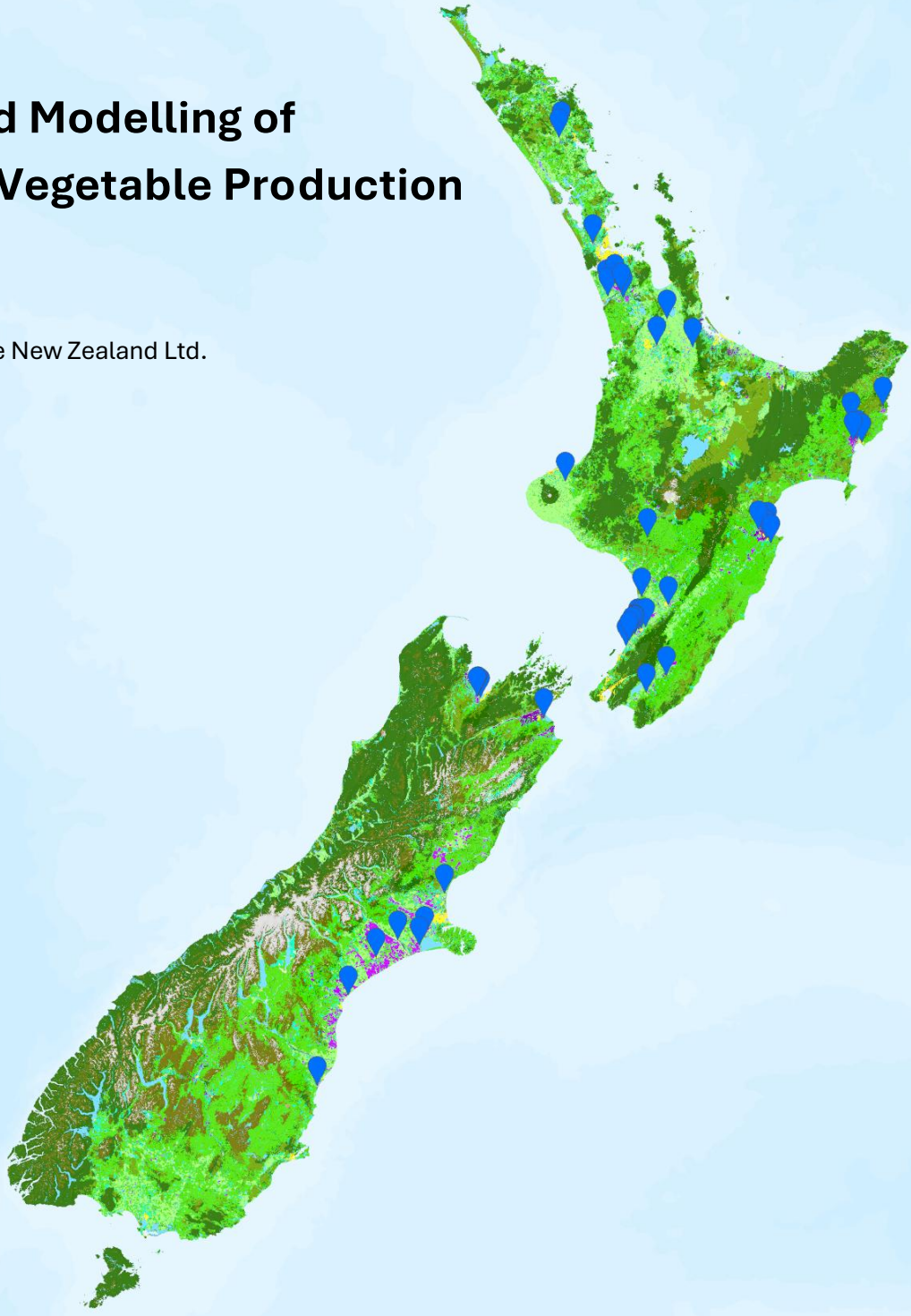
Nitrogen Load Modelling of Commercial Vegetable Production

March 2025

Prepared for: Horticulture New Zealand Ltd.



14-MAR-25

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Summary

This report documents the data sources and processing undertaken to develop a Nitrogen Load Model (NLM) to estimate the relative contribution of diffuse Nitrogen (N) loads from different land uses in the major vegetable production zones in New Zealand.

Model results for the current state are provided alongside water quality state information and land use area for 46 LAWA catchments in the major Commercial Vegetable Growing (CVG) production zones. Future scenarios are tested to estimate the impact of CVG expansion in-line with population growth and the adoption of Good Management Practices (GMPs) for CVG.

In general, it is predicted that CVG contributes a relatively small proportion of total N load (< 5% across the 46 modelled catchments). For 6 small lowland streams, CVG systems are predicted to contribute the majority of the total N load across land uses. The combined area of the 6 catchments (8,605 ha) equates to 0.25% of the assessed area (3,505,792 ha across 46 catchments). Catchment N load change following expansion is predicted to be small (± < 2%) with both increases and reductions predicted for the modelled catchments. Most of the modelled scenarios show that with the adoption of GMPs for CVG, CVG production can expand to meet population growth without an overall increase in catchment N loads.

Contents

1 Introduction

Collaborations have been engaged by Horticulture New Zealand Limited (HortNZ) to map land use and model annual diffuse Nitrogen (N) loads across New Zealand with a focus on Commercial Vegetable Growing (CVG) and the catchments where CVG occurs.

Section 2 describes the mapping data sources. The N load modelling methodology and literature is described in Section 3. Scenario modelling methods are given in Section 0 and results are presented and discussed in Section 5.

2 Land use mapping

The land use mapping methodology and data sources are described under the following headings. The mapping represents a snapshot in time of approximately 2018 for most land uses, however more recent information has been included for Horticulture derived from the NZGAP Environmental Management System (EMS) and other local information. It is expected that the mapping is updated as new and updated information becomes available. In general, the mapping represents the current best available information and provides a robust estimate of land use configuration for catchment mapping and modelling purposes.

2.1 Non-CVG land use

Spatial extents for land-uses other than CVG have been derived from the Landcover Database (LCDB, version 5[1]) for the year 2018. Dairy and Sheep and Beef systems were mapped using the available typology shapefiles described in Monaghan et al. (2021), intersected with the LCDB pastoral land categories ('high producing grassland' and 'low producing grassland'). The remaining LCDB pastoral land was assigned as Other Animals and Lifestyle Blocks.

2.2 Cropping and CVG

Cropping and CVG growing extents have been estimated from multiple sources as listed in Table 1 below. Mapping was based on available information which differed per region. It is recognised that the accuracy of the mapped cropping and CVG growing extents is variable, however it is reflective of the best information currently available and/or held by Collaborations and Horticulture New Zealand.

In general, the mapping accuracy is best in the major vegetable production areas of Pukekohe, Gisborne, Horowhenua, and Waimea where extensive mapping under the NZGAP EMS has been undertaken. In these places, the majority of vegetable growers have submitted operational farm maps as part of their EMS farm plan to manage freshwater risks.

Elsewhere, where the LCDB mapping of 'short-rotation cropland' is used with minimal or no additional data (e.g. EMS or Agribase information), accuracy is expected to be reduced as the LCDB categorisation includes cropping types other than CVG such as arable and pastoral fodder cropping systems. For these regions, the 'short-rotation cropland' area has been assumed to be

[1] https://lris.scinfo.org.nz/layer/104400-lcdb-v50-land-cover-database-version-50-mainland-new-zealand/

either all Broadacre Vegetables (CVG) or all Ryegrass and silage maize (pastoral cropping) based on the dominant farming type in the region, likely resulting in an overestimate and underestimate of CVG area, respectively. Table 1 provides an estimate of relative mapping accuracy for each region.

Table 1 CVG mapping data sources and assumed crop rotation

Region	Spatial Accuracy	Spatial Data	Cropping System for N loss estimates
Auckland Region	Good	EMS, LCDB short rotation cropland.	APSIM intensive vegetables (Pukekohe), APSIM broadacre vegetables (North Auckland).
Bay of Plenty Region	Poor	LCDB short rotation cropland.	APSIM broadacre vegetables.
Canterbury Region	Average	EMS, LCDB short rotation cropland, Agribase.	APSIM broadacre vegetables (where mapped by the EMS and/or Agribase), APSIM Ryegrass and silage maize (remaining LCDB short rotation cropland).
Gisborne Region	Good	EMS, LCDB short rotation cropland.	APSIM intensive vegetables (Gisborne), APSIM broadacre vegetables (elsewhere).
Hawke's Bay Region	Average	EMS, LCDB short rotation cropland.	APSIM broadacre vegetables.
Manawatū-Whanganui Region	Good	EMS, LCDB short rotation cropland.	APSIM intensive vegetables (Horowhenua), APSIM broadacre vegetables (Ohakune and elsewhere where mapped by the EMS), APSIM Ryegrass and silage maize (remaining LCDB short rotation cropland) .
Marlborough Region	Poor	LCDB short rotation cropland.	APSIM broadacre vegetables.
Nelson Region	Average	LCDB short rotation cropland.	APSIM broadacre vegetables.
Northland Region	Average	EMS, LCDB short rotation cropland.	APSIM broadacre vegetables.
Otago Region	Average	EMS, ORC land use data, LCDB short rotation cropland.	APSIM broadacre vegetables.
Southland Region	Average	EMS, LCDB short rotation cropland.	APSIM broadacre vegetables (where mapped by the EMS), APSIM Ryegrass and silage maize (elsewhere).
Taranaki Region	Poor	LCDB short rotation cropland.	APSIM broadacre vegetables.
Tasman Region	Good	EMS, TDC land use data, LCDB short rotation cropland.	APSIM intensive vegetables.
Waikato Region	Good	EMS, LCDB short rotation cropland.	APSIM intensive vegetables (Pukekohe), APSIM broadacre Vegetables (elsewhere).
Wellington Region	Poor	EMS, LCDB short rotation cropland.	APSIM intensive vegetables (Otaki), APSIM broadacre vegetables (elsewhere).
West Coast Region	Poor	LCDB short rotation cropland.	APSIM Ryegrass and silage maize.

2.3 NZGAP environmental management system coverage

Table 2 summarises the NZGAP EMS mapping for LAWA catchments within primary vegetable growing hubs: Kumeu, Pukekohe, Gisborne, Ohakune, Horowhenua, Waimea, and Canterbury where EMS mapping has been undertaken. Table 2 compares mapped CVG areas only; Fruit & Tree crops mapped in the EMS have been precluded from the analysis. Note the limitations in estimating total CVG area as set out in Section 2.2.

Table 2 Summary of mapped area in the NZGAP Environment Management System (EMS) as of August 2024 for selected LAWA catchments.

