,474	25,264,474
TOTAL	1,709,428	278.6	476,237,183	4,997,949	228.4	1,141,474,950	1,617,712,133

In the absence of the M1 mitigation bundle, little reduction is realised by the prior applied mitigations. Under this scenario, the majority of P reduction is achieved by the beef and sheep sector through additional mitigations, accounting for 79% of the total reduction under the scenario, but now it does so at over double the cost of mitigations in the dairy sector.

Table 4.18 Sectoral impacts of lowest cost mitigation bundle for P

	Load reductions from previously applied mitigations (t)	Total additional P reduction realised (t)	Total cost ($)
Dairy	2.8	616.6	476,237,183
Beef and Sheep	0.2	2354.8	1,141,474,950
TOTAL	2.9	2,971.4	1,617,712,133

4.3.3 Scenario 3 – Periphyton 20%, DIN 1.0, M1 and M2 only

This scenario assumes a situation where the ENM bundle M3 is not available, and considers what reductions can be achieved in the short-medium term using bundles M1 and M2.

4.3.3.1 Nitrogen – lowest cost mitigation bundle

Table 4.19 below summarises the results from the application of the lowest cost bundles to each region on the following pages under the scenario constraint.

Under the constraint, there is an achievement of 57.2% of the required target of N load reductions under the NPS 2020 policy. All regions are able to meet their load reduction targets with the exception of Canterbury, Southland and Hawke's Bay under this policy (notably the same regional distribution as under Scenario 2).

As shown in Table 4.20, cost impacts vary significantly between regions and sectors, with some regions being able to realise their reductions through applying mitigations to a single sector. For the dairy sector, Canterbury, Southland and Waikato bear significant costs from implementing mitigations, while in the beef and sheep sector, the Canterbury, Otago and Hawke's Bay regions have the largest reduction in profits.

Table 4.19 Lowest cost mitigation bundles for N – effectiveness and cost

Region	N target under NPS 2020 (t)	Total reduction achieved (t)	% of target load reduction achieved (%)	Average dairy farm profit ($/ha)	Costs of dairy mitigations bundle ($/ha)	% reduction in average dairy farm profit from mitigation costs	Average beef and sheep farm profit ($/ha)	Costs of beef and sheep mitigations bundle ($/ha)	% reduction in average beef and sheep farm profit from mitigation costs
Northland	124.0	124.0	100.0%	17,047	0.0	0.0%	5,215	4.1	0.1%
Auckland	168.8	168.8	100.0%	17,047	0.0	0.0%	5,625	15.3	0.3%
Waikato	3,808.5	3,808.5	100.0%	21,992	0.0	0.0%	5,162	94.9	1.8%
Bay of Plenty	299.6	299.6	100.0%	21,970	0.0	0.0%	5,754	24.9	0.4%
Gisborne	9.2	9.2	100.0%	21,970	0.0	0.0%	3,596	94.6	2.6%
Taranaki	1,696.5	1,696.5	100.0%	21,400	0.0	0.0%	3,570	222.2	6.2%
Manawatu-Whanganui	1,147.2	1,147.2	100.0%	22,346	512.3	2.3%	3,606	106.3	2.9%
Hawke's Bay	1,007.6	1,003.6	99.6%	22,346	432.9	1.9%	4,054	154.3	3.8%
Wellington	171.6	171.6	100.0%	22,346	0.0	0.0%	4,114	27.0	0.7%
Tasman	9.1	9.1	100.0%	13,666	0.0	0.0%	1,655	2.2	0.1%
Nelson	0.3	0.3	100.0%	-	0.0	0.0%	1,635	0.4	0.0%
Marlborough	14.7	14.7	100.0%	29,399	59.5	0.2%	1,242	0.0	0.0%
West Coast	21.9	21.9	100.0%	13,666	0.0	0.0%	3,607	4.0	0.1%
Canterbury	10,689.7	2,354.9	22.0%	29,399	299.5	1.0%	1,853	162.1	8.7%
Otago	680.4	680.4	100.0%	23,772	176.5	0.7%	1,335	87.4	6.5%
Southland	4,281.6	2,296.0	53.6%	23,772	711.8	3.0%	6,172	325.9	5.3%
TOTAL	24,130.6	13,806.2	57.2%	-					

Table 4.20 Regional cost distribution under lowest cost mitigation bundles for N

	DAIRY			BEEF AND SHEEP			TOTAL
Region	**Total applicable area (ha)**	**Bundle cost per hectare ($/ha)**	**Total bundle cost ($)**	**Total applicable area (ha)**	**Bundle cost per hectare ($/ha)**	**Total bundle cost ($)**	**Total cost ($)**
Northland	101,518	0.0	0	1,131,444,666	4.1	467,963	467,963
Auckland	14,499	0.0	0	276,792,514	15.3	422,655	422,655
Waikato	534,504	0.0	0	3,472,633,430	94.9	32,953,694	32,953,694
Bay of Plenty	62,360	0.0	0	632,614,668	24.9	1,573,505	1,573,505
Gisborne	764	0.0	0	1,798,578,008	94.6	17,022,324	17,022,324
Taranaki	95,211	0.0	0	472,123,357	222.2	10,492,001	10,492,001
Manawatu-Whanganui	146,849	512.3	75,232,131	7,024,992,480	106.3	74,675,483	149,907,614
Hawke's Bay	23,652	432.9	10,239,310	3,808,255,773	154.3	58,747,347	68,986,658
Wellington	30,356	0.0	0	1,401,749,213	27.0	3,785,028	3,785,028
Tasman	13,350	0.0	0	184,303,466	2.2	41,337	41,337
Nelson	-	0.0	0	2,672,550	0.4	118	118
Marlborough	4,481	59.5	266,485	1,325,645,297	0.0	0	266,485
West Coast	65,272	0.0	0	351,119,833	4.0	139,404	139,404
Canterbury	310,858	299.5	93,107,369	11,434,391,713	162.1	185,373,552	278,480,921
Otago	93,869	176.5	16,564,899	11,730,554,068	87.4	102,475,762	119,040,661
Southland	211,885	711.8	150,819,151	4,931,636,594	325.9	160,712,468	311,531,619
TOTAL	1,709,426	202.5	346,229,345	49,979,507,631	129.8	648,882,640	995,111,985

Under this scenario, the majority of reduction is achieved by the beef and sheep sector, accounting for 72% of the total reduction under the scenario. In contrast to the previous two scenarios, these load reductions are realised at a higher cost than the dairy sector, with the beef and sheep sector accounting for 65% of total cost.

Table 4.21 Sectoral impacts of lowest cost mitigation bundle for N

	Total N reduction (t)	Total cost ($)
Dairy	3,880.0	346,229,345
Beef and Sheep	9,926.1	648,882,640
TOTAL	13,806.2	995,111,985

4.3.3.2 Phosphorus – lowest cost mitigation bundle

As the omitted mitigation bundle (M3) does not contain any mitigations that would reduce P loads, the distribution and outcomes under this scenario are the same as in Scenario 1.

4.3.4 Scenario 4 – Periphyton 20%, DIN 1.0, all ENM bundles, EFW marginal targets

This scenario allows for all ENM bundles to be incorporated, but instead considers the extent to which the EFW marginal targets can be realised.

4.3.4.1 Nitrogen – lowest cost mitigation bundle

Table 4.22 below summarises the results from the application of the lowest cost bundles to each region to the EFW marginal targets. Under this scenario and with all mitigations employed, there is a 100% achievement of the required target of N load reductions of the EFW marginal targets.

As all targets are realised, cost impacts broadly tend to correlate with total target loads, and as such, Canterbury and Waikato bear the largest costs across all regions at 4.6% and 1.7% of per hectare profit respectively.

Table 4.22 Lowest cost mitigation bundles for N – effectiveness and cost

Region	N target under NPS 2020 (t)	Total reduction achieved (t)	% of target load reduction achieved (%)	Average dairy farm profit ($/ha)	Costs of dairy mitigations bundle ($/ha)	% reduction in average dairy farm profit from mitigation costs	Average beef and sheep farm profit ($/ha)	Costs of beef and sheep mitigations bundle ($/ha)	% reduction in average beef and sheep farm profit from mitigation costs
Northland	58.4	58.4	100.0%	17,047	28.7	0.2%	5,215	0.0	0.0%
Auckland	57.7	57.7	100.0%	17,047	0.0	0.0%	5,625	5.2	0.1%
Waikato	2,577.5	2,577.5	100.0%	21,992	374.9	1.7%	5,162	0.0	0.0%
Bay of Plenty	144.5	144.5	100.0%	21,970	52.5	0.2%	5,754	0.0	0.0%
Gisborne	0.3	0.3	100.0%	21,970	9.6	0.0%	3,596	0.0	0.0%
Taranaki	140.7	140.7	100.0%	21,400	20.8	0.1%	3,570	0.0	0.0%
Manawatu-Whanganui	229.0	229.0	100.0%	22,346	72.6	0.3%	3,606	0.0	0.0%
Hawke's Bay	116.6	116.6	100.0%	22,346	243.7	1.1%	4,054	0.0	0.0%
Wellington	13.2	13.2	100.0%	22,346	13.8	0.1%	4,114	0.0	0.0%
Tasman	6.5	6.5	100.0%	13,666	5.1	0.0%	1,655	0.0	0.0%
Nelson	0.0	0.0	-	-	0.0	0.0%	1,635	0.0	0.0%
Marlborough	11.0	11.0	100.0%	29,399	44.5	0.2%	1,242	0.0	0.0%
West Coast	3.3	3.3	100.0%	13,666	0.0	0.0%	3,607	0.6	0.0%
Canterbury	3,079.8	3,079.8	100.0%	29,399	1,339.3	4.6%	1,853	277.0	14.9%
Otago	136.8	136.8	100.0%	23,772	64.5	0.3%	1,335	0.0	0.0%
Southland	604.5	604.5	100.0%	23,772	128.7	0.5%	6,172	0.0	0.0%
TOTAL	7,179.9	7,179.9	100.0%	-					

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Table 4.23 Regional cost distribution under lowest cost mitigation bundles for N

	DAIRY			BEEF AND SHEEP			TOTAL
Region	**Total applicable area (ha)**	**Bundle cost per hectare ($/ha)**	**Total bundle cost ($)**	**Total applicable area (ha)**	**Bundle cost per hectare ($/ha)**	**Total bundle cost ($)**	**Total cost ($)**
Northland	101,518	28.7	2,911,985	1,131,444,666	0.0	0	2,911,985
Auckland	14,499	0.0	0	276,792,514	5.2	144,394	144,394
Waikato	534,504	374.9	200,363,580	3,472,633,430	0.0	0	200,363,580
Bay of Plenty	62,360	52.5	3,272,983	632,614,668	0.0	0	3,272,983
Gisborne	764	9.6	7,340	1,798,578,008	0.0	0	7,340
Taranaki	95,211	20.8	1,984,751	472,123,357	0.0	0	1,984,751
Manawatu-Whanganui	146,849	72.6	10,668,285	7,024,992,480	0.0	0	10,668,285
Hawke's Bay	23,652	243.7	5,764,192	3,808,255,773	0.0	0	5,764,192
Wellington	30,356	13.8	419,052	1,401,749,213	0.0	0	419,052
Tasman	13,350	5.1	68,122	184,303,466	0.0	0	68,122
Nelson	-	0.0	0	2,672,550	0.0	0	0
Marlborough	4,481	44.5	199,465	1,325,645,297	0.0	0	199,465
West Coast	65,272	0.0	0	351,119,833	0.6	20,984	20,984
Canterbury	310,858	1,339.3	416,330,511	11,434,391,713	277.0	316,679,818	733,010,329
Otago	93,869	64.5	6,053,301	11,730,554,068	0.0	0	6,053,301
Southland	211,885	128.7	27,279,967	4,931,636,594	0.0	0	27,279,967
TOTAL	1,709,426	395.1	675,323,535	49,979,507,631	63.4	316,845,196	992,168,730

Under the lowest cost mitigation bundles, the majority of reductions are achieved by the dairy sector, accounting for 82% of the total reduction of the required targets. Due to the majority of reductions being realised by the Dairy sector, the costs to the sector are larger (more than double that of the Beef and Sheep sector), though the total cost is relatively small.