Site Name	Region	Growing Hub	EMS mapped area (ha)	Estimated total CVG area (ha)	Proportion of total in EMS
Kumeu @ Weza	Auckland Region	Kumeu	9	79	12%
Whangamarie Stream	Auckland Region	Pukekohe	146	340	43%
Waitangi Stream	Auckland Region		66	238	28%
Whakapipi Stm at SH22 Br	Waikato Region		577	967	60%
Ohaeroa Stm at SH22 Br	Waikato Region		171	277	61%
Turanganui R. at Gladstone Rd Br.	Gisborne Region	Gisborne	386	1556	25%
Taruheru River at Tuckers Rd Bridge	Gisborne Region		161	707	23%
Waipaoa River at Kanakanaia	Gisborne Region		893	1547	58%
Waipaoa River at Matawhero Br.	Gisborne Region		2468	4802	51%
Mangawhero at Raupiu Road	Manawatū-Whanganui	Ohakune	1152	1717	67%
Waikawa Stream at Huritini	Manawatū-Whanganui	Horowhenua	76	162	47%
Kuku at N. Johnstone Farm Bridge	Manawatū-Whanganui		140	159	89%
Hokio at Lake Horowhenua	Manawatū-Whanganui		486	618	79%
Ohau at Haines Property	Manawatū-Whanganui		340	448	76%
Koputaroa at Tavistock Rd	Manawatū-Whanganui		109	148	73%
Arawhata Drain at Hokio Beach Rd.	Manawatū-Whanganui		366	439	83%
Patiki Stream at Kawiu Road	Manawatū-Whanganui		66	96	69%
Harts Creek d/s Lower Lake Rd	Canterbury Region	Canterbury	432	852	51%
Selwyn River u/s Coes Ford bridge	Canterbury Region		80	1034	8%
Opihi River mouth/Milford Lagoon	Canterbury Region		39	149	27%
Borck at 400m d-s Queen St	Tasman Region	Waimea	97	266	37%
Neimann 600m u-s Lansdowne Rd	Tasman Region		9	29	31%
Waimea at SH60 Appleby	Tasman Region		452	721	63%
Total			8721	17351	50%

3 Nitrogen load modelling

A diffuse Nitrogen Load Model (NLM) has been developed by associating the mapped land uses (Section 2) with average annual N loss rates derived from modelling and New Zealand literature. More than 100 unique N loss rates have been applied to the mapped land use categories. The selected N loss rates are reflective of the best available data suitable for national scale modelling. Adopted N loss rates are summarised in Table 4.

The modelling represents a simple approach to N load estimates based on the product of area and annual average N loss rate for each land use type. The approach provides a robust and transparent method to estimate the total N load within a catchment to understand the relative contribution of N loading across land uses at a catchment scale. The adopted N loss rates are representative of losses from the bottom of the rootzone, N attenuation and transformation processes are not accounted for, nor are N point sources.

3.1 Cropping and vegetables

Nitrogen loss rates for cropping and CVG systems have been derived from spatial APSIM modelling undertaken by Plant and Food research[2] for three different cropping systems across New Zealand:

1. grass-maize,
2. broadacre vegetables (squash, onions, beetroot, sweetcorn, beans, and oats), and
3. intensive vegetables (lettuce, cabbage, spinach, cauliflower, and oats).

Crop rotations have been applied regionally to the mapped cropping and CVG areas following Table 1. Intensive Vegetables have been applied to the main vegetable production hubs (Pukekohe, Gisborne, Horowhenua, and Waimea). Broadacre vegetables have been applied to the mapped cropping and vegetable areas outside of the main vegetable production hubs except for the Manawatū-Whanganui, Canterbury, West Coast, and Southland regions where a grass-maize cropping system has been assumed for areas specified as ‘short-rotation cropland’ in the LCDB and not mapped by the EMS or other available data. This is because the LCDB ‘short-rotation cropland’ is not limited to vegetable growing systems and includes extensive arable and pastoral cropping systems (e.g. fodder cropping).

Loss rates for each combination of cropping system and region have been derived from the mean value of the APSIM model outputs within the mapped area. In total, loss rates associated with 22 different combinations of cropping system and region have been used. The loss rates account for soil and climate variability as modelled in APSIM. It has been assumed that the management for all cropping systems is irrigated to fully overcome soil water deficit and using a fixed fertiliser schedule. There is an opportunity to test adoption of flexible fertiliser scheduling on catchment N loads in future iterations of the modelling.

[2] https://landuseopportunities.nz/dataset/crop-rotation-nitrogen-leaching-loss-estimate-maps

3.1.1 CVG Nitrogen loss comparison

Table 3 compares the adopted APSIM loss rates to alternative modelled loss rates from other modelling studies. For most regions, loss rates in APSIM compare well to other modelled estimates except for Auckland where the APSIM losses are lower than estimated in Muller & Inness (2023), and in Tasman and Gisborne where the APSIM losses are higher than modelled in SPASMO (Fenemor et al., 2023 and Gentile et al., 2014). For this modelling it is appropriate to use a nationally consistent approach, however we note that for localised studies the regional modelling may be more accurate.

Table 3 N loss rate comparison

Region	Adopted APSIM loss rate (kg/N/ha/yr)	Alternative loss rate (kg/N/ha/yr)	Description	Model and Reference
Tasman Region (Waimea)	91	49	Average loss rate for 'Outdoor Vegetables' across soil types.	SPASMO (Fenemor et al., 2023)
Auckland Region (Pukekohe)	33	95 - 182	Average loss rate for 5 different Intensive rotations.	APSIM (Muller & Inness, 2023)
Manawatū-Whanganui Region (Horowhenua)	81	31 - 93	Loss rates for 3 different Extensive and Intensive rotations.	Overseer (Bloomer et al., 2020)
Manawatū-Whanganui Region (Ohakune)	42	35	Extensive Ohakune rotation.	Overseer (Updated loss rate for 'Waimarino - Rotation 4' in The Agribusiness Group (2014)
Gisborne Region	65	17.7	Broccoli/Lettuce rotation (leaching + runoff losses).	SPASMO (Gentile et al., 2014)
Canterbury Region	42	39-55	Average loss rate for 4 different rotations.	Overseer (Agribusiness group, 2019)

3.2 Pastoral land use

Pastoral land N loss rates are derived from Monaghan et al. (2021), an extensive summary of Overseer[3] modelling across New Zealand for different 'typologies' – combinations of physical attributes such as temperature, soil drainage, rainfall, slope, and stocking rate.

Pastoral land uses were mapped using the available typology shapefiles spatially intersected with the LCDB pastoral land categories. 17 typologies for sheep and beef systems, and 61 typologies for dairy are mapped. For dairy, Monaghan et al. (2021) do not provide N loss rates for some typologies; for these locations the spatially averaged loss rate was applied based on the remaining dairy area with associated loss rates for each region.

[3] Overseer® Nutrient Budgeting software version 6.3.1

3.3 Urban land use

The N loss rate within the urban zone is derived from Moores et al. (2017), based on annual urban N loss rates from NZ and international stormwater runoff studies.

3.4 Other land uses

N loss rates for other rural land uses including lifestyle blocks, forestry, native forest, orchards, and scrub have been derived from Drewry (2018), an extensive literature review of non-pastoral N loss rate studies.

Table 4 Adopted Nitrogen Loss Rates

Land use Category 1	Land use Category 2	Land use Category 3	N loss rate (kg/ha/yr)	Literature Source	Result Category (Table 6)
Native and Permanent Vegetation	Non-Woody Native and Permanent Vegetation		1.6	Drewry (2018)	Other
	Woody Native and Permanent Vegetation	Woody Native and Permanent Vegetation	1.6	Drewry (2018)	
		Gorse	33.5	Drewry (2018)	
Water, Wetlands, and Estuaries			0	No N generation modelled	
Other	Surface Mine or Dump		15	Loss rate adopted from Urban	
	Gravel, Sand, and Snow		1.6	Loss rate adopted from Native and Permanent Vegetation	
Forestry	Forestry		1.8	Drewry (2018)	
Horticulture	Fruit & Tree crops		9.9	Drewry (2018)	Other Horticulture
	Cropping and CVG	Ryegrass and silage maize	25-33 (region dependent)	Plant & Food Research (2024)	
		Broadacre Vegetables	24-83 (region dependent)	Plant & Food Research (2024)	CVG
		Intensive Vegetables	31-91 (region dependent)	Plant & Food Research (2024)	
Pasture	Sheep and Beef	17 Typologies	4-21 (typology dependent)	Monaghan et al. (2021)	Pastoral Farming
	Dairy	61 Typologies	24-103 (typology dependent)	Monaghan et al. (2021)	
	Ungrazed Pasture		10.7	Loss rate adopted from Other Animals and Lifestyle Blocks	

	Other Animals and Lifestyle Blocks		10.7	Drewry (2018)	
Urban	Urban		15	Moores et al. (2017)	Urban
	Parkland/Open Space		15	Moores et al. (2017)	

4 Scenario modelling

Three scenarios have been modelled to estimate the change in catchment N load following CVG expansion in line with population growth through to 2043. The scenarios test different levels of N loss mitigation associated with the adoption of Good Management Practices (GMPs) for CVG (applied to both current CVG and expansion). The percentages below in each scenario refer to the percentage reduction in N loss from adopting varying levels of GMPs for the rotations:

- Scenario 5/10 : -5% (broadacre vegetables) and -10% (intensive vegetables).
- Scenario 10/20 : -10% (broadacre vegetables) and -20% (intensive vegetables).
- Scenario 15/30: -15% (broadacre vegetables) and -30% (intensive vegetables).

Industry identifies a range of GMPs for managing nitrogen loss risk in the NZGAP EMS add-on. Bundles of GMPs for CVG in published modelling literature relate to improved matching of fertiliser applications to crop demand (timing, rate, and placement), and improved matching of irrigation applications to optimum soil moisture conditions for crop growth (timing, rate, and placement). The scenarios for N reduction from GMP adoption above were chosen to reflect the wide variety of estimated N loss change by different models in different regions. Some recently published predictions of N load reduction following the adoption of various mitigations are reported here:

- Plant and Food research (2024) spatial APSIM modelling estimates an average N loss reduction of -44% for Intensive Vegetables and -39% for Broadacre Vegetables across the CVG area modelled in this study following the adoption of deficit irrigation and flexible fertiliser applications (from fixed irrigation and fixed fertiliser scheduling).
- PerrinAg APSIM modelling in Auckland predicted annual N loss reductions between -24% and -34% for different levels of mitigations applied to CVG rotations (Muller and Inness, 2023).
- Landcare Research SPASMO modelling in Waimea (Tasman) estimated annual N loss reductions between 0% and -31% following reduced fertiliser applications depending on the combination of fertiliser regime, soil type, and CVG rotation (Fenemor et al., 2023).
- Page Bloomer Overseer modelling in Horowhenua predicted that the implementation of GMP, Best Management Practice (BMP), and elements of system change (e.g. retirement of land), N leaching rates from CVG would decrease by between -7% and -46%, depending on the rotation (Bloomer et al., 2020).
- AgriBusiness Group (2017) Overseer modelling for three different rotations in Horowhenua estimated annual load reductions between -4% and -15% depending on the combination of mitigation and CVG rotation.

The reported N loss reductions above are derived from process-based models for specific CVG systems. Scenario modelling in this study instead uses a broad, catchment-average approach that recognises the increased capacity of intensive rotations to reduce N losses (e.g. through reduced

fertiliser application) compared to broadacre systems. Model and scenario limitations are further discussed in Section 5.3.

4.1 Scenario methodology

For each catchment:

1. The expansion area required to meet population demand has been estimated:
   - Vegetable production area has been modelled to increase by 15.5%, equivalent to the Statistics New Zealand estimate of national population growth from 2022 to 2043[4].
2. The potential vegetable expansion area has been mapped:
   - Appropriate expansion land is defined as Land Use Capability (LUC) class 1 or 2, currently in pasture (either Dairy, Sheep and Beef, Ungrazed Pasture, or Other Animals and Lifestyle Blocks).
3. The marginal N loss rate for expansion Vegetables has been estimated:
   - The difference between the area-weighted average N loss rate for the potential vegetable expansion area (current land use) and the area-weighted catchment average N loss rate for Vegetable production has been calculated.
4. The change in N load is estimated:
   - The product of the vegetable production area required to meet population demand and the marginal N loss rate has been added to the total catchment N load.

4.2 Catchments

Results are summarised for catchments within the primary vegetable production zones, where EMS mapping has been undertaken, and where LAWA water quality information is available. Catchment boundaries were based on the River Environments Classification (REC2) version 5[5]. Not all catchments where vegetable growing is present have been included, nor do the LAWA catchments cover all agricultural production areas.

5 Results

Current-state 'baseline' water quality metrics and estimated N loads are provided in Section 5.1. Expansion scenario results are presented in Section 5.2 and discussed in Section 5.3.

5.1 Baseline Nitrogen load estimates

Figure 1 to Figure 4 show the mapped land use and EMS areas for four primary vegetable growing hubs where the intensive vegetable rotation has been assumed in the NLM: Pukekohe, Gisborne, Horowhenua, and Waimea. Water quality attributes from LAWA are summarised in Table 5. N load per land use category is summarised for each catchment in Table 6.

In total for the 46 modelled LAWA catchments, CVG systems are predicted to produce 4.6% of the total N load (from 1.1% of the total area). In 6 of the 46 modelled catchments, CVG systems are

[4] https://www.stats.govt.nz/information-releases/national-population-projections-2022base2073/ Accessed 20/11/2024.
[5] https://niwa.co.nz/freshwater/river-environment-classification-2

predicted to contribute the majority of the total N load across land uses. These 6 catchments are all small (< 5,000 ha), lowland streams characterised by poor water quality; likely driven by a lack of dilution as a function of their catchment size. The combined area of the 6 catchments (8,605 ha) equates to 0.25% of the assessed area (3,505,792 ha across 46 catchments). This indicates that where CVG does significantly impact water quality, the impacted stream length is relatively short. In general, CVG contributes a relatively small proportion of the total N load for most assessed catchments (on average 17.4% across the 46 modelled catchments) (Table 6), and also at the national and regional level (Figure 5).

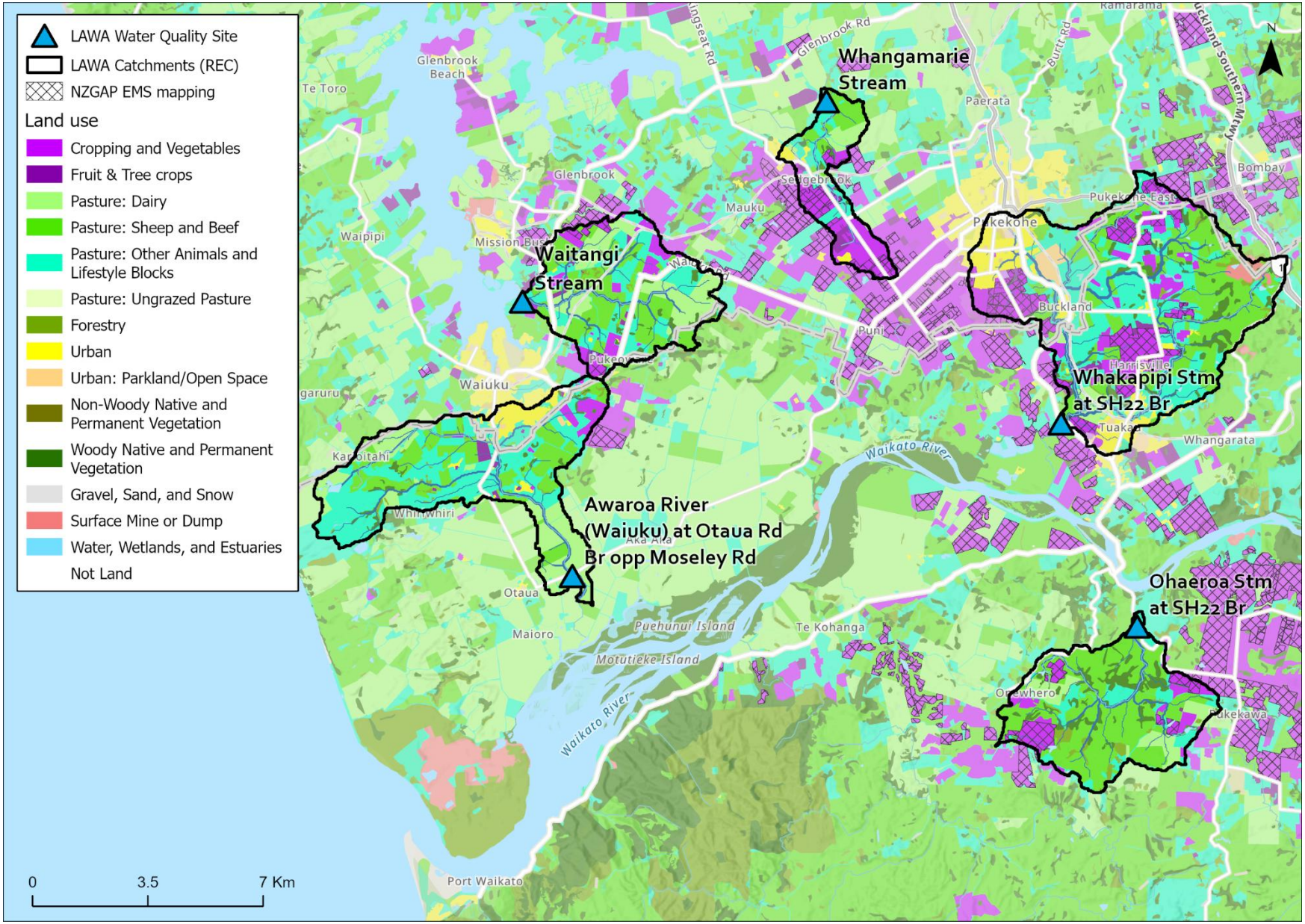

Figure 1 Pukekohe land use.

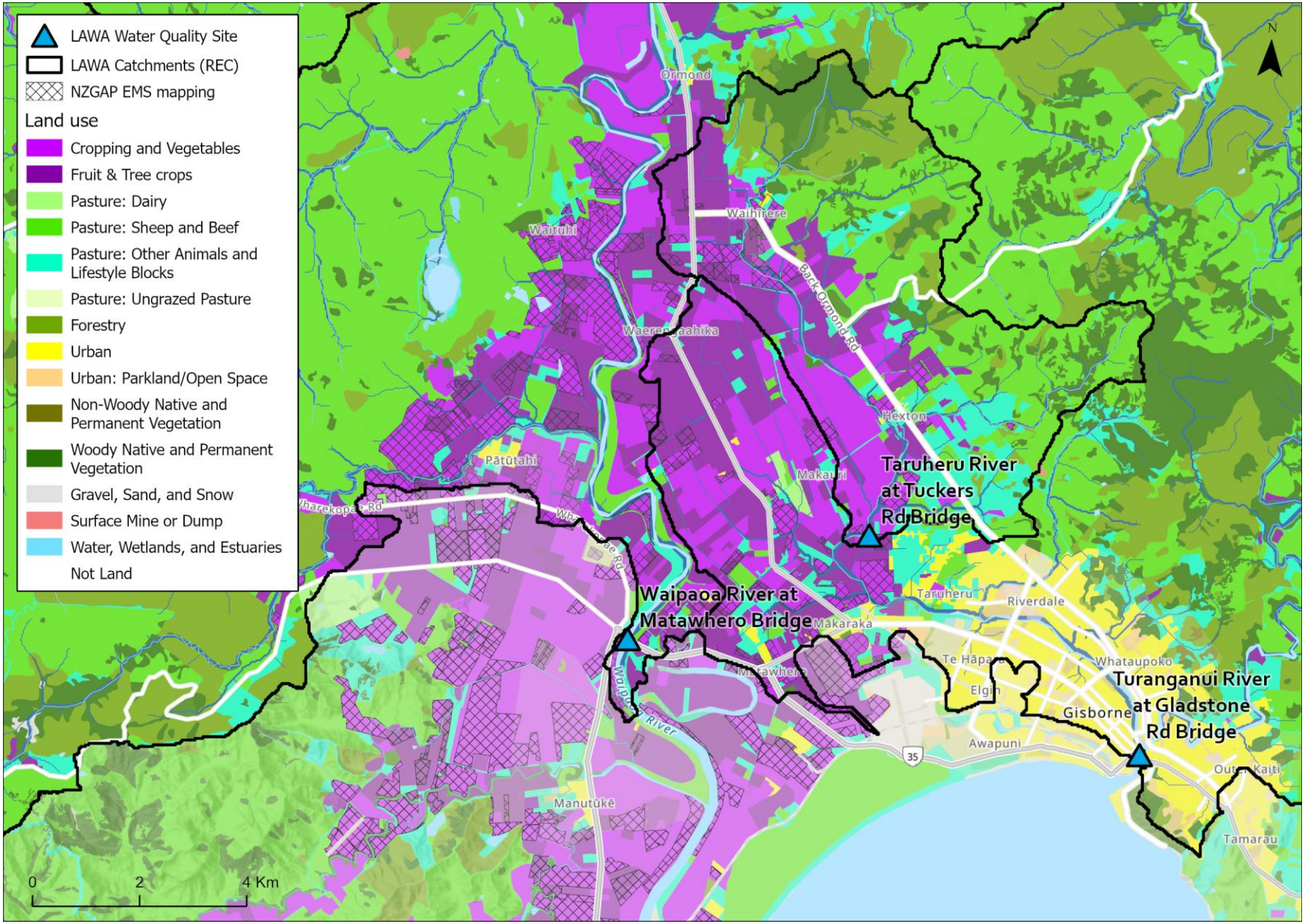

Figure 2 Gisborne land use.