Table 4.24 Sectoral impacts of lowest cost mitigation bundle for N

	Total N reduction (t)	Total cost ($)
Dairy	5,905.3	675,323,535
Beef and Sheep	1,274.6	316,845,196
TOTAL	7,179.9	992,168,730

4.3.4.2 Phosphorus – lowest cost mitigation bundle

After the application of the mitigation bundles for N, we also consider the potential additional mitigations that would be required to meet the P load reduction targets under the marginal targets of the EFW policy. As in the Scenario 1, we include the P load reduction from previous ENM bundles.

Under the lowest cost mitigation bundle, there is an achievement of 78.3% of the target of P load reductions required under the EFW policy. With the exception of Northland, Manawatu-Whanganui and Nelson, all other regions are able to achieve their targets. Nelson, despite its small target, is unable to reach its target due to the lack area identified by the model as eligible for mitigations.

Table 4.25 Lowest cost mitigation bundle for P - impacts

Region	P target under EFW policy (t)	P Reduction from implemented N mitigations (t)	Remaining P target	Potential additional reduction achievable (t)	Total achieved reduction in P (t)	% reduction in total P target
Northland	125.1	4.7	120.4	92.3	97.0	77.5%
Auckland	9.9	0.0	9.9	9.9	9.9	100.0%
Waikato	309.5	263.0	46.5	46.5	309.5	100.0%
Bay of Plenty	118.0	141.1	0.0	0.0	118.0	100.0%
Gisborne	2.3	0.2	2.1	2.1	2.3	100.0%
Taranaki	29.9	33.2	0.0	0.0	29.9	100.0%
Manawatu-Whanganui	245.3	26.4	218.9	44.1	70.5	28.8%
Hawke's Bay	29.3	0.0	29.3	29.3	29.3	100.0%
Wellington	22.6	0.0	22.6	22.6	22.6	100.0%
Tasman	4.9	125.6	0.0	0.0	4.9	100.0%
Nelson	0.2	0.0	0.2	0.1	0.1	42.1%
Marlborough	12.7	0.0	12.7	12.7	12.7	100.0%
West Coast	0.1	255.5	0.0	0.0	0.1	100.0%
Canterbury	7.8	0.2	7.7	7.7	7.8	100.0%
Otago	8.2	35.8	0.0	0.0	8.2	100.0%
Southland	10.5	89.5	0.0	0.0	10.5	100.0%
TOTAL	936.4	975.1	470.3	267.4	733.4	78.3%

In both sectors, the cost impacts of the additional P focused mitigations have the largest reduction in average farm profit in Manawatu-Whanganui and Hawke's Bay. Most dairy regions ended up bearing a slight reduction in average farm profit as a result of implementation of the targeted P mitigations, whilst the majority of beef and sheep regions could realise cost savings through regional achievement of optimal Olsen P.

Table 4.26 Lowest cost mitigation bundles for P – sector impacts

	DAIRY			BEEF AND SHEEP		
Region	Average farm profit ($/ha)	Cost of additional P mitigations applied($/ha) [28]	Reduction in average farm profit	Average farm profit ($/ha)	Cost of additional P mitigations applied($/ha)	Reduction in average farm profit
Northland	17,047	0.0	0.0%	5,215	-285.5	-5.5%
Auckland	17,047	0.0	0.0%	5,625	-256.5	-4.6%
Waikato	21,992	-1.7	0.0%	5,162	-280.2	-5.4%
Bay of Plenty	21,970	-271.7	-1.2%	5,754	-192.3	-3.3%
Gisborne	21,970	0.0	0.0%	3,596	-107.6	-3.0%
Taranaki	21,400	0.0	0.0%	3,570	-185.0	-5.2%
Manawatu-Whanganui	22,346	2,255.0	10.1%	3,606	1,030.5	28.6%
Hawke's Bay	22,346	2,255.0	10.1%	4,054	212.3	5.2%
Wellington	22,346	302.0	1.4%	4,114	-21.3	-0.5%
Tasman	13,666	-518.1	-3.8%	1,655	-116.9	-7.1%
Nelson	-	0.0	0.0%	1,635	-99.3	-6.1%
Marlborough	29,399	320.4	1.1%	1,242	130.6	10.5%
West Coast	13,666	-518.1	-3.8%	3,607	0.0	0.0%
Canterbury	29,399	607.6	2.1%	1,853	-118.7	-6.4%
Otago	23,772	0.0	0.0%	1,335	-184.8	-13.8%
Southland	23,772	0.0	0.0%	6,172	0.0	0.0%

[28] Negative cost values indicate cost savings realised

Table 4.27 Regional cost distribution under lowest cost mitigation bundles for P

	DAIRY			BEEF AND SHEEP			TOTAL
Region	**Total applicable area (ha)**	**Bundle cost per hectare ($/ha)**	**Total bundle cost ($ NPV)**	**Total applicable area (ha)**	**Bundle cost per hectare ($/ha)**	**Total bundle cost ($ NPV)**	**Total cost ($ NPV)**
Northland	101,518	0	0.0	113,144	-285.5	-32,301,835	-32,301,835
Auckland	14,499	0	0.0	27,679	-256.5	-7,099,994	-7,099,994
Waikato	534,504	-884,199	-1.7	347,263	-280.2	-97,307,287	-98,191,486
Bay of Plenty	62,360	-16,944,004	-271.7	63,261	-192.3	-12,163,022	-29,107,026
Gisborne	764	0	0.0	179,858	-107.6	-19,348,063	-19,348,063
Taranaki	95,211	0	0.0	47,212	-185.0	-8,736,379	-8,736,379
Manawatu-Whanganui	146,849	331,140,209	2,255.0	702,499	1,030.5	723,901,447	1,055,041,656
Hawke’s Bay	23,652	53,334,570	2,255.0	380,826	212.3	80,854,845	134,189,415
Wellington	30,356	9,166,004	302.0	140,175	-21.3	-2,979,890	6,186,113
Tasman	13,350	-6,916,198	-518.1	18,430	-116.9	-2,153,990	-9,070,188
Nelson	0	0	0.0	267	-99.3	-26,523	-26,523
Marlborough	4,481	1,435,789	320.4	132,565	130.6	17,309,097	18,744,886
West Coast	65,272	-33,815,286	-518.1	35,112	0.0	0	-33,815,286
Canterbury	310,858	188,865,356	607.6	1,143,439	-118.7	-135,704,166	53,161,189
Otago	93,869	0	0.0	1,173,055	-184.8	-216,813,803	-216,813,803
Southland	211,885	0	0.0	493,164	0.0	0	0
TOTAL	1,709,428	525,382,240	307.3	4,997,949	57.5	287,430,437	812,812,677

Under the lowest cost mitigation bundles, the majority of P reduction is achieved by the beef and sheep sector, accounting for 81% of the total reduction under the scenario, at less than half the cost of mitigations applied to the beef and sheep sector.

Table 4.28 Sectoral impacts of lowest cost mitigation bundle for P

	Load reductions from previously applied mitigations (t)	Total additional P reduction realised (t)	Total cost of additional mitigations ($)
Dairy	12.2	69.4	525,382,240
Beef and sheep	873.3	302.6	287,430,437
TOTAL	885.5	371.9	812,812,677

4.3.5 Comparison of scenario bundles

4.3.5.1 Comparison of N reductions

Table 4.33 Summary of N reductions under scenarios

	Total reduction (t)	% of target	Total cost ($)
Scenario 1 – All mitigation bundles	18,991.7	78.7%	7,025,373,783
Scenario 2 – No M1	15,592.1	64.6%	7,943,994,916
Scenario 3 – No M3	14,037.9	57.2%	995,111,985
Scenario 4 – EFW Marginal targets	7,179.9	100.0%	992,168,730

Table 4.33 shows the difference in N load reductions that can be realised under each of the different scenarios modelled. Comparing Scenario 1 and Scenario 2 illustrates the effectiveness of the M1 bundle in reducing N loads, as in its absence, lower load reductions are realised at a higher cost. In contrast, Scenario 3 highlights that a significant proportion of load reduction can be realised, and that while the M3 mitigation bundle can enable significant load reductions, it does so at a significant cost.

Scenario 4 shows that under the current mitigation set, the N load reductions required under the EFW policy can all be realised.

4.3.5.2 Comparison of P reductions

Table 4.34 Summary of P reductions under scenarios

	Total reduction (t)	% of target	Total cost ($)
Scenario 1 – All mitigation bundles	1,051.0	86.3%	769,878,683
Scenario 2 – No M1	1,024.0	84.0%	1,617,712,133
Scenario 3 – No M3	1,051.0	86.3%	769,878,683
Scenario 4 – EFW Marginal targets	738.6	78.3%	812,812,677

Table 4.34 shows the difference in P load reductions that can be realised under each of the different scenarios modelled. Comparing Scenario 1 and Scenario 2 illustrates the effectiveness of fencing and vegetated buffer strips, particularly when applied to the beef and sheep sector[29] and once this option is removed, the same scale of load reductions is only realised at a significantly higher cost. Scenario 3 results in the same outcome for P as compared to Scenario 1.

Scenario 4 shows that under the current mitigation set, the total P load reduction targets cannot be realised, implying that additional measures or land use change may be required. Notably, the difference between additional costs under Scenario 1 and Scenario 4 highlight

[29] The reduced effectiveness of this mitigation in the dairy sector is due to the assumption that a significant proportion of the sector already has fencing and VBS installed

5. Limitations

We note certain limitations in the analysis undertaken for this report as a result of time, data and information constraints. In particular, several simplifying assumptions were made to enable the modelling in this report, and as such, we stress the importance of interpreting the results of our analysis in the context of these limitations.

5.1 Assumption of average costs, profits and mitigation effectiveness

Due to timing and data constraints, our model ultimately used estimates of averages for costs of mitigations, farm profits and mitigation effectiveness across farm typologies. In practice, all three of these parameters would vary from farm to farm, with farms likely being distributed across a spectrum on all three dimensions. Different distributions of farm profit could likely have significant impact on the results of mitigations – farms with lower profits would be less likely to be able to apply the full suite of mitigations, which would likely lead to lower load reductions in some regions. The analysis also does not include consideration for potential covariances that could exist between farm typologies, mitigation costs and mitigation effectiveness, or between farm profit and pollution loads – in reality, these factors are likely to be all be related, which our simplified analysis did not attempt to model. If this analysis were to be extended, then modelling each of these parameters as distributions might be a more sophisticated way of representing this data (although research would likely have to be undertaken to determine the distributions of each of these parameters).