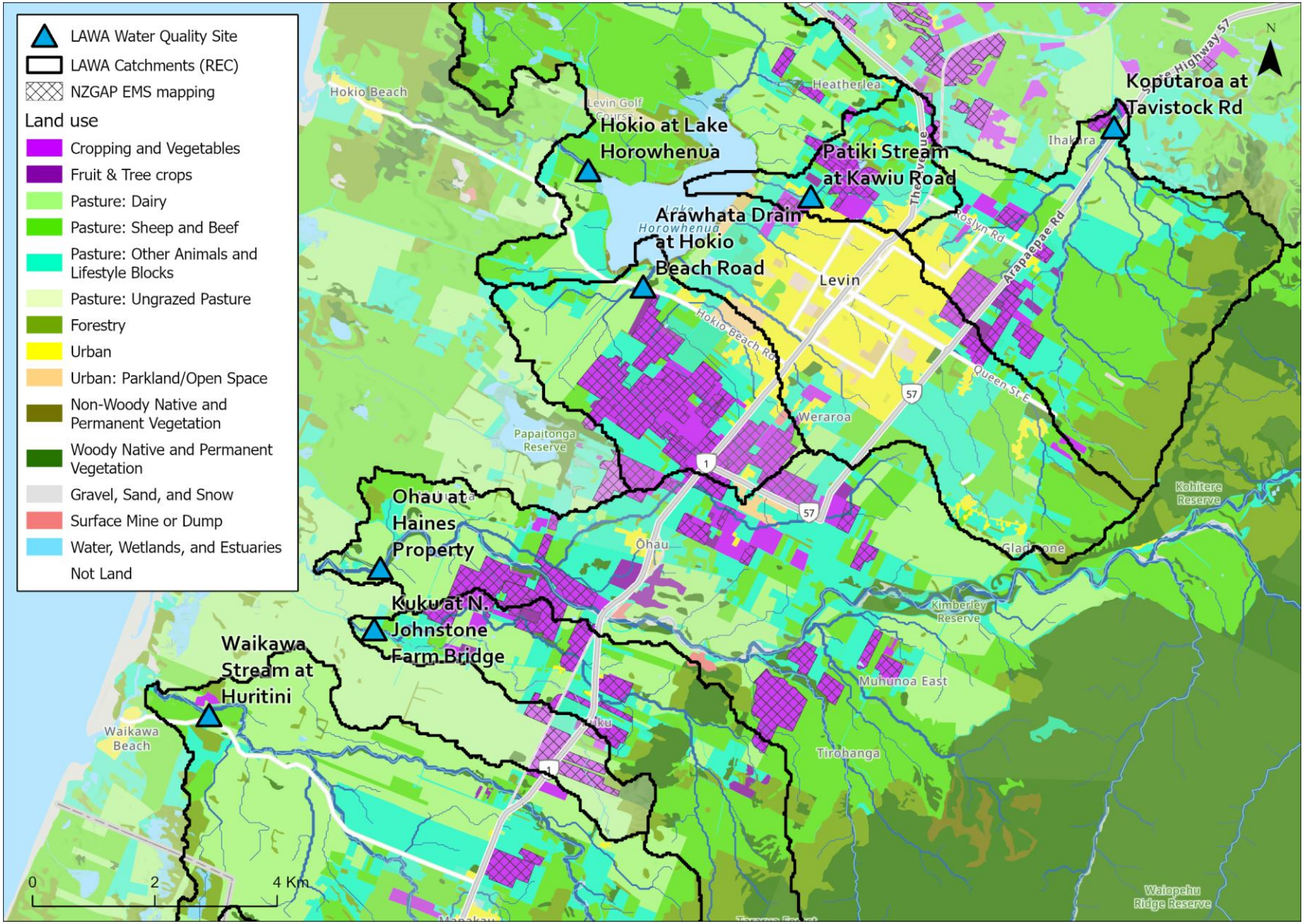

Figure 3 Horowhenua land use.

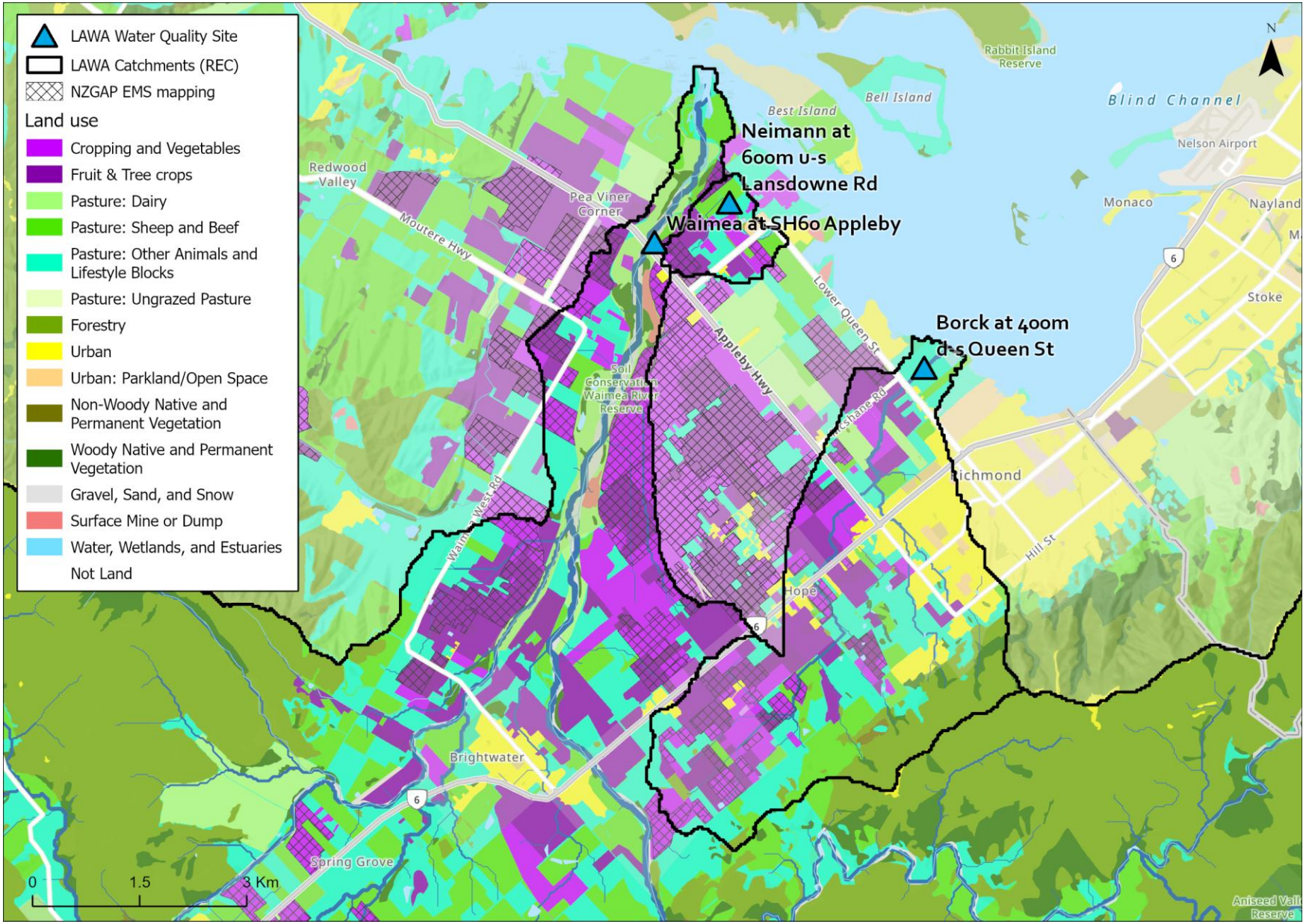

Figure 4 Waimea land use.

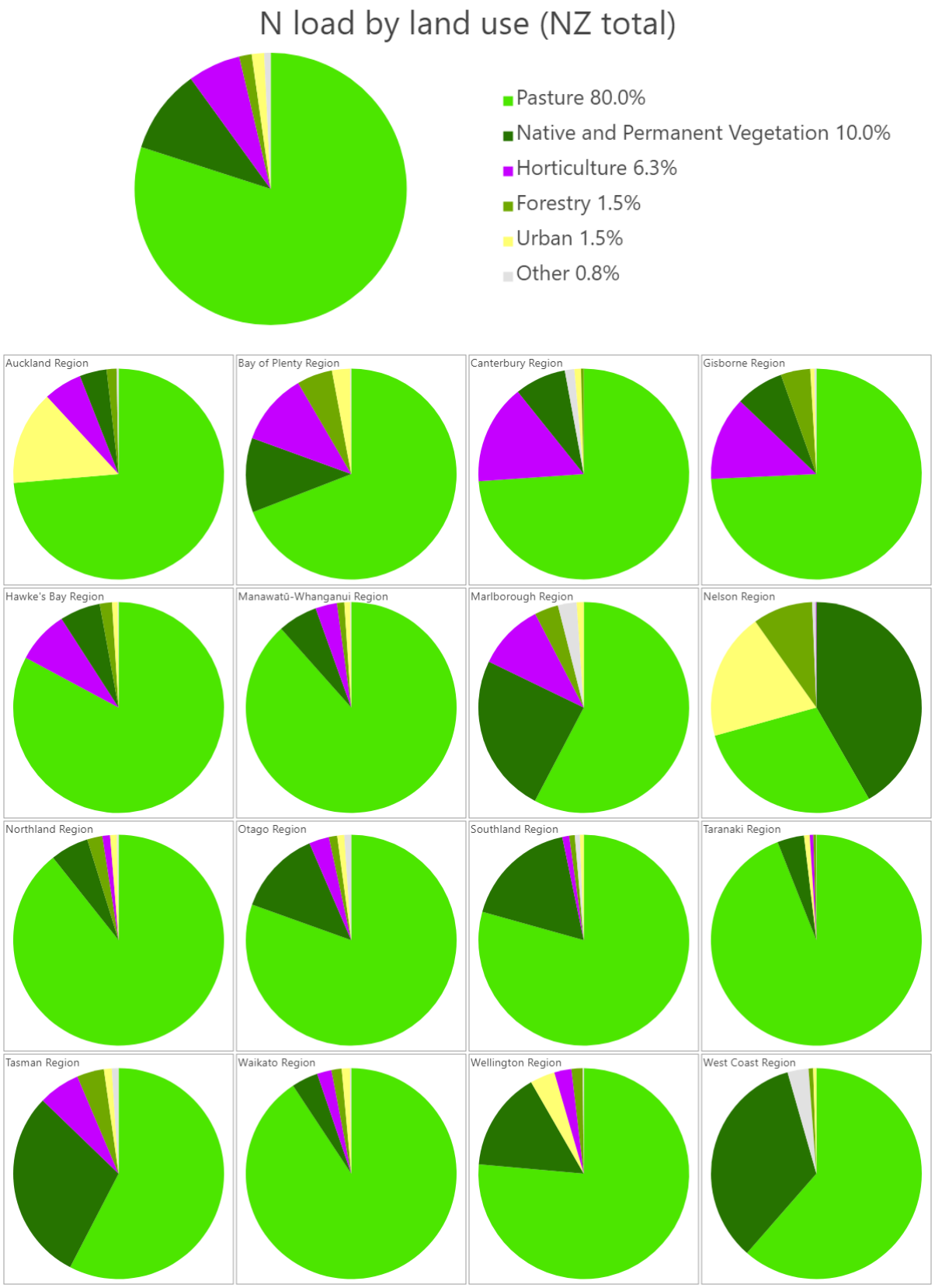

Figure 5 Relative N loading as estimated by the Nitrogen Load Model (NLM). Note the Horticulture category includes CVG and all other cropping systems and fruit and tree crops.

Table 5 LAWA Water Quality for selected LAWA river water quality monitoring locations (September 2023 data).

Site Name	Region	NO3N		TON		Nitrate (toxicity)	Ammonia (toxicity)	DRP	*E. coli*	Suspended Sediment (Clarity)
		Median (mg/l)	Attribute band	Median (mg/l)	Attribute band	Attribute band	Attribute band	Attribute band	Attribute band	Attribute band
Whangamarie Stream	Auckland Region	NA	NA	13	D	D	A	B	E	A
Kumeu @ Weza	Auckland Region	NA	NA	0.22	A	A	A	B	D	C
Waitangi Stream	Auckland Region	NA	NA	1.94	C	C	A	A	D	A
Harts Creek d/s Lower Lake Rd	Canterbury Region	NA	NA	7.7	D	D	A	B	E	NA
Selwyn River u/s Coes Ford bridge	Canterbury Region	NA	NA	6.65	C	C	A	B	D	A
Opihi River mouth/Milford Lagoon	Canterbury Region	NA	NA	NA	NA	NA	NA	NA	NA	NA
Rakaia River north bank d/s SH1	Canterbury Region	NA	NA	0.07	A	A	A	A	B	NA
Ashburton River at SH1	Canterbury Region	NA	NA	1	B	B	A	A	D	NA
Ashley River 50m u/s SH1	Canterbury Region	NA	NA	0.18	A	A	A	A	A	A
Turanganui River at Gladstone Rd Bridge	Gisborne Region	0.0365	A	0.0465	A	A	B	D	D	NA
Hikuwai River at Willowflat	Gisborne Region	0.0063	A	0.0084	A	A	B	A	C	NA
Taruheru River at Tuckers Rd Bridge	Gisborne Region	1.3	C	1.3	C	C	C	D	E	NA
Waipaoa River at Kanakanaia	Gisborne Region	0.12	A	0.12	A	A	B	C	E	NA
Waipaoa River at Matawhero Bridge	Gisborne Region	0.145	A	0.145	A	A	B	C	E	NA
Karamu-Clive River upstream of the Whakatu Rail Bridge	Hawke's Bay Region	0.36	B	0.37	B	B	B	D	D	NA
Ngaruroro at Fernhill	Hawke's Bay Region	0.092	A	0.093	A	A	A	C	D	NA
Tukituki at Red Br.	Hawke's Bay Region	NA	NA	0.494	B	B	B	B	C	A
Herehere Stream at Te Aute Rd	Hawke's Bay Region	0.075	A	0.078	A	A	B	D	E	NA
Waikawa Stream at Huritini	Manawatū-Whanganui Region	1.01	B	1.02	B	B	NA	C	NA	NA
Kuku at N. Johnstone Farm Bridge	Manawatū-Whanganui Region	NA	NA	0.935	B	B	NA	NA	NA	NA
Hokio at Lake Horowhenua	Manawatū-Whanganui Region	0.3585	B	0.37	B	B	NA	D	NA	NA
Ohau at Haines Property	Manawatū-Whanganui Region	0.2975	A	0.3	A	A	NA	B	A	NA
Koputaroa at Tavistock Rd	Manawatū-Whanganui Region	2.34	C	2.34	C	C	A	C	E	NA
Arawhata Drain at Hokio Beach Road	Manawatū-Whanganui Region	10.3	D	10.35	D	D	B	D	E	NA
Manawatu at Teachers College	Manawatū-Whanganui Region	0.33	A	0.34	A	A	A	C	E	NA
Rangitikei at McKelvies	Manawatū-Whanganui Region	0.038	A	0.04	A	A	A	C	D	NA
Patiki Stream at Kawiu Road	Manawatū-Whanganui Region	5.435	C	5.445	C	C	A	D	D	NA
Mangawhero at Raupiu Road	Manawatū-Whanganui Region	0.277	A	0.28	A	A	A	C	D	NA
Opaoa River at Swamp Road	Marlborough Region	0.56	A	0.56	A	A	A	C	B	NA
Wairua at Purua	Northland Region	0.3395	A	0.3498	A	A	B	D	D	A
Waipao at Draffins Road	Northland Region	2.25	B	2.25	B	B	A	D	E	A
Kakanui River at McCones	Otago Region	0.38	A	0.38	A	A	A	A	D	NA
Maketawa Stream at Tarata Rd.	Taranaki Region	0.309	A	0.31	A	A	B	D	E	A
Borck at 400m d-s Queen St	Tasman Region	5.95	C	NA	NA	C	A	B	E	A
Neimann at 600m u-s Lansdowne Rd	Tasman Region	2.3	C	NA	NA	C	A	B	E	A
Waimea at SH60 Appleby	Tasman Region	0.34	A	NA	NA	A	A	A	A	A
Piako River at Paeroa-Tahuna Rd Br	Waikato Region	NA	NA	1.13	B	B	B	D	E	B
Mangaonua Stm at Hoeka Rd	Waikato Region	NA	NA	1.34	B	B	B	B	E	B

Waihou River at Okauia	Waikato Region	NA	NA	1.19	B	B	A	D	E	D
Awaroa River (Waiuku) at Otaua Rd Br opp Moseley Rd	Waikato Region	NA	NA	1.34	B	B	B	C	NA	NA
Whakapipi Stm at SH22 Br	Waikato Region	NA	NA	3.6	C	C	A	D	NA	A
Ohaeroa Stm at SH22 Br	Waikato Region	NA	NA	1.675	B	B	A	B	NA	NA
Waitohu Stream at Norfolk Crescent	Wellington Region	0.315	A	0.325	A	A	A	C	E	NA
Mangaone Stream at Sims Road Bridge	Wellington Region	1.395	B	1.405	B	B	B	D	E	NA
Ruamahanga River at Pukio	Wellington Region	0.315	A	0.325	A	A	A	C	NA	NA
Ruamahanga River at Gladstone Bridge	Wellington Region	0.405	A	0.405	A	A	A	C	A	NA

Table 6 Nitrogen Load Model results for selected LAWA river water quality monitoring locations. Percentages in parentheses indicate proportion of the catchment area or N load. Row colour indicates relative N loading from CVG: Orange >50%, Yellow 20-50%, Green <20%.

Site Name	Region	Attribute Band		Pastoral Farming		CVG		Other Horticulture (including pastoral cropping, arable, and orchards)		Urban		Other		Catchment Total	
		NO3N	TON	Area (ha)	N load (t/yr)	Area (ha)	N load (t/yr)	Area (ha)	N load (t/yr)	Area (ha)	N load (t/yr)	Area (ha)	N load (t/yr)	Area (ha)	N load (t/yr)
Whangamarie Stream	Auckland Region	NA	D	382 (47%)	7 (37%)	340 (42%)	11 (58.5%)	33 (4%)	0 (1.7%)	36 (4%)	1 (3%)	23 (3%)	0 (0%)	813	19
Kumeu @ Weza	Auckland Region	NA	A	3376 (75%)	49 (86%)	79 (2%)	3 (5.3%)	123 (3%)	1 (2.2%)	106 (2%)	2 (3%)	829 (18%)	2 (3%)	4512	56
Waitangi Stream	Auckland Region	NA	C	1521 (81%)	32 (79%)	238 (13%)	8 (19.4%)	29 (2%)	0 (0.7%)	3 (0%)	0 (0%)	96 (5%)	0 (0%)	1887	40
Harts Creek d/s Lower Lake Rd	Canterbury Region	NA	D	33741 (86%)	1995 (93%)	852 (2%)	36 (1.7%)	3421 (9%)	112 (5.2%)	175 (0%)	3 (0%)	994 (3%)	4 (0%)	39183	2149
Selwyn River u/s Coes Ford bridge	Canterbury Region	NA	C	69397 (72%)	1571 (80%)	1034 (1%)	44 (2.2%)	6443 (7%)	211 (10.7%)	517 (1%)	8 (0%)	18675 (19%)	132 (7%)	96066	1966
Opihi River mouth/Milford Lagoon	Canterbury Region	NA	NA	150206 (63%)	2363 (76%)	149 (0%)	6 (0.2%)	14101 (6%)	463 (14.9%)	885 (0%)	13 (0%)	71672 (30%)	268 (9%)	237012	3114
Rakaia River north bank d/s SH1	Canterbury Region	NA	A	62778 (23%)	842 (63%)	144 (0%)	6 (0.5%)	1494 (1%)	49 (3.7%)	18 (0%)	0 (0%)	213193 (77%)	439 (33%)	277627	1337
Ashburton River at SH1	Canterbury Region	NA	B	67639 (45%)	1571 (77%)	114 (0%)	5 (0.2%)	8429 (6%)	276 (13.6%)	283 (0%)	4 (0%)	74909 (49%)	178 (9%)	151374	2034
Ashley River 50m u/s SH1	Canterbury Region	NA	A	50240 (44%)	512 (63%)	8 (0%)	0 (0%)	2234 (2%)	70 (8.6%)	144 (0%)	2 (0%)	62404 (54%)	225 (28%)	115030	809
Turanganui River at Gladstone Rd Bridge	Gisborne Region	A	A	13887 (44%)	206 (55%)	1556 (5%)	102 (27.4%)	1667 (5%)	17 (4.4%)	1557 (5%)	23 (6%)	12937 (41%)	24 (6%)	31605	371
Hikuwai River at Willowflat	Gisborne Region	A	A	7611 (25%)	118 (67%)	312 (1%)	17 (9.6%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	22841 (74%)	40 (23%)	30764	175
Taruheru River at Tuckers Rd Bridge	Gisborne Region	C	C	1652 (40%)	23 (29%)	707 (17%)	46 (58.8%)	691 (17%)	7 (8.7%)	8 (0%)	0 (0%)	1056 (26%)	3 (3%)	4114	79
Waipaoa River at Kanakanaia	Gisborne Region	A	A	87825 (56%)	1339 (85%)	1547 (1%)	101 (6.4%)	58 (0%)	1 (0%)	52 (0%)	1 (0%)	68041 (43%)	125 (8%)	157522	1567
Waipaoa River at Matawhero Bridge	Gisborne Region	A	A	107596 (56%)	1652 (77%)	4802 (2%)	314 (14.7%)	1596 (1%)	16 (0.7%)	137 (0%)	2 (0%)	78374 (41%)	151 (7%)	192505	2135
Karamu-Clive River upstream of the Whakatu Rail Bridge	Hawke's Bay Region	B	B	31545 (64%)	508 (54%)	5464 (11%)	304 (32.4%)	7617 (15%)	75 (8%)	3348 (7%)	50 (5%)	1681 (3%)	3 (0%)	49656	941
Ngaruroro at Fernhill	Hawke's Bay Region	A	A	69161 (36%)	1154 (81%)	757 (0%)	42 (3%)	1877 (1%)	19 (1.3%)	42 (0%)	1 (0%)	122679 (63%)	212 (15%)	194516	1427
Tukituki at Red Br.	Hawke's Bay Region	NA	B	191077 (78%)	3675 (91%)	4200 (2%)	234 (5.8%)	601 (0%)	6 (0.1%)	826 (0%)	12 (0%)	49666 (20%)	91 (2%)	246370	4017
Herehere Stream at Te Aute Rd	Hawke's Bay Region	A	A	739 (77%)	10 (74%)	16 (2%)	1 (6.7%)	8 (1%)	0 (0.6%)	168 (18%)	3 (19%)	28 (3%)	0 (0%)	960	13
Waikawa Stream at Huritini	Manawatū-Whanganui	B	B	3420 (47%)	70 (78%)	162 (2%)	13 (14.5%)	2 (0%)	0 (0%)	38 (1%)	1 (1%)	3707 (51%)	6 (7%)	7329	90
Kuku at N. Johnstone Farm Bridge	Manawatū-Whanganui	NA	B	848 (56%)	18 (55%)	159 (10%)	13 (39.6%)	22 (1%)	0 (0.7%)	4 (0%)	0 (0%)	477 (32%)	2 (5%)	1510	32
Hokio at Lake Horowhenua	Manawatū-Whanganui	B	B	3899 (62%)	66 (50%)	618 (10%)	50 (37.9%)	18 (0%)	0 (0.1%)	988 (16%)	15 (11%)	781 (12%)	1 (1%)	6303	132
Ohau at Haines Property	Manawatū-Whanganui	A	A	3963 (26%)	76 (57%)	448 (3%)	36 (27.3%)	52 (0%)	1 (0.4%)	47 (0%)	1 (1%)	10903 (71%)	19 (15%)	15414	133
Koputaroa at Tavistock Rd	Manawatū-Whanganui	C	C	1242 (63%)	22 (60%)	148 (8%)	12 (33.2%)	16 (1%)	0 (0.4%)	77 (4%)	1 (3%)	488 (25%)	1 (3%)	1972	36
Arawhata Drain at Hokio Beach Road	Manawatū-Whanganui	D	D	625 (52%)	11 (23%)	439 (36%)	35 (73.9%)	10 (1%)	0 (0.2%)	100 (8%)	1 (3%)	34 (3%)	0 (0%)	1208	48
Manawatu at Teachers College	Manawatū-Whanganui	A	A	291230 (74%)	5972 (95%)	353 (0%)	15 (0.2%)	870 (0%)	21 (0.3%)	2430 (1%)	36 (1%)	96829 (25%)	240 (4%)	391712	6284
Rangitikei at McKelvies	Manawatū-Whanganui	A	A	213581 (55%)	3274 (89%)	561 (0%)	24 (0.6%)	3195 (1%)	80 (2.2%)	1633 (0%)	24 (1%)	168578 (43%)	287 (8%)	387549	3690
Patiki Stream at Kawiu Road	Manawatū-Whanganui	C	C	269 (56%)	4 (29%)	96 (20%)	8 (63.6%)	4 (1%)	0 (0.3%)	58 (12%)	1 (7%)	52 (11%)	0 (0%)	479	12
Mangawhero at Raupiu Road	Manawatū-Whanganui	A	A	45642 (68%)	730 (87%)	1717 (3%)	73 (8.7%)	0 (0%)	0 (0%)	370 (1%)	6 (1%)	19040 (29%)	34 (4%)	66768	843
Opaoa River at Swamp Road	Marlborough Region	A	A	18992 (42%)	165 (47%)	384 (1%)	13 (3.7%)	11644 (25%)	115 (32.6%)	1575 (3%)	24 (7%)	13150 (29%)	36 (10%)	45745	353
Wairua at Purua	Northland Region	A	A	34750 (64%)	907 (95%)	46 (0%)	1 (0.1%)	177 (0%)	2 (0.2%)	292 (1%)	4 (0%)	19083 (35%)	36 (4%)	54348	950
Waipao at Draffins Road	Northland Region	B	B	2519 (69%)	59 (86%)	96 (3%)	2 (3.4%)	663 (18%)	7 (9.6%)	2 (0%)	0 (0%)	369 (10%)	1 (1%)	3650	68
Kakanui River at McCones	Otago Region	A	A	50570 (75%)	767 (91%)	598 (1%)	21 (2.5%)	75 (0%)	1 (0.1%)	50 (0%)	1 (0%)	16355 (24%)	57 (7%)	67648	847.0
Maketawa Stream at Tarata Rd.	Taranaki Region	A	A	1822 (56%)	101 (98%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	1458 (44%)	2 (2%)	3280	104
Borck at 400m d-s Queen St	Tasman Region	C	NA	647 (35%)	8 (19%)	266 (14%)	24 (59.6%)	368 (20%)	4 (9%)	304 (17%)	5 (11%)	249 (14%)	1 (1%)	1834	41
Neimann at 600m u-s Lansdowne Rd	Tasman Region	C	NA	69 (44%)	1 (22%)	29 (19%)	3 (63.8%)	47 (30%)	0 (11.3%)	8 (5%)	0 (3%)	3 (2%)	0 (0%)	157	4
Waimea at SH60 Appleby	Tasman Region	A	NA	12137 (16%)	150 (42%)	721 (1%)	66 (18.4%)	823 (1%)	8 (2.3%)	404 (1%)	6 (2%)	62908 (82%)	128 (36%)	76994	358
Piako River at Paeroa-Tahuna Rd Br	Waikato Region	NA	B	49197 (91%)	1462 (97%)	410 (1%)	20 (1.3%)	46 (0%)	0 (0%)	803 (1%)	12 (1%)	3435 (6%)	6 (0%)	53892	1500