5.2 Assumptions relating to timing of costs and effects of mitigations

While this report presents the costs and profit impacts of each mitigation set in terms of a 30-year NPV estimate, the model is designed to assess the impact of these mitigations without any modelling of timing in relation to costs and effects of the mitigation. As such, the model assumes that all capital costs are incurred upfront and that, unless specified otherwise, all operating costs continue for 30 years. In reality, some mitigations would likely be implemented over a number of years, and in the case of the ENM bundles, dependencies would likely dictate that some bundles would likely be phased in only after a period of time.

Timing is also not considered for load reductions, as the model only considers whether or not the load reduction target can be achieved over a 30-year period, as we have assumed that the reported effectiveness of mitigations is achieved over 30 years. Future analysis could incorporate timing into realisation of benefits, but this would likely require considerable modelling of how mitigation effects would take place, which were not undertaken for this analysis.

5.3 Assumption of no land use change

Our model assumes the absence of land use change, both as a mitigation for achieving load reduction, but also with respect to the distribution of farm types across regions in New Zealand. This means that the model assumes that the current profile of farm typologies across each region remains the same through to 2050, which in reality, is unlikely to be the case.

5.4 Limited consideration of complementarities between mitigations

While some element of complementarity between mitigations is incorporated, such as the sequencing required for the ENM bundles, the linking of fencing and vegetated buffer strips and the requirement that Optimal Olsen P be achieved before switching to Low water soluble phosphate fertiliser, our model largely does not incorporate any consideration of complementarity between different mitigations. Discussions with experts suggested that there would likely be complementarities that could be realised through particular bundles of mitigations being applied, but this proved too complex to construct and introduce into our modelling set. As such, there is the possibility that the mitigation bundles in our model, which are currently constructed with mitigations being treated as mostly independent to each other, could in fact underestimate potential load reductions that could be realised. Given that load reductions in N and P could be realised across some regions even with the existing mitigation set, this suggests a possibility that load reductions could be realised at a lower cost than what is identified in this report.

6. Conclusion

In this report, we developed a model for assessing the potential impact of the NPS and EFW 2020 policies on the dairy and beef and sheep sectors across New Zealand. This was undertaken by considering the load reduction impacts that would be required at a catchment level to meet the requirements of the policy and considering how successful a strategy of applying a bundle of mitigations aimed at reducing N and P would be in realising these targets. We also undertook scenario analysis constraining the use of specific mitigations to evaluate their importance when constructing mitigation bundles.

Based on applying all available mitigations in sequence starting with the most cost-effective, this indicates the potential to achieve 78.7% of the N load reduction target and 86.3% of the P load reduction target, at a total cost of $8.02B. Under this setting, most regions are able to realise their targets, both under the NPS (2017) and EFW (2020) policies. The exceptions tend to be regions with very large targets such as Canterbury in the case of N and Manawatu-Whanganui in the case of P. Load reductions in these regions will therefore need to be realised through mitigations not incorporated in this analysis, or through land use change to alternative uses that produce much lower concentrations of N and P. The use of scenarios constraining particular mitigations highlights the relative effectiveness of mitigations such as fencing and changes in nitrogen management practice – where these mitigations can be employed, they typically can achieve load reductions at a lower cost.

Under the baseline scenario, the majority of N reductions are realised from the Dairy sector, which realises 69% of the reduction at an NPV cost of $6.2B, while the Beef and Sheep sector realises 31% of the reduction at an NPV cost of $817M. This is in part due to the fact that the majority of N load reductions can be realised by applying mitigations to the Dairy sector without a need to apply mitigations to the Beef and Sheep sector. Conversely, the majority of mitigations for realising P tend to be realised through the Beef and Sheep sector, where mitigations tend to be more effective at reducing loads without a significant increase in price.

It is important to note that our analysis has been undertaken using regional averages, and as such, variations in profitability and cost across farms by their type, sectors and regions are not specifically captured in the model developed for this report, beyond those used to classify Beef and Sheep farms. It is likely in practice, that the most appropriate set of mitigations will vary on a farm-by-farm basis, and it is also possible that individual farms may have already applied particular mitigations or have specific characteristics that yield higher reductions than what has been applied in our analysis. As such, the findings of this report provide an indication of where potential load reductions across sector and region could be realised, as well as highlighting how the potential costs of mitigations may be distributed.

Attachment 1: Mitigation cost modelling assumptions

Mitigation category	Assumptions

Fencing	• Only applies to land classified as 'flat' or 'moderate'
	• Fencing mitigations are only effective where new fencing would be additive – the proportion of areas in each region where this is the case are summarised in Table 3.1
	• Metres of fencing are based on total stream length (in km) as identified by the stock exclusion report and the estimates of m/ha per typology and region calculated by Tim
	• Streams are assumed to be straight lines, and as such, total area fenced off is assumed to be a rectangular polygon of dimensions (river length) x (setback length)
	• Setback is assumed to be 5m
	• Capital and operational costs are based on a range of the minimum and maximum estimates provided by Perrin Ag, differentiated by region and by sheep/cattle and dairy cattle
	• Cost of fencing is based on the following costs:
	  o Beef and sheep sector: Electric 4 wire
	  o Dairy: Electric 2 wire
	• Land retirement costs are calculated based on the per hectare profitability across region and sector, and applied to the total fenced off area
	• Capital costs are assumed to all be applied in Y0 (2020-21) while maintenance costs are assumed to begin from Y1 (2021-22) through to Y30 (2050-51)
	• Fencing is assumed to have a 30-year life and thus all capital cost is incurred once at Y0

Vegetated buffer strips	• Only applies to land classified as 'flat' or 'moderate' • Vegetated buffer strips are assumed to be planted in 20% of the areas designated for setback identified in the fencing and riparian exclusion section • Foregone profits and fencing costs are not included in the calculation of costs to avoid double counting with Fencing assumptions • Capital and operational costs are based on a range of the minimum and maximum estimates provided by Perrin Ag • Capital costs are assumed to all be applied in Y0 (2020-21) while maintenance costs are assumed to begin from Y1 (2021-22) through to Y30 (2050-51)
Achieving Optimal Olsen P levels	• Assumes costs are only borne for regions which are currently above optimum Olsen P – for regions which are currently below optimum Olsen P, it is assumed that they would increase the use of P fertiliser driven by commercial incentive independent of the policy • For all regions above optimal Olsen P, movement to the optimum currently applies to all hectares across all sectors • Annual savings/costs are based on a range of the minimum and maximum estimates provided by Perrin Ag, differentiated by region and by sector and values assigned to defined typologies

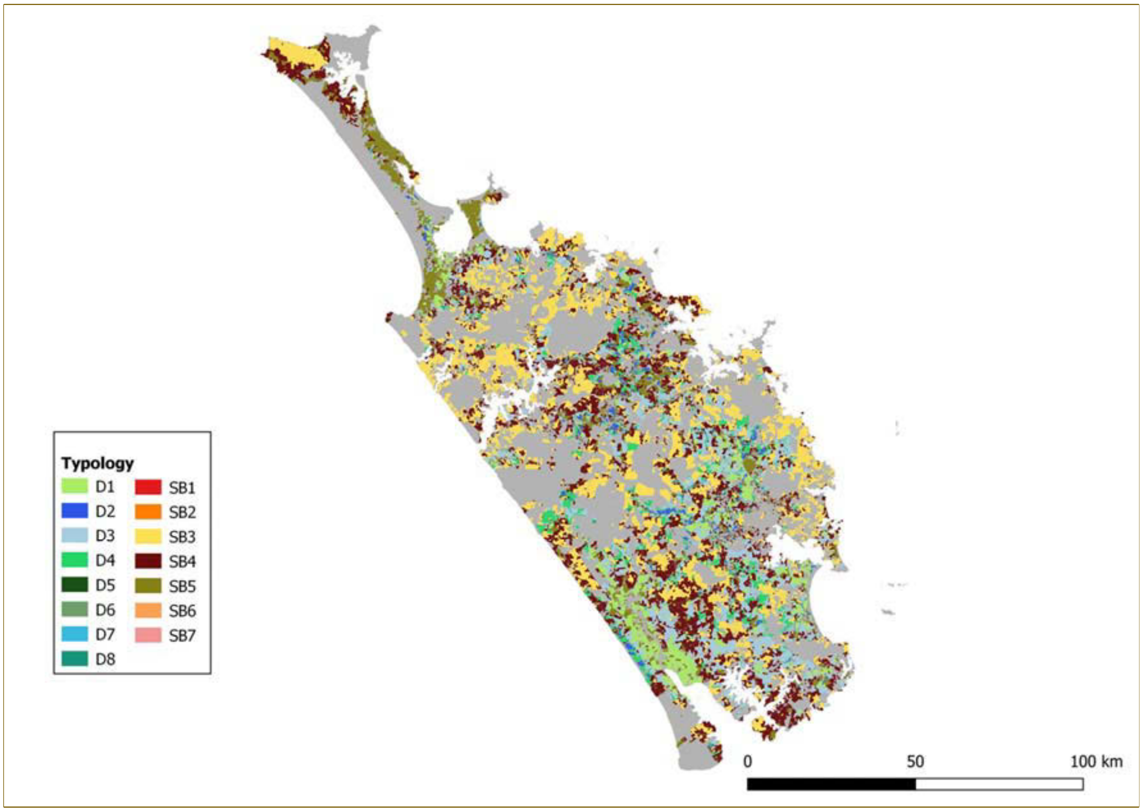
	• Where Perrin Ag regions have not directly aligned with Regional Councils, we have chosen the closest regional analogue based on the region's physical factors
	• For the purposes of costing this mitigation, the formula is as such:
	  ○ For the number of years of no phosphorus required, the region is able to use no P fertiliser and this will realise cost savings of (the total current cost of phosphorus in $/ha)*(total number of hectares in the region under each typology). Essentially, in this instance, the region can benefit from reducing its P concentration and so does not need apply any fertiliser.
	  ○ Once the number of years of no phosphorus required has elapsed, the region will then need to apply at the maintenance level ($/ha)* (total number of hectares in each region under each typology)
	  ○ The base case for this mitigation is assuming regions continue their current P fertiliser regime, and so they pay (the cost of current phosphorus in $/ha)*(total number of hectares in the region under each typology) – thus, the additional cost (or saving) is the difference between the maintenance regime and the current regime applied to all hectares

Switching to low water-soluble phosphorus fertiliser	• Currently applies to all hectares across all sectors • Assumes all applicable farms are applying maintenance phosphorus fertiliser to maintain optimum Olsen P • Annual costs are based on a range of the minimum and maximum estimates provided by Perrin Ag, differentiated by region and by sector and values assigned to defined typologies • Assumes a 3-year transition period from 100% Superphosphate (the base case) to applying 100% Dicalcic phosphate, at which point the latter's cost rate applies from Y3 onward • Where Perrin Ag regions have not directly aligned with Regional Councils, we have chosen the closest regional analogue based on physical characteristics
Construction of wetlands	• Assumes 2% of all hectares in each region where land is 'flat' or 'moderate' and with a 'poor' drainage class are transformed into wetlands • Wetlands are assumed to take the form of 1 hectare squares – this means each hectare incorporates 400m (4 x 100m) of fencing and include the cost of planting of vegetated buffer strips based on the fence size and a buffer offset (5m in this case) • Capital and operational costs are based on a range of the minimum and maximum estimates provided by Perrin Ag with differentiated cost for fencing associated by sector (different costs for beef/sheep and dairy) • Land retirement costs are calculated based on the per hectare profitability differentiated by region and sector applied to total land converted to wetlands
Stock reduction	• Assumes an equivalent reduction in profitability following a reduction in stock numbers (e.g. a 10% reduction in stock numbers results in a 10% reduction in profit)

Attachment 2: Regional typologies

Northland

Distribution of farms by typology in the Northland Region

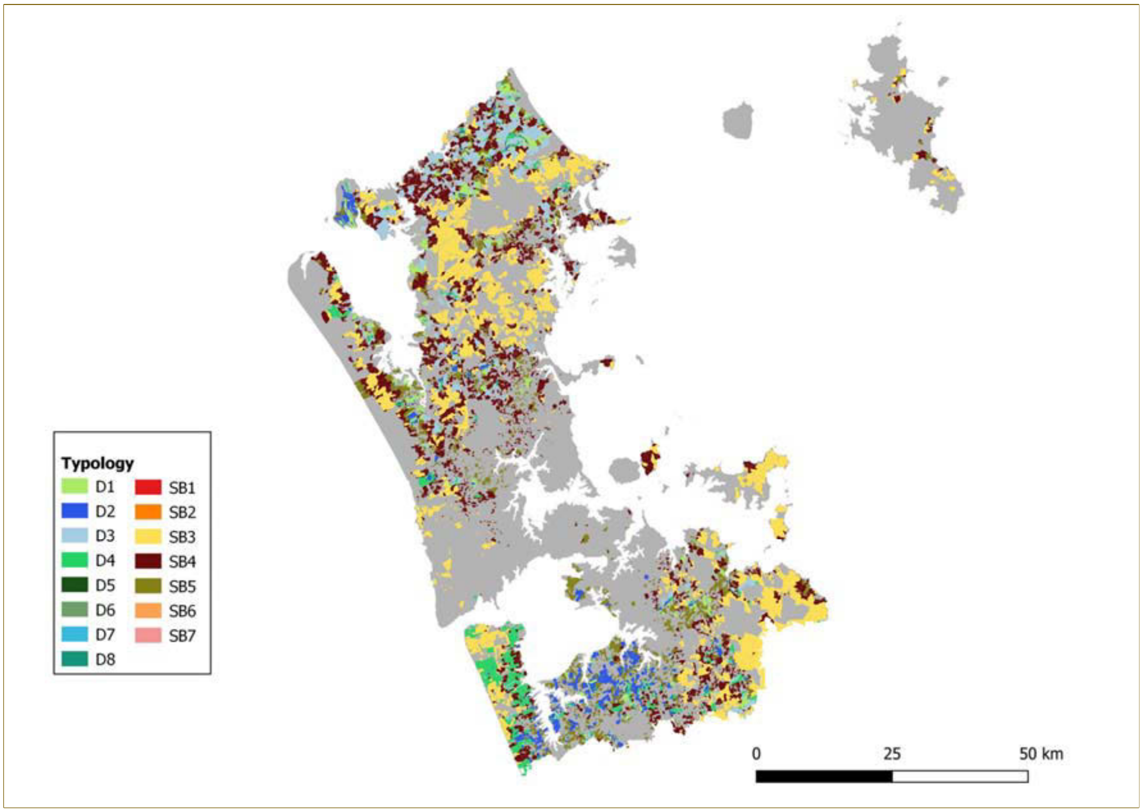


Breakdown of Northland region by typology

	Area (ha)		Area (ha)
D1	42,124	SB1	0
D2	12,222	SB2	0
D3	80,966	SB3	143,908
D4	33,413	SB4	118,113
D5	0	SB5	45,803
D6	0	SB6	0
D7	0	SB7	0
D8	48		

Auckland

Distribution of farms by typology in the Auckland Region

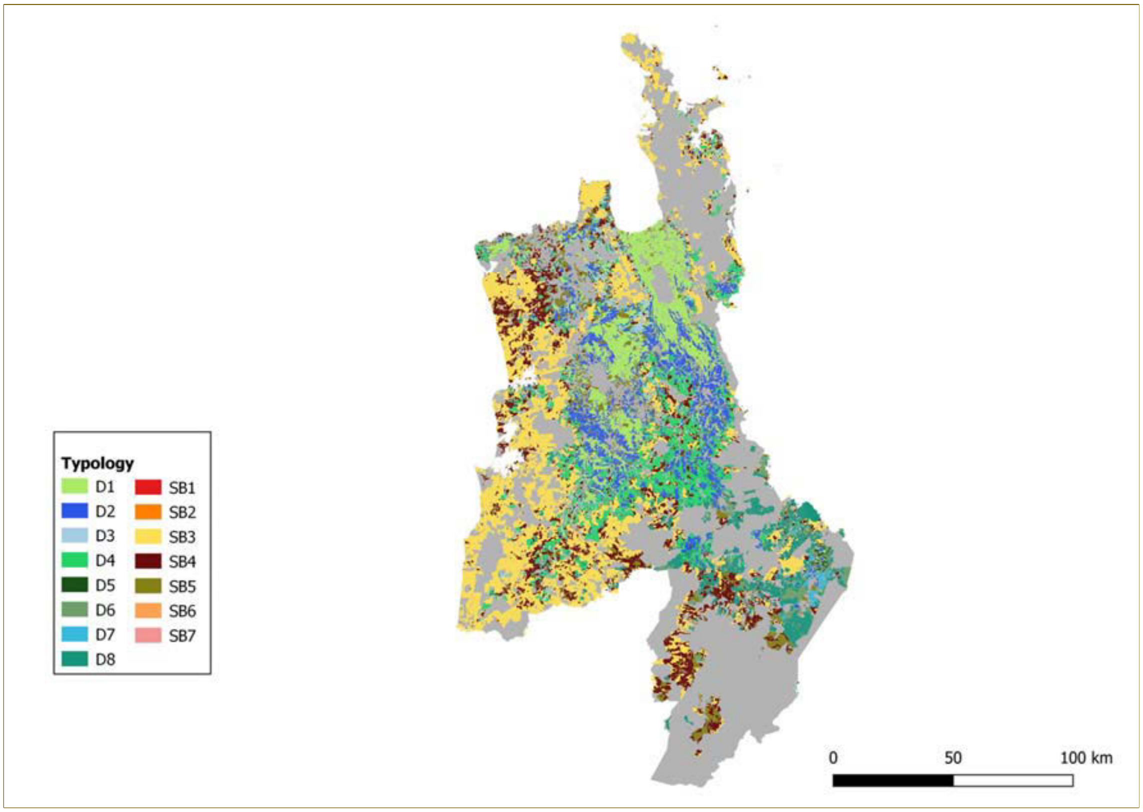


Breakdown of Auckland region by typology

	Area (ha)		Area (ha)
D1	6,534	SB1	0
D2	8,799	SB2	0
D3	13,765	SB3	44,176
D4	9,367	SB4	35,346
D5	0	SB5	14,944
D6	0	SB6	0
D7	0	SB7	0
D8	0		

Waikato

Distribution of farms by typology in the Waikato Region

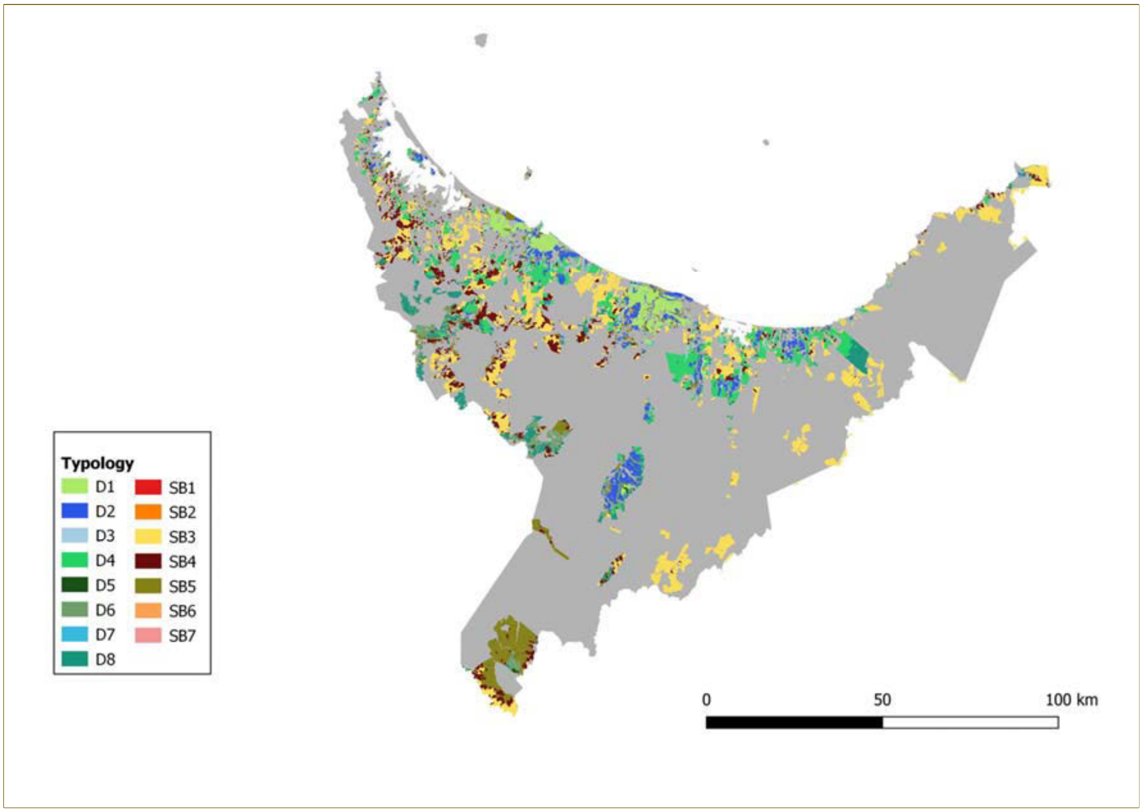


Breakdown of Waikato region by typology

	Area (ha)		Area (ha)
D1	147,369	SB1	0
D2	123,793	SB2	0
D3	28,108	SB3	290,339
D4	139,742	SB4	120,323
D5	2,528	SB5	57,724
D6	26,654	SB6	0
D7	6,307	SB7	0
D8	84,601		