Mangaonua Stm at Hoeka Rd	Waikato Region	NA	B	7106 (85%)	157 (91%)	207 (2%)	10 (5.9%)	54 (1%)	1 (0.3%)	75 (1%)	1 (1%)	885 (11%)	3 (2%)	8326	171
Waihou River at Okauia	Waikato Region	NA	B	44322 (55%)	1325 (91%)	1123 (1%)	55 (3.8%)	0 (0%)	0 (0%)	641 (1%)	10 (1%)	34552 (43%)	65 (4%)	80637	1455
Awaroa River (Waiuku) at Otaua Rd Br opp Moseley Rd	Waikato Region	NA	B	2212 (85%)	41 (88%)	90 (3%)	3 (5.9%)	39 (2%)	0 (0.8%)	156 (6%)	2 (5%)	110 (4%)	0 (0%)	2608	47
Whakapipi Stm at SH22 Br	Waikato Region	NA	C	2514 (55%)	38 (48%)	967 (21%)	30 (38.3%)	40 (1%)	0 (0.5%)	613 (13%)	9 (12%)	428 (9%)	2 (2%)	4562	79
Ohaeroa Stm at SH22 Br	Waikato Region	NA	B	1467 (72%)	28 (74%)	277 (14%)	8 (22.1%)	1 (0%)	0 (0%)	3 (0%)	0 (0%)	292 (14%)	2 (4%)	2040	38
Waitohu Stream at Norfolk Crescent	Wellington Region	A	A	1957 (43%)	37 (76%)	36 (1%)	3 (5.9%)	18 (0%)	0 (0.4%)	215 (5%)	3 (7%)	2292 (51%)	5 (11%)	4518	49
Mangaone Stream at Sims Road Bridge	Wellington Region	B	B	2587 (67%)	54 (88%)	50 (1%)	4 (6.3%)	95 (2%)	1 (1.5%)	43 (1%)	1 (1%)	1078 (28%)	2 (3%)	3853	61
Ruamahanga River at Pukio	Wellington Region	A	A	157140 (64%)	2967 (89%)	4834 (2%)	152 (4.5%)	1764 (1%)	17 (0.5%)	2459 (1%)	37 (1%)	79944 (32%)	177 (5%)	246141	3350
Ruamahanga River at Gladstone Bridge	Wellington Region	A	A	87576 (65%)	1577 (88%)	2706 (2%)	85 (4.7%)	529 (0%)	5 (0.3%)	1631 (1%)	24 (1%)	41357 (31%)	99 (6%)	133799	1791

5.2 Scenario Nitrogen load estimates

In total for the modelled catchments, CVG is required to expand by 6,173 ha to meet demand from population growth. The 5/10 Scenario results are presented alongside current LAWA attribute bands for Nitrate-Nitrogen and Total Organic Nitrogen in Table 7. Additional 5/10 scenario metrics to demonstrate the calculation procedure are presented in Table 8. Table 9 summarises the results for the expansion scenario under the three different levels of GMP:

- Scenario 5/10 : -5% (broadacre vegetables) and -10% (intensive vegetables).
- Scenario 10/20 : -10% (broadacre vegetables) and -20% (intensive vegetables).
- Scenario 15/30: -15% (broadacre vegetables) and -30% (intensive vegetables).

Catchment N load change in the expansion scenarios are predicted to be small: in Scenario 5/10 expansion is predicted to increase N loading by an average of 0.1%, and no catchment is modelled to increase in total load by more than 2%. For some catchments where much of the appropriate expansion land is currently in high-intensity pastoral systems, it is predicted that land use change to CVG production and the adoption of GMP will reduce overall catchment loads. The largest increase in catchment loads are predicted in Hawkes Bay, where the mapped CVG area is likely over-predicted in the model (see Section 2.2), thus also resulting in a very large area of CVG expansion.

For the 10/20 and 15/30 scenarios, a net decrease in total N load is predicted for all catchments. At these levels of GMP, the modelled N loss reductions offset any additional N load associated with CVG expansion.

5.3 Discussion and limitations

CVG systems are challenging to both map and model due to their rotational nature (i.e. moving to and from different land parcels), annual or sub-annual cropping cycles, and variable inputs that are influenced by climate, market demand, and labour availability amongst other factors. While the developed nitrogen load model offers a robust, literature-based approach to estimating annual diffuse N loads at a catchment scale, it has certain limitations related to the simplification of the modelled operations and availability of appropriate data.

The modelling implicitly accounts for variations in soil types, climate, and management practice via the APSIM-modelled loss rates, however the rotations modelled may not accurately represent cropping systems in some regions. For example, potatoes—widely grown in Canterbury and Manawatū-Whanganui—are not specifically modelled. Instead, the APSIM ‘broadacre’ rotation is used as a proxy. Section 3.1.1 compares the adopted APSIM loss rates to alternative loss rates from other modelling studies; CVG N loads may be underestimated for Pukekohe catchments and overestimated for Gisborne and Tasman. Additionally, all CVG systems are assumed to be irrigated and follow a fixed fertilization schedule which simplifies real-world practices which may vary within and between regions. The accuracy of the mapped CVG boundaries also varies between regions and is discussed in Section 2.2.

Furthermore, sub-catchment variability in CVG systems is not explicitly considered in the catchment-average approach. CVG N loss rates and mitigation potential vary widely, so the modelled values may

be accurate at catchment scales but not applicable to specific operations. The three levels of GMP-related N loss reductions assessed in this report are based on a range of modelled reductions from the literature as identified in Section 0. The modelled reductions depended on various assumptions about the CVG rotations and the application of GMPs as set out in the cited reports. In some instances, the application of GMPs resulted in scenarios that may not have been economically viable. This report seeks to represent the overall range of N-loss reductions likely to be achieved at a catchment scale.

For other land uses, the accuracy of the model relies on various information sources and data sets, each with their own sources of error. Any error in those data sets will also be present in the model and results.

Despite these limitations, the developed nitrogen load model provides a reliable methodology using best-available data to estimate catchment N loads. Modelled scenarios show that with the adoption of GMPs for CVG, CVG production can expand to meet population growth without increasing catchment N loads. Model results are intended to inform broad scale freshwater planning; they are not intended for, nor accurate enough to inform mitigations or regulation at a farm or sub-farm scale.

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Table 7 Nitrogen Load Model results for selected LAWA river water quality monitoring locations under current land use and CVG Expansion Scenario 5/10.