Bay of Plenty

Distribution of farms by typology in the Bay of Plenty Region

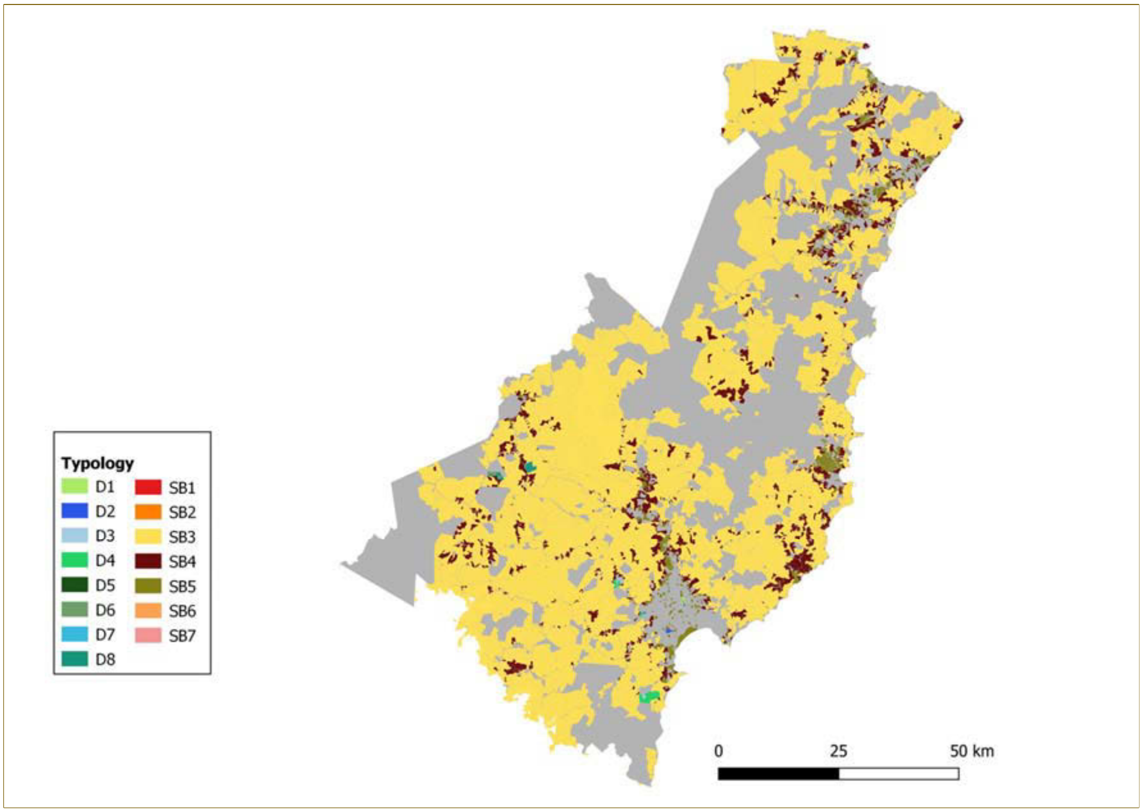


Breakdown of Bay of Plenty region by typology

	Area (ha)		Area (ha)
D1	16,719	SB1	0
D2	19,858	SB2	0
D3	2,715	SB3	61,105
D4	37,419	SB4	22,512
D5	524	SB5	19,375
D6	9,943	SB6	0
D7	296	SB7	0
D8	15,910		

Gisborne

Distribution of farms by typology in the Gisborne Region

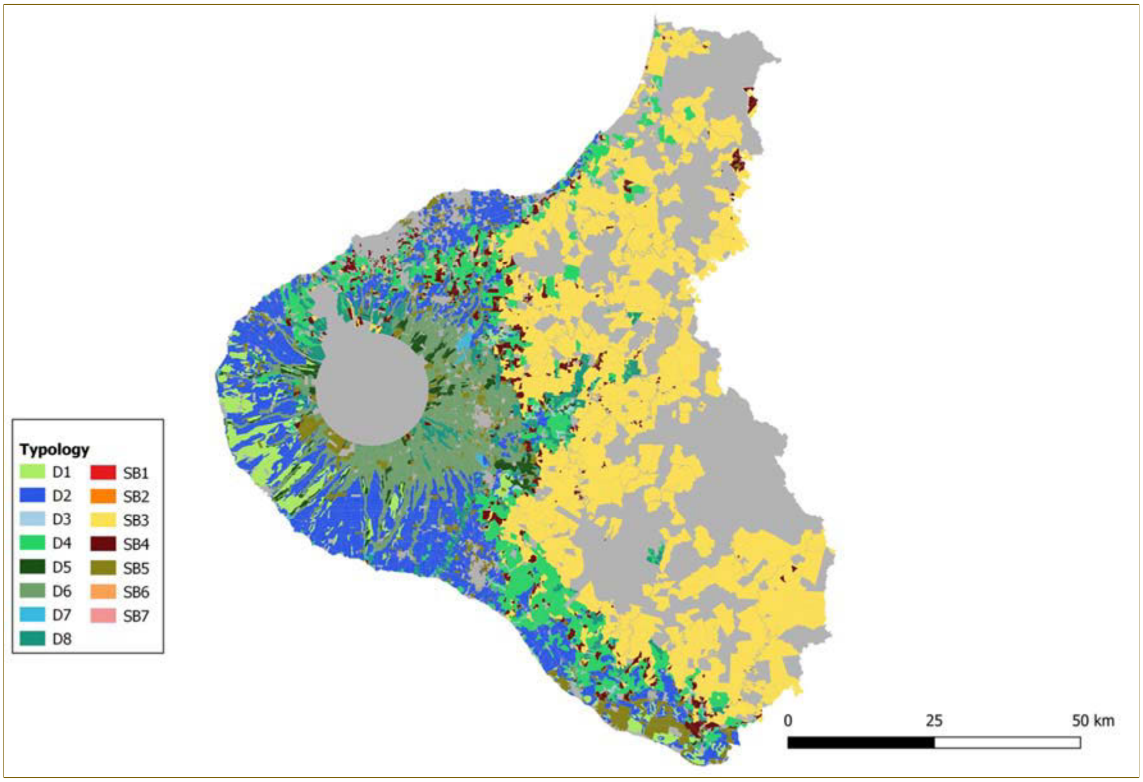


Breakdown of Gisborne region by typology

	Area (ha)		Area (ha)
D1	89	SB1	0
D2	113	SB2	0
D3	157	SB3	307,083
D4	754	SB4	28,168
D5	0	SB5	7,460
D6	138	SB6	0
D7	0	SB7	0
D8	437		

Taranaki

Distribution of farms by typology in the Taranaki Region

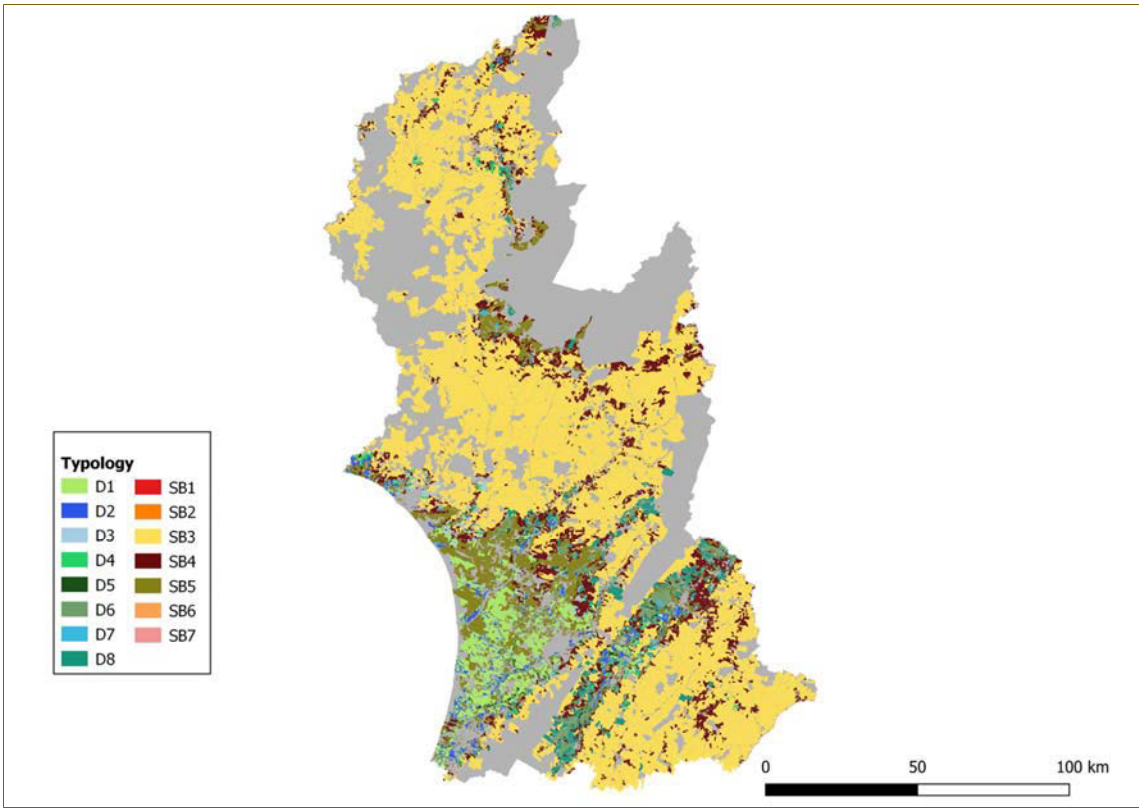


Breakdown of Taranaki region by typology

	Area (ha)		Area (ha)
D1	15,205	SB1	0
D2	68,503	SB2	0
D3	1,959	SB3	133,332
D4	43,224	SB4	11,550
D5	6,708	SB5	13,174
D6	40,522	SB6	0
D7	960	SB7	0
D8	15,835		

Manawatu-Whanganui

Distribution of farms by typology in the Manawatu-Whanganui Region

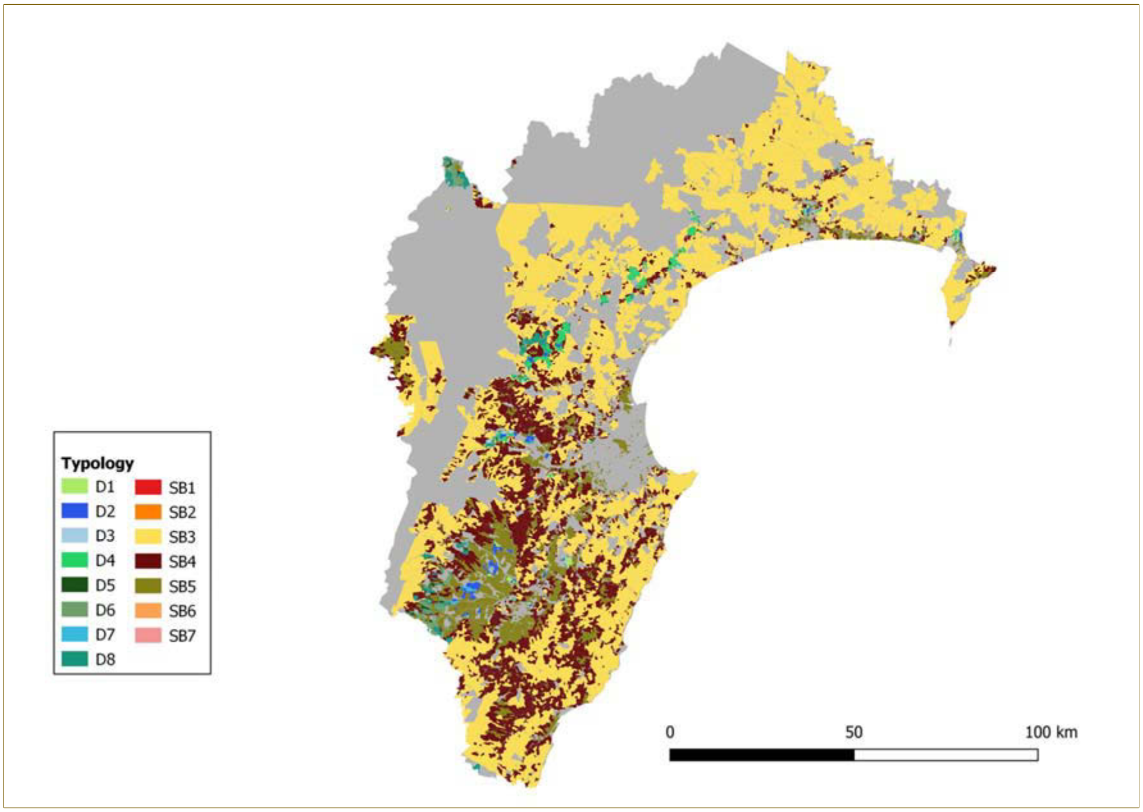


Breakdown of Manawatu-Whanganui region by typology

	Area (ha)		Area (ha)
D1	54,410	SB1	0
D2	18,950	SB2	0
D3	6,986	SB3	594,826
D4	8,967	SB4	99,226
D5	6,929	SB5	84,017
D6	21,290	SB6	0
D7	2,247	SB7	0
D8	31,590		

Hawke's Bay

Distribution of farms by typology in the Hawkes Bay Region

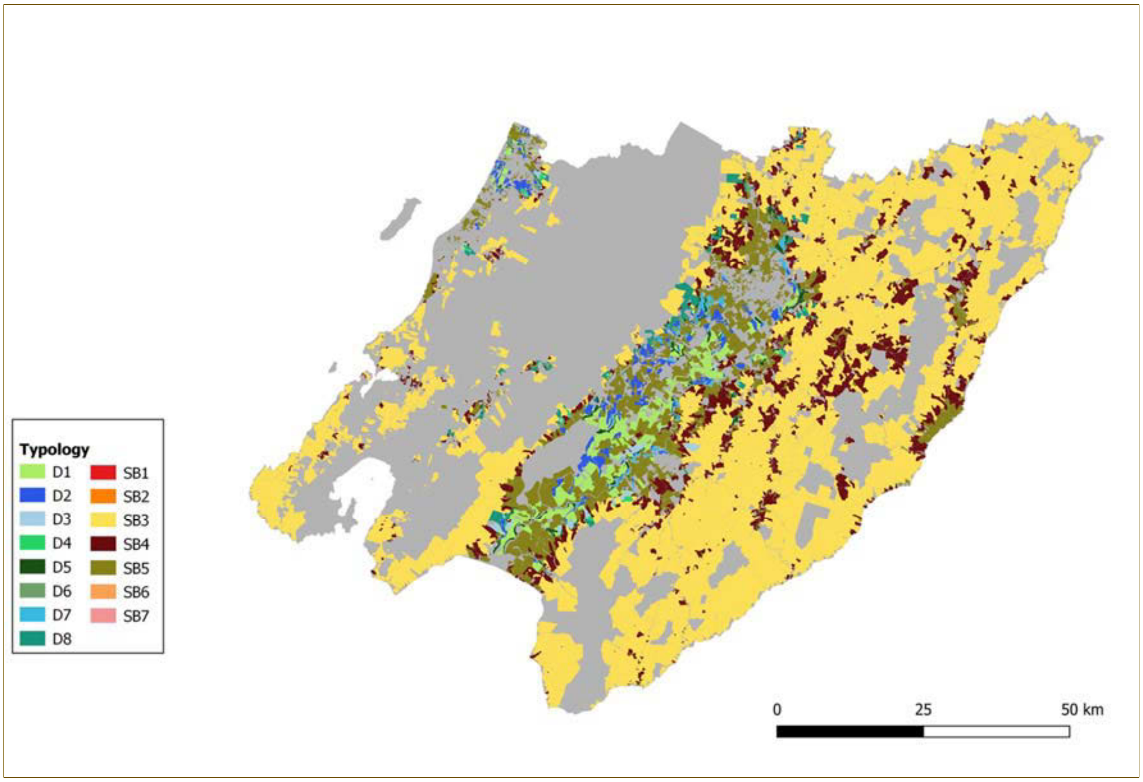


Breakdown of Hawke's Bay region by typology

	Area (ha)		Area (ha)
D1	1,277	SB1	0
D2	3,689	SB2	0
D3	1,198	SB3	333,507
D4	6,729	SB4	116,743
D5	1,054	SB5	50,170
D6	4,738	SB6	0
D7	687	SB7	0
D8	6,805		

Wellington

Distribution of farms by typology in the Northland Region

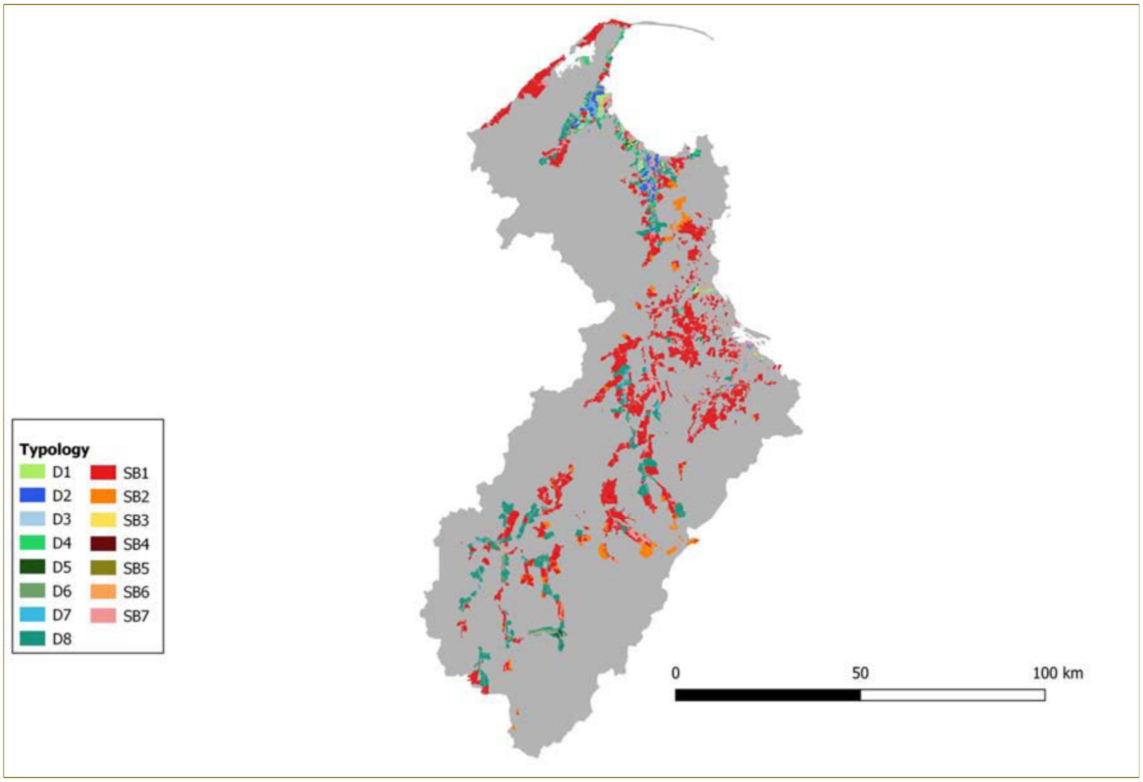


Breakdown of Wellington region by typology

	Area (ha)		Area (ha)
D1	12,203	SB1	0
D2	6,731	SB2	0
D3	1,859	SB3	201,201
D4	614	SB4	30,863
D5	2,668	SB5	33,648
D6	1,465	SB6	0
D7	1,993	SB7	0
D8	4,480		

Tasman

Distribution of farms by typology in the Tasman Region

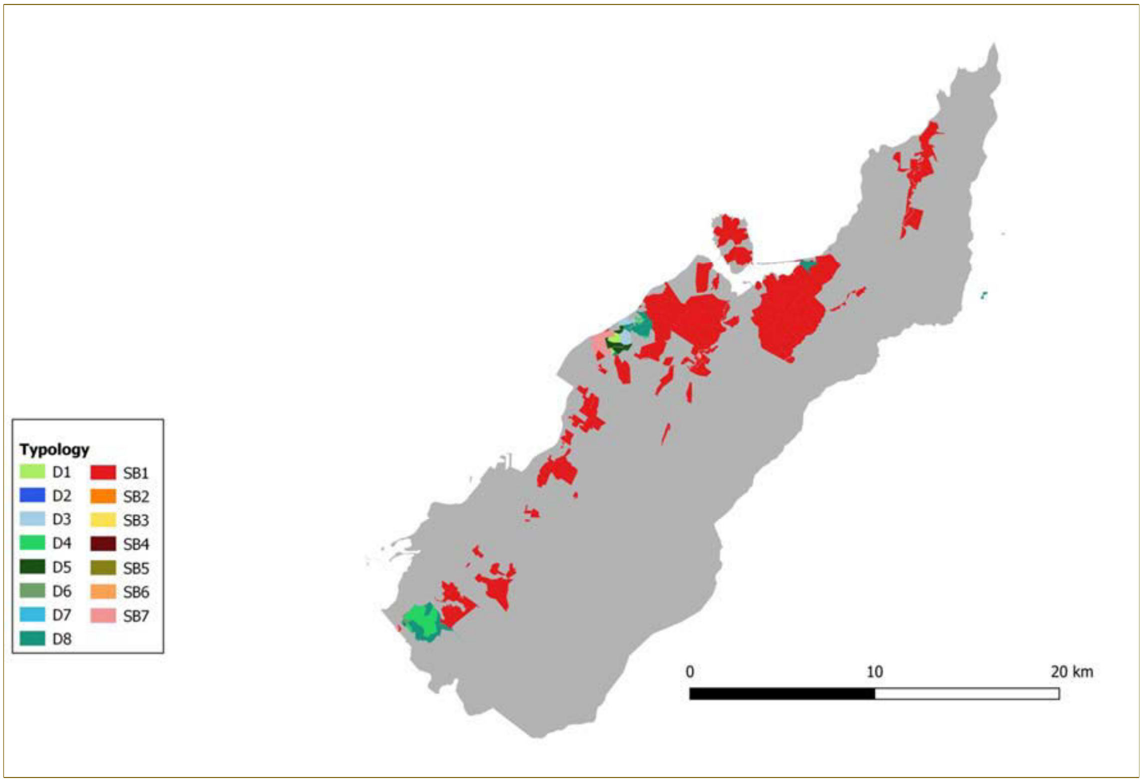


Breakdown of Tasman region by typology

	Area (ha)		Area (ha)
D1	2,054	SB1	53,259
D2	3,215	SB2	6,313
D3	1,336	SB3	0
D4	2,863	SB4	0
D5	806	SB5	0
D6	2,310	SB6	0
D7	1,778	SB7	5,479
D8	21,207		