Site Name	Region	Attribute Band		Catchment Total (current)	15% CVG Expansion with CVG GMP Scenario 5/10		
		NO3N	TON	N load (t/yr)	Expansion Area (ha)	Net Change in Catchment N Load (t/yr)	Net Change in Catchment N Load (%)
Whangamarie Stream	Auckland Region	NA	D	19	53	-0.27	-1.4%
Kumeu @ Weza	Auckland Region	NA	A	56	12	0.12	0.2%
Waitangi Stream	Auckland Region	NA	C	40	37	-0.49	-1.2%
Harts Creek d/s Lower Lake Rd	Canterbury Region	NA	D	2149	132	-1.81	-0.1%
Selwyn River u/s Coes Ford bridge	Canterbury Region	NA	C	1966	160	0.49	0.0%
Opihi River mouth/Milford Lagoon	Canterbury Region	NA	NA	3114	23	-0.23	0.0%
Rakaia River north bank d/s SH1	Canterbury Region	NA	A	1337	22	-0.27	0.0%
Ashburton River at SH1	Canterbury Region	NA	B	2034	18	-0.47	0.0%
Ashley River 50m u/s SH1	Canterbury Region	NA	A	809	1	0.01	0.0%
Turanganui River at Gladstone Rd Bridge	Gisborne Region	A	A	371	241	0.52	0.1%
Hikuwai River at Willowflat	Gisborne Region	A	A	175	48	0.94	0.5%
Taruheru River at Tuckers Rd Bridge	Gisborne Region	C	C	79	110	0.43	0.5%
Waipaoa River at Kanakanaia	Gisborne Region	A	A	1567	240	0.21	0.0%
Waipaoa River at Matawhero Bridge	Gisborne Region	A	A	2135	739	0.13	0.0%
Karamu-Clive River upstream of the Whakatu Rail Bridge	Hawke's Bay Region	B	B	941	847	16.10	1.7%
Ngaruroro at Fernhill	Hawke's Bay Region	A	A	1427	117	1.93	0.1%
Tukituki at Red Br.	Hawke's Bay Region	NA	B	4017	651	8.23	0.2%
Herehere Stream at Te Aute Rd	Hawke's Bay Region	A	A	13	3	0.04	0.3%
Waikawa Stream at Huritini	Manawatū-Whanganui	B	B	90	25	-0.05	-0.1%
Kuku at N. Johnstone Farm Bridge	Manawatū-Whanganui	NA	B	32	25	-0.04	-0.1%
Hokio at Lake Horowhenua	Manawatū-Whanganui	B	B	132	96	0.40	0.3%
Ohau at Haines Property	Manawatū-Whanganui	A	A	133	69	0.09	0.1%

Koputaroa at Tavistock Rd	Manawatū-Whanganui	C	C	36	23	0.04	0.1%
Arawhata Drain at Hokio Beach Road	Manawatū-Whanganui	D	D	48	68	0.30	0.6%
Manawatu at Teachers College	Manawatū-Whanganui	A	A	6284	55	-0.17	0.0%
Rangitikei at McKelvies	Manawatū-Whanganui	A	A	3690	87	0.59	0.0%
Patiki Stream at Kawiu Road	Manawatū-Whanganui	C	C	12	15	0.11	0.9%
Mangawhero at Raupiu Road	Manawatū-Whanganui	A	A	843	266	2.75	0.3%
Opaoa River at Swamp Road	Marlborough Region	A	A	353	60	0.57	0.2%
Wairua at Purua	Northland Region	A	A	950	7	-0.07	0.0%
Waipao at Draffins Road	Northland Region	B	B	68	15	-0.11	-0.2%
Kakanui River at McCones	Otago Region	A	A	847	93	-2.25	-0.3%
Maketawa Stream at Tarata Rd.	Taranaki Region	A	A	104	0	0.00	0.0%
Borck at 400m d-s Queen St	Tasman Region	C	NA	41	41	0.47	1.2%
Neimann at 600m u-s Lansdowne Rd	Tasman Region	C	NA	4	5	0.05	1.1%
Waimea at SH60 Appleby	Tasman Region	A	NA	358	112	0.74	0.2%
Piako River at Paeroa-Tahuna Rd Br	Waikato Region	NA	B	1500	64	-0.15	0.0%
Mangaonua Stm at Hoeka Rd	Waikato Region	NA	B	171	32	0.24	0.1%
Waihou River at Okauia	Waikato Region	NA	B	1455	174	0.15	0.0%
Awaroa River (Waiuku) at Otaua Rd Br opp Moseley Rd	Waikato Region	NA	B	47	14	-0.11	-0.2%
Whakapipi Stm at SH22 Br	Waikato Region	NA	C	79	150	-0.89	-1.1%
Ohaeroa Stm at SH22 Br	Waikato Region	NA	B	38	43	-0.61	-1.6%
Waitohu Stream at Norfolk Crescent	Wellington Region	A	A	49	6	0.01	0.0%
Mangaone Stream at Sims Road Bridge	Wellington Region	B	B	61	8	-0.04	-0.1%
Ruamahanga River at Pukio	Wellington Region	A	A	3350	749	-3.86	-0.1%
Ruamahanga River at Gladstone Bridge	Wellington Region	A	A	1791	419	-1.61	-0.1%

Table 8 Nitrogen Load Model results for selected LAWA river water quality monitoring locations under current land use and CVG Expansion Scenario 5/10 (additional reporting metrics to Table 7).

Site Name	Region	Current Land use			15% CVG Expansion with CVG GMP Scenario 5/10		
		Catch-ment N Load (t/yr)	CVG N Load (proportion of catchment total)	Change in N Load with CVG GMP 5/10 Adoption (change in catchment load)	Change in CVG N Load	N Load Removed from Replaced Land (t/yr)	Net Change in Catchment N Load
Whangamarie Stream	Auckland Region	19	11 (58%)	-1.1 (-5.8%)	+0.4 (4%)	-0.7	-0.27 (-1.4%)
Kumeu @ Weza	Auckland Region	56	3 (5%)	-0.1 (-0.3%)	+0.3 (9.7%)	-0.2	0.12 (0.2%)
Waitangi Stream	Auckland Region	40	8 (19%)	-0.8 (-1.9%)	+0.3 (4%)	-0.8	-0.49 (-1.2%)
Harts Creek d/s Lower Lake Rd	Canterbury Region	2144	36 (2%)	-1.8 (-0.1%)	+3.5 (9.7%)	-5.3	-1.81 (-0.1%)
Selwyn River u/s Coes Ford bridge	Canterbury Region	1950	44 (2%)	-2.2 (-0.1%)	+4.3 (9.7%)	-3.8	0.49 (0%)
Opihi River mouth/Milford Lagoon	Canterbury Region	3112	6 (0%)	-0.3 (0%)	+0.6 (9.7%)	-0.8	-0.23 (0%)
Rakaia River north bank d/s SH1	Canterbury Region	1335	6 (0%)	-0.3 (0%)	+0.6 (9.7%)	-0.9	-0.27 (0%)
Ashburton River at SH1	Canterbury Region	2032	5 (0%)	-0.2 (0%)	+0.5 (9.7%)	-0.9	-0.47 (0%)
Ashley River 50m u/s SH1	Canterbury Region	809	0 (0%)	0 (0%)	+0 (9.7%)	0.0	0.01 (0%)
Turanganui River at Gladstone Rd Bridge	Gisborne Region	371	102 (27%)	-10.2 (-2.7%)	+4 (4%)	-3.5	0.52 (0.1%)
Hikuwai River at Willowflat	Gisborne Region	175	17 (10%)	-0.8 (-0.5%)	+1.6 (9.7%)	-0.7	0.94 (0.5%)
Taruheru River at Tuckers Rd Bridge	Gisborne Region	79	46 (59%)	-4.6 (-5.9%)	+1.8 (4%)	-1.4	0.43 (0.5%)
Waipaoa River at Kanakanaia	Gisborne Region	1567	101 (6%)	-10.1 (-0.6%)	+4 (4%)	-3.8	0.21 (0%)
Waipaoa River at Matawhero Bridge	Gisborne Region	2135	311 (15%)	-31.1 (-1.5%)	+12.3 (4%)	-12.2	0.13 (0%)
Karamu-Clive River upstream of the Whakatu Rail Bridge	Hawke's Bay Region	941	304 (32%)	-15.2 (-1.6%)	+29.6 (9.7%)	-13.5	16.1 (1.7%)
Ngaruroro at Fernhill	Hawke's Bay Region	1427	42 (3%)	-2.1 (-0.1%)	+4.1 (9.7%)	-2.2	1.93 (0.1%)
Tukituki at Red Br.	Hawke's Bay Region	4017	234 (6%)	-11.7 (-0.3%)	+22.8 (9.7%)	-14.5	8.23 (0.2%)
Herehere Stream at Te Aute Rd	Hawke's Bay Region	13	1 (7%)	0 (-0.3%)	+0.1 (9.7%)	0.0	0.04 (0.3%)

Waikawa Stream at Huritini	**Manawatū-Whanganui**	90	13 (15%)	-1.3 (-1.5%)	+0.5 (3.9%)	-0.6	-0.05 (-0.1%)
Kuku at N. Johnstone Farm Bridge	**Manawatū-Whanganui**	32	13 (40%)	-1.3 (-4%)	+0.5 (4%)	-0.5	-0.04 (-0.1%)
Hokio at Lake Horowhenua	**Manawatū-Whanganui**	132	50 (38%)	-5 (-3.8%)	+2 (4%)	-1.6	0.4 (0.3%)
Ohau at Haines Property	**Manawatū-Whanganui**	133	36 (27%)	-3.6 (-2.7%)	+1.4 (4%)	-1.3	0.09 (0.1%)
Koputaroa at Tavistock Rd	**Manawatū-Whanganui**	36	12 (33%)	-1.2 (-3.3%)	+0.5 (3.9%)	-0.4	0.04 (0.1%)
Arawhata Drain at Hokio Beach Road	**Manawatū-Whanganui**	48	35 (74%)	-3.5 (-7.4%)	+1.4 (3.9%)	-1.1	0.3 (0.6%)
Manawatu at Teachers College	**Manawatū-Whanganui**	6284	15 (0%)	-0.7 (0%)	+1.5 (9.7%)	-1.6	-0.17 (0%)
Rangitikei at McKelvies	**Manawatū-Whanganui**	3690	24 (1%)	-1.2 (0%)	+2.3 (9.7%)	-1.7	0.59 (0%)
Patiki Stream at Kawiu Road	**Manawatū-Whanganui**	12	8 (64%)	-0.8 (-6.4%)	+0.3 (4%)	-0.2	0.11 (0.9%)
Mangawhero at Raupiu Road	**Manawatū-Whanganui**	843	73 (9%)	-3.6 (-0.4%)	+7.1 (9.7%)	-4.3	2.75 (0.3%)
Opaoa River at Swamp Road	**Marlborough Region**	353	13 (4%)	-0.7 (-0.2%)	+1.3 (9.7%)	-0.7	0.57 (0.2%)
Wairua at Purua	**Northland Region**	950	1 (0%)	-0.1 (0%)	+0.1 (9.7%)	-0.2	-0.07 (0%)
Waipao at Draffins Road	**Northland Region**	68	2 (3%)	-0.1 (-0.2%)	+0.2 (9.7%)	-0.3	-0.11 (-0.2%)
Kakanui River at McCones	**Otago Region**	847	21 (3%)	-1.1 (-0.1%)	+2.1 (9.7%)	-4.3	-2.25 (-0.3%)
Maketawa Stream at Tarata Rd.	**Taranaki Region**	104	0 (0%)	0 (0%)	0 (0%)	0	0 (0%)
Borck at 400m d-s Queen St	**Tasman Region**	41	24 (60%)	-2.4 (-6%)	+1 (4%)	-0.5	0.47 (1.2%)
Neimann at 600m u-s Lansdowne Rd	**Tasman Region**	4	3 (64%)	-0.3 (-6.4%)	+0.1 (4%)	-0.1	0.05 (1.1%)
Waimea at SH60 Appleby	**Tasman Region**	358	66 (18%)	-6.6 (-1.8%)	+2.6 (4%)	-1.9	0.74 (0.2%)
Piako River at Paeroa-Tahuna Rd Br	**Waikato Region**	1500	20 (1%)	-1 (-0.1%)	+2 (9.7%)	-2.1	-0.15 (0%)
Mangaonua Stm at Hoeka Rd	**Waikato Region**	171	10 (6%)	-0.5 (-0.3%)	+1 (9.7%)	-0.8	0.24 (0.1%)
Waihou River at Okauia	**Waikato Region**	1455	55 (4%)	-2.8 (-0.2%)	+5.4 (9.7%)	-5.2	0.15 (0%)
Awaroa River (Waiuku) at Otaua Rd Br opp Moseley Rd	**Waikato Region**	47	3 (6%)	-0.3 (-0.6%)	+0.1 (4%)	-0.2	-0.11 (-0.2%)
Whakapipi Stm at SH22 Br	**Waikato Region**	79	30 (38%)	-3 (-3.8%)	+1.2 (4%)	-2.1	-0.89 (-1.1%)
Ohaeroa Stm at SH22 Br	**Waikato Region**	38	8 (22%)	-0.8 (-2.2%)	+0.3 (4%)	-0.9	-0.61 (-1.6%)
Waitohu Stream at Norfolk Crescent	**Wellington Region**	49	3 (6%)	-0.3 (-0.6%)	+0.1 (4%)	-0.1	0.01 (0%)
Mangaone Stream at Sims Road Bridge	**Wellington Region**	61	4 (6%)	-0.4 (-0.6%)	+0.2 (4%)	-0.2	-0.04 (-0.1%)
Ruamahanga River at Pukio	**Wellington Region**	3350	152 (5%)	-7.6 (-0.2%)	+14.8 (9.7%)	-18.6	-3.86 (-0.1%)
Ruamahanga River at Gladstone Bridge	**Wellington Region**	1791	85 (5%)	-4.2 (-0.2%)	+8.3 (9.7%)	-9.9	-1.61 (-0.1%)

Table 9 Nitrogen Load Model results for selected LAWA river water quality monitoring locations under 3 CVG Expansion Scenarios.