Nelson

Distribution of farms by typology in the Nelson Region

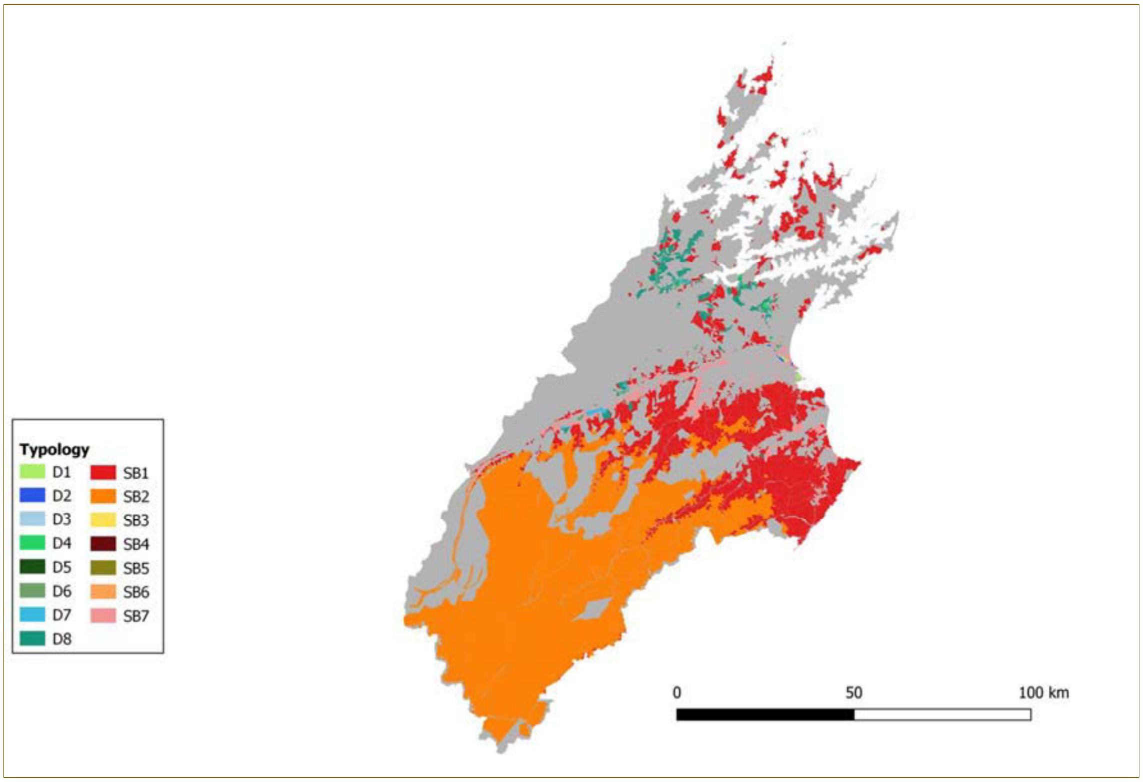


Breakdown of Nelson region by typology

	Area (ha)		Area (ha)
D1	25	SB1	3,164
D2	0	SB2	0
D3	56	SB3	0
D4	157	SB4	0
D5	55	SB5	0
D6	9	SB6	0
D7	0	SB7	75
D8	239		

Marlborough

Distribution of farms by typology in the Marlborough Region

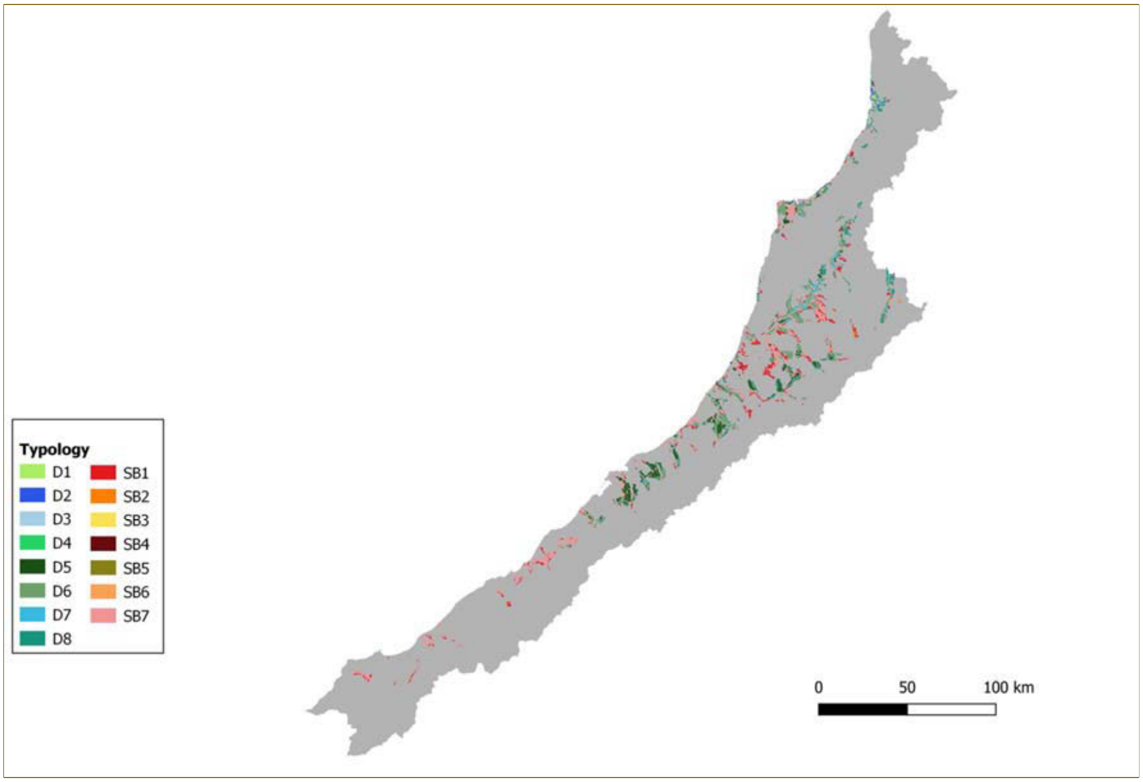


Breakdown of Marlborough region by typology

	Area (ha)		Area (ha)
D1	474	SB1	105,748
D2	231	SB2	223,352
D3	65	SB3	0
D4	789	SB4	0
D5	88	SB5	0
D6	489	SB6	0
D7	1,226	SB7	11,630
D8	10,741		

West Coast

Distribution of farms by typology in the West Coast Region

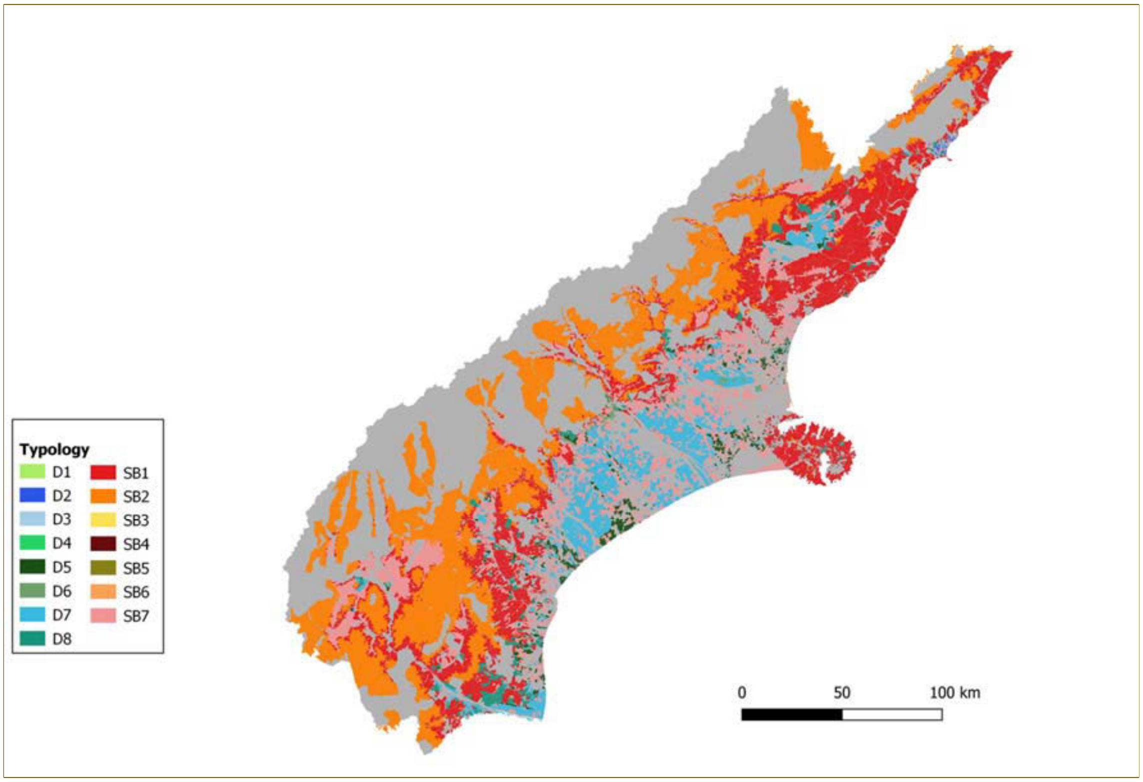


Breakdown of West Coast region by typology

	Area (ha)		Area (ha)
D1	1,351	SB1	22,194
D2	2,085	SB2	514
D3	371	SB3	0
D4	657	SB4	0
D5	24,103	SB5	0
D6	32,745	SB6	0
D7	3,861	SB7	29,668
D8	26,764		

Canterbury

Distribution of farms by typology in the Canterbury Region

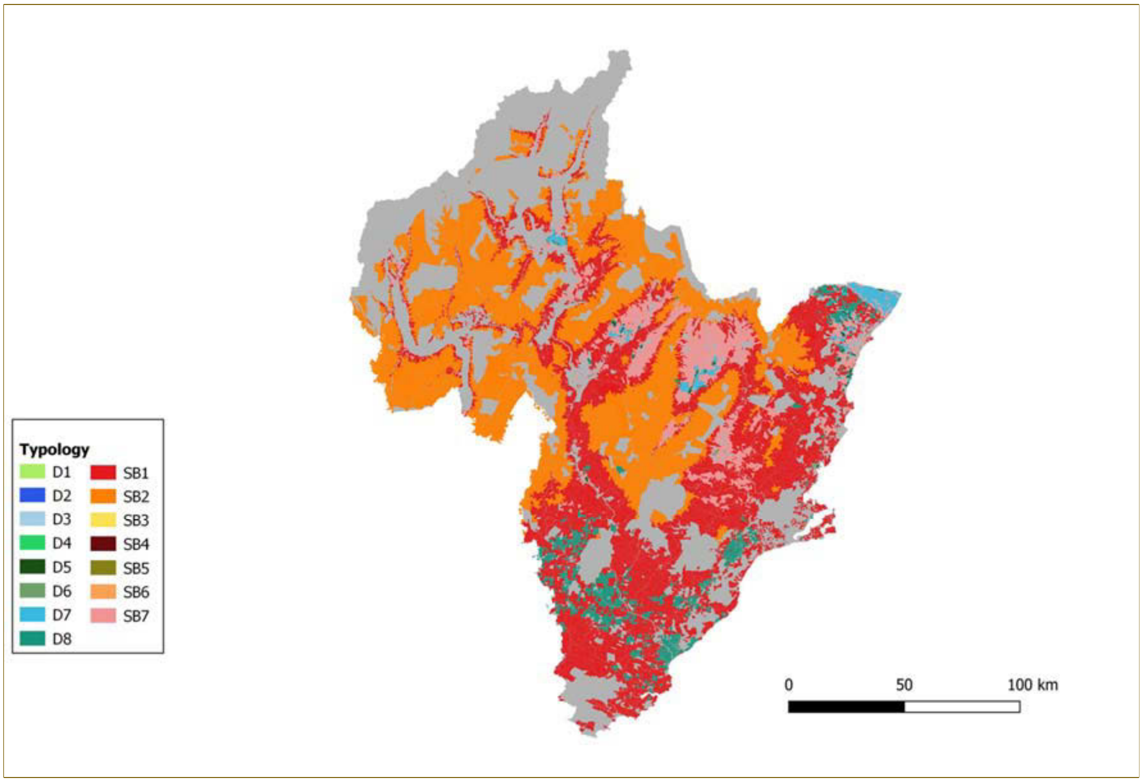


Breakdown of Canterbury region by typology

	Area (ha)		Area (ha)
D1	182	SB1	468,485
D2	1,879	SB2	637,347
D3	91	SB3	0
D4	269	SB4	0
D5	47,194	SB5	0
D6	14,571	SB6	0
D7	212,608	SB7	267,939
D8	47,145		

Otago

Distribution of farms by typology in the Otago Region

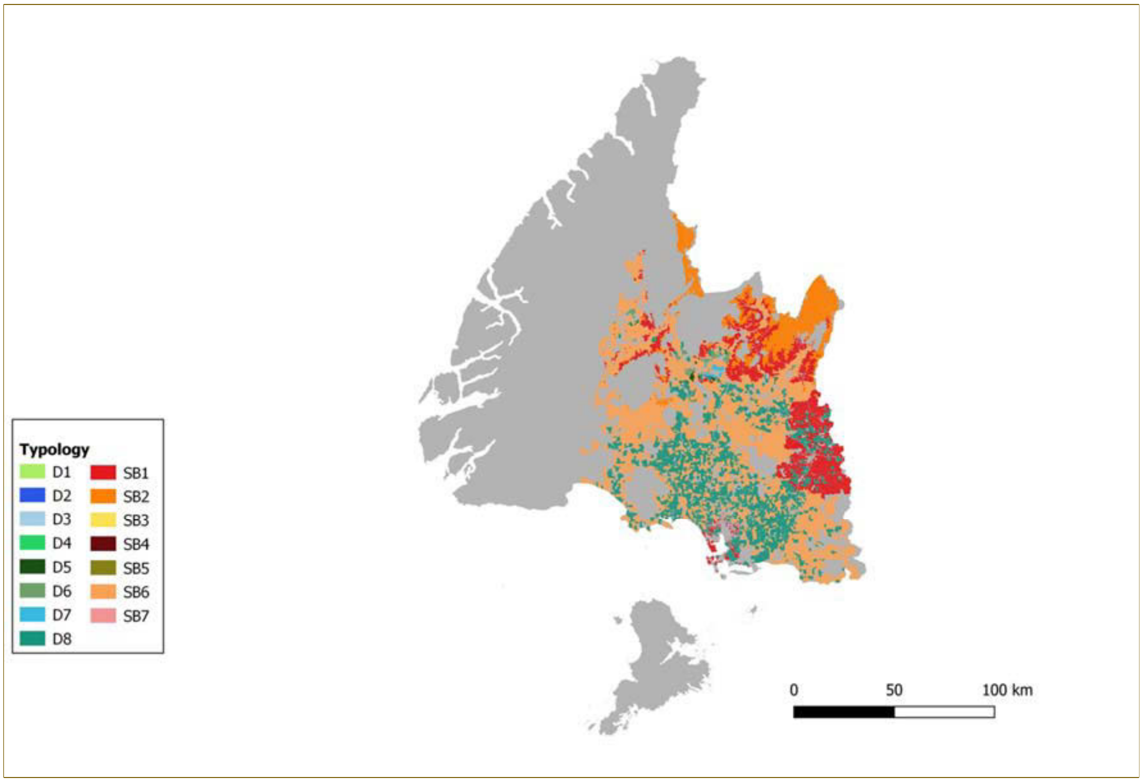


Breakdown of Otago region by typology

	Area (ha)		Area (ha)
D1	0	SB1	583,901
D2	0	SB2	590,635
D3	0	SB3	0
D4	2	SB4	0
D5	3,873	SB5	0
D6	1,108	SB6	0
D7	22,333	SB7	116,679
D8	86,122		

Southland

Distribution of farms by typology in the Southland Region



Breakdown of Southland region by typology

	Area (ha)		Area (ha)
D1	0	SB1	112,504
D2	0	SB2	77,352
D3	2	SB3	0
D4	0	SB4	0
D5	2,156	SB5	0
D6	6,739	SB6	320,252
D7	2,814	SB7	0
D8	203,709		

Attachment 3: Mitigations applied

The table below summarises the total mitigations applied to each region aimed at reducing N under Scenario 1.

Mitigations applied in each region to achieve N reduction at lowest cost in Scenario 1

	Mitigations in bundle
Northland	1. Enhanced Nitrogen Management – Bundle 1 (Dairy)
Auckland	1. Enhanced Nitrogen Management – Bundle 1 (Beef and Sheep)
Waikato	1. Enhanced Nitrogen Management – Bundle 1 (Dairy) 2. Enhanced Nitrogen Management – Bundle 2 (Dairy) 3. Enhanced Nitrogen Management – Bundle 1 (Beef and Sheep)
Bay of Plenty	1. Enhanced Nitrogen Management – Bundle 1 (Dairy)
Gisborne	1. Enhanced Nitrogen Management – Bundle 1 (Dairy) 2. Enhanced Nitrogen Management – Bundle 2 (Dairy) 3. Enhanced Nitrogen Management – Bundle 1 (Beef and Sheep)
Taranaki	1. Enhanced Nitrogen Management – Bundle 1 (Dairy) 2. Enhanced Nitrogen Management – Bundle 1 (Beef and Sheep)
Manawatu-Wanganui	1. Enhanced Nitrogen Management – Bundle 1 (Dairy) 2. Enhanced Nitrogen Management – Bundle 2 (Dairy) 3. Enhanced Nitrogen Management – Bundle 1 (Beef and Sheep) 4. Enhanced Nitrogen Management – Bundle 2 (Beef and Sheep)
Hawke's Bay	1. Enhanced Nitrogen Management – Bundle 1 (Dairy) 2. Enhanced Nitrogen Management – Bundle 2 (Dairy) 3. Enhanced Nitrogen Management – Bundle 3 (Dairy) 4. Enhanced Nitrogen Management – Bundle 1 (Beef and Sheep)
Wellington	1. Enhanced Nitrogen Management – Bundle 1 (Dairy) 2. Enhanced Nitrogen Management – Bundle 2 (Dairy)
Tasman	1. Enhanced Nitrogen Management – Bundle 1 (Dairy)
Nelson	1. Enhanced Nitrogen Management – Bundle 1 (Beef and Sheep)
Marlborough	1. Enhanced Nitrogen Management – Bundle 1 (Dairy)
West Coast	1. Enhanced Nitrogen Management – Bundle 1 (Beef and Sheep)
Canterbury	1. Enhanced Nitrogen Management – Bundle 1 (Dairy) 2. Enhanced Nitrogen Management – Bundle 2 (Dairy) 3. Enhanced Nitrogen Management – Bundle 1 (Beef and Sheep) 4. Enhanced Nitrogen Management – Bundle 2 (Beef and Sheep) 5. Enhanced Nitrogen Management – Bundle 3 (Beef and Sheep) 6. Enhanced Nitrogen Management – Bundle 3 (Dairy)
Otago	1. Enhanced Nitrogen Management – Bundle 1 (Dairy) 2. Enhanced Nitrogen Management – Bundle 1 (Beef and Sheep)
Southland	1. Enhanced Nitrogen Management – Bundle 1 (Dairy) 2. Enhanced Nitrogen Management – Bundle 1 (Beef and Sheep) 3. Enhanced Nitrogen Management – Bundle 2 (Beef and Sheep) 4. Enhanced Nitrogen Management – Bundle 2 (Dairy) 5. Enhanced Nitrogen Management – Bundle 3 (Beef and Sheep) 6. Enhanced Nitrogen Management – Bundle 3 (Dairy)

The following mitigation bundles are applied at each region to achieve P load reduction following from the application of the mitigations targeted at N in the previous table, which includes the following mitigations that reduce P:

- Enhanced Nitrogen Management – Bundle 1 includes Fencing and Vegetated Buffer Strips
- Enhanced Nitrogen Management – Bundle 2 includes Constructed Wetlands

As such, with the exception of West Coast, where only Fencing and Vegetated Buffer Strips were applied for Beef and Sheep and Nelson, which had no mitigations applied for N, every other region has the above three mitigations already applied.

Mitigations applied in each region to achieve P reduction at lowest cost

	Additional mitigations applied specifically to reduce P
Northland	1. Achieving optimal Olsen P (Beef and Sheep)
Auckland	1. Achieving optimal Olsen P (Beef and Sheep) 2. Achieving optimal Olsen P (Dairy) 3. Low water-soluble phosphate fertiliser (Dairy)
Waikato	1. Achieving optimal Olsen P (Dairy) 2. Achieving optimal Olsen P (Beef and Sheep) 3. Low water-soluble phosphate fertiliser (Beef and Sheep) 4. Low water-soluble phosphate fertiliser (Dairy)
Bay of Plenty	1. Achieving optimal Olsen P (Dairy) 2. Achieving optimal Olsen P (Beef and Sheep)
Gisborne	1. Achieving optimal Olsen P (Beef and Sheep)
Taranaki	1. Achieving optimal Olsen P (Beef and Sheep) 2. Achieving optimal Olsen P (Dairy) 3. Low water-soluble phosphate fertiliser (Dairy) 4. Low water-soluble phosphate fertiliser (Beef and Sheep)
Manawatu-Wanganui	1. Achieving optimal Olsen P (Beef and Sheep) 2. Achieving optimal Olsen P (Dairy) 3. Low water-soluble phosphate fertiliser (Dairy)
Hawke's Bay	1. Achieving optimal Olsen P (Beef and Sheep) 2. Achieving optimal Olsen P (Dairy) 3. Low water-soluble phosphate fertiliser (Dairy) 4. Low water-soluble phosphate fertiliser (Beef and Sheep)
Wellington	1. Achieving optimal Olsen P (Beef and Sheep) 2. Achieving optimal Olsen P (Dairy) 3. Low water-soluble phosphate fertiliser (Dairy)
Tasman	1. Achieving optimal Olsen P (Dairy)
Nelson	1. Achieving optimal Olsen P (Beef and Sheep) 2. Low water-soluble phosphate fertiliser (Beef and Sheep)
Marlborough	1. Achieving optimal Olsen P (Dairy) 2. Achieving optimal Olsen P (Beef and Sheep) 3. Low water-soluble phosphate fertiliser (Dairy) 4. Low water-soluble phosphate fertiliser (Beef and Sheep)
West Coast	1. Achieving optimal Olsen P (Dairy)
Canterbury	1. Achieving optimal Olsen P (Beef and Sheep) 2. Achieving optimal Olsen P (Dairy)

	3. Low water-soluble phosphate fertiliser (Dairy) 4. Low water-soluble phosphate fertiliser (Beef and Sheep)
Otago	1. Achieving optimal Olsen P (Beef and Sheep) 2. Achieving optimal Olsen P (Dairy) 3. Low water-soluble phosphate fertiliser (Dairy) 4. Low water-soluble phosphate fertiliser (Beef and Sheep)
Southland	1. Achieving optimal Olsen P (Dairy)

Attachment 4: Bibliography and references

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'Sapere' comes from Latin (to be wise) and the phrase 'sapere aude' (dare to be wise). The phrase is associated with German philosopher Immanuel Kant, who promoted the use of reason as a tool of thought; an approach that underpins all Sapere's practice groups.

We build and maintain effective relationships as demonstrated by the volume of repeat work. Many of our experts have held leadership and senior management positions and are experienced in navigating complex relationships in government, industry, and academic settings.

We adopt a collaborative approach to our work and routinely partner with specialist firms in other fields, such as social research, IT design and architecture, and survey design. This enables us to deliver a comprehensive product and to ensure value for money.

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