Site Name	Region	Catchment Total (current)		Scenario CVG Expansion Area (ha)	Scenario Net Change in Catchment N Load (t/year, % change in parentheses)		
		Area (ha)	N load (t/yr)		5%/10% CVG GMP	10%/20% CVG GMP	15%/30% CVG GMP
Whangamarie Stream	Auckland Region	813	19	53	-0.27 (-1.4%)	-1.56 (-8.2%)	-2.85 (-14.9%)
Kumeu @ Weza	Auckland Region	4512	56	12	0.12 (0.2%)	-0.05 (-0.1%)	-0.22 (-0.4%)
Waitangi Stream	Auckland Region	1887	40	37	-0.49 (-1.2%)	-1.39 (-3.5%)	-2.29 (-5.7%)
Harts Creek d/s Lower Lake Rd	Canterbury Region	39290	2144	132	-1.81 (-0.1%)	-3.89 (-0.2%)	-5.97 (-0.3%)
Selwyn River u/s Coes Ford bridge	Canterbury Region	96609	1950	160	0.49 (0%)	-2.03 (-0.1%)	-4.56 (-0.2%)
Opihi River mouth/Milford Lagoon	Canterbury Region	237034	3112	23	-0.23 (0%)	-0.59 (0%)	-0.95 (0%)
Rakaia River north bank d/s SH1	Canterbury Region	277635	1335	22	-0.27 (0%)	-0.62 (0%)	-0.98 (-0.1%)
Ashburton River at SH1	Canterbury Region	151435	2032	18	-0.47 (0%)	-0.75 (0%)	-1.02 (-0.1%)
Ashley River 50m u/s SH1	Canterbury Region	115033	809	1	0.01 (0%)	-0.01 (0%)	-0.03 (0%)
Turanganui River at Gladstone Rd Bridge	Gisborne Region	31605	371	241	0.52 (0.1%)	-11.22 (-3%)	-22.95 (-6.2%)
Hikuwai River at Willowflat	Gisborne Region	30764	175	48	0.94 (0.5%)	-0.03 (0%)	-0.99 (-0.6%)
Taruheru River at Tuckers Rd Bridge	Gisborne Region	4114	79	110	0.43 (0.5%)	-4.91 (-6.2%)	-10.24 (-13%)
Waipaoa River at Kanakanaia	Gisborne Region	157522	1567	240	0.21 (0%)	-11.45 (-0.7%)	-23.1 (-1.5%)
Waipaoa River at Matawhero Bridge	Gisborne Region	192505	2135	739	0.13 (0%)	-35.84 (-1.7%)	-71.8 (-3.4%)
Karamu-Clive River upstream of the Whakatu Rail Bridge	Hawke's Bay Region	49656	941	847	16.1 (1.7%)	-1.48 (-0.2%)	-19.06 (-2%)
Ngaruroro at Fernhill	Hawke's Bay Region	194516	1427	117	1.93 (0.1%)	-0.51 (0%)	-2.94 (-0.2%)
Tukituki at Red Br.	Hawke's Bay Region	246370	4017	651	8.23 (0.2%)	-5.28 (-0.1%)	-18.79 (-0.5%)
Herehere Stream at Te Aute Rd	Hawke's Bay Region	960	13	3	0.04 (0.3%)	-0.01 (-0.1%)	-0.06 (-0.5%)
Waikawa Stream at Huritini	Manawatū-Whanganui	7329	90	25	-0.05 (-0.1%)	-1.56 (-1.7%)	-3.07 (-3.4%)
Kuku at N. Johnstone Farm Bridge	Manawatū-Whanganui	1510	32	25	-0.04 (-0.1%)	-1.52 (-4.7%)	-3 (-9.3%)
Hokio at Lake Horowhenua	Manawatū-Whanganui	6303	132	96	0.4 (0.3%)	-5.36 (-4.1%)	-11.13 (-8.4%)

Ohau at Haines Property	**Manawatū-Whanganui**	15414	133	69	0.09 (0.1%)	-4.09 (-3.1%)	-8.28 (-6.2%)
Koputaroa at Tavistock Rd	**Manawatū-Whanganui**	1972	36	23	0.04 (0.1%)	-1.34 (-3.7%)	-2.73 (-7.6%)
Arawhata Drain at Hokio Beach Road	**Manawatū-Whanganui**	1208	48	68	0.3 (0.6%)	-3.79 (-7.9%)	-7.88 (-16.4%)
Manawatu at Teachers College	**Manawatū-Whanganui**	391712	6284	55	-0.17 (0%)	-1.03 (0%)	-1.9 (0%)
Rangitikei at McKelvies	**Manawatū-Whanganui**	387549	3690	87	0.59 (0%)	-0.78 (0%)	-2.16 (-0.1%)
Patiki Stream at Kawiu Road	**Manawatū-Whanganui**	479	12	15	0.11 (0.9%)	-0.78 (-6.4%)	-1.68 (-13.8%)
Mangawhero at Raupiu Road	**Manawatū-Whanganui**	66768	843	266	2.75 (0.3%)	-1.46 (-0.2%)	-5.68 (-0.7%)
Opaoa River at Swamp Road	**Marlborough Region**	45745	353	60	0.57 (0.2%)	-0.19 (-0.1%)	-0.95 (-0.3%)
Wairua at Purua	**Northland Region**	54348	950	7	-0.07 (0%)	-0.13 (0%)	-0.2 (0%)
Waipao at Draffins Road	**Northland Region**	3650	68	15	-0.11 (-0.2%)	-0.24 (-0.4%)	-0.37 (-0.5%)
Kakanui River at McCones	**Otago Region**	67648	847	93	-2.25 (-0.3%)	-3.48 (-0.4%)	-4.72 (-0.6%)
Maketawa Stream at Tarata Rd.	**Taranaki Region**	3280	104	0	0 (0%)	0 (0%)	0 (0%)
Borck at 400m d-s Queen St	**Tasman Region**	1834	41	41	0.47 (1.2%)	-2.32 (-5.7%)	-5.12 (-12.6%)
Neimann at 600m u-s Lansdowne Rd	**Tasman Region**	157	4	5	0.05 (1.1%)	-0.26 (-6.3%)	-0.57 (-13.6%)
Waimea at SH60 Appleby	**Tasman Region**	76994	358	112	0.74 (0.2%)	-6.84 (-1.9%)	-14.42 (-4%)
Piako River at Paeroa-Tahuna Rd Br	**Waikato Region**	53892	1500	64	-0.15 (0%)	-1.32 (-0.1%)	-2.48 (-0.2%)
Mangaonua Stm at Hoeka Rd	**Waikato Region**	8326	171	32	0.24 (0.1%)	-0.35 (-0.2%)	-0.94 (-0.5%)
Waihou River at Okauia	**Waikato Region**	80637	1455	174	0.15 (0%)	-3.04 (-0.2%)	-6.23 (-0.4%)
Awaroa River (Waiuku) at Otaua Rd Br opp Moseley Rd	**Waikato Region**	2608	47	14	-0.11 (-0.2%)	-0.44 (-0.9%)	-0.76 (-1.6%)
Whakapipi Stm at SH22 Br	**Waikato Region**	4562	79	150	-0.89 (-1.1%)	-4.39 (-5.5%)	-7.89 (-10%)
Ohaeroa Stm at SH22 Br	**Waikato Region**	2040	38	43	-0.61 (-1.6%)	-1.59 (-4.1%)	-2.57 (-6.7%)
Waitohu Stream at Norfolk Crescent	**Wellington Region**	4518	49	6	0.01 (0%)	-0.32 (-0.7%)	-0.65 (-1.3%)
Mangaone Stream at Sims Road Bridge	**Wellington Region**	3853	61	8	-0.04 (-0.1%)	-0.49 (-0.8%)	-0.94 (-1.5%)
Ruamahanga River at Pukio	**Wellington Region**	246141	3350	749	-3.86 (-0.1%)	-12.63 (-0.4%)	-21.39 (-0.6%)
Ruamahanga River at Gladstone Bridge	**Wellington Region**	133799	1791	419	-1.61 (-0.1%)	-6.52 (-0.4%)	-11.42 (-0.6%)

EMS area by LAWA catchment (from Collaborations national N load modelling March 2025)

Site Name	Region	Growing Hub	EMS mapped area (ha)	Estimated total CVG area (ha)	Proportion of total in EMS
Kumeu @ Weza	Auckland Region	Kumeu	9	79	12%
Whangamarie Stream	Auckland Region	Pukekohe	146	340	43%
Waitangi Stream	Auckland Region		66	238	28%
Whakapipi Stm at SH22 Br	Waikato Region		577	967	60%
Ohaeroa Stm at SH22 Br	Waikato Region		171	277	61%
Turanganui R. at Gladstone Rd Br.	Gisborne Region	Gisborne	386	1556	25%
Taruheru River at Tuckers Rd Bridge	Gisborne Region		161	707	23%
Waipaoa River at Kanakanaia	Gisborne Region		893	1547	58%
Waipaoa River at Matawhero Br.	Gisborne Region		2468	4802	51%
Mangawhero at Raupiu Road	Manawatū-Whanganui	Ohakune	1152	1717	67%
Waikawa Stream at Huritini	Manawatū-Whanganui	Horowhenua	76	162	47%
Kuku at N. Johnstone Farm Bridge	Manawatū-Whanganui		140	159	89%
Hokio at Lake Horowhenua	Manawatū-Whanganui		486	618	79%
Ohau at Haines Property	Manawatū-Whanganui		340	448	76%
Koputaroa at Tavistock Rd	Manawatū-Whanganui		109	148	73%
Arawhata Drain at Hokio Beach Rd.	Manawatū-Whanganui		366	439	83%
Patiki Stream at Kawiu Road	Manawatū-Whanganui		66	96	69%
Harts Creek d/s Lower Lake Rd	Canterbury Region	Canterbury	432	852	51%
Selwyn River u/s Coes Ford bridge	Canterbury Region		80	1034	8%
Opihi River mouth/Milford Lagoon	Canterbury Region		39	149	27%
Borck at 400m d-s Queen St	Tasman Region	Waimea	97	266	37%
Neimann 600m u-s Lansdowne Rd	Tasman Region		9	29	31%
Waimea at SH60 Appleby	Tasman Region		452	721	63%
Total			8721	17351	50%

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