BEFORE THE ENVIRONMENT COURT	**ENV-2021-WLG-000020**
AT WELLINGTON	**ENV-2021-WLG-000021**
I MUA I TE KŌTI TAIAO	**ENV-2021-WLG-000022**
I TE WHANGANUI-Ā-TARA ROHE	**ENV-2021-WLG-000023**

IN THE MATTER	of the Resource Management Act 1991 (**RMA** or **the Act**)
AND	
IN THE MATTER	of appeals under Clause 14(1) of the First Schedule of the Act in relation to a decision of Manawatū-Whanganui Regional Council on Proposed Plan Change 2 to the Horizons One Plan
BETWEEN	**TE RUNANGA O RAUKAWA** **Appellant** **ANDREW DAY** **Appellant** **WELLINGTON FISH AND GAME COUNCIL** **Appellant** **NGĀTI TURANGA** **Appellant**
AND	**MANAWATŪ-WHANGANUI REGIONAL COUNCIL** **Respondent**

STATEMENT OF EVIDENCE OF GILLIAN HOLMES (WATER QUALITY)
ON BEHALF OF HORTICULTURE NEW ZEALAND

13 OCTOBER 2023

HOLM | MAJUREY

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Contents

EXECUTIVE SUMMARY

1. I have been asked to prepare evidence outlining the water quality modelling undertaken by Mr Easton, providing my opinion on the current direction of PC2 with regards to water quality improvements, and the impact of crop rotation on water quality.

2. In my view the provisions within PC2 provide workable, regulatory pathways for IFLU's. From a water quality perspective, I think it is appropriate to provide alternative approaches for demonstrating nitrogen leaching is being appropriately managed.

3. In my opinion, the provisions in PC2 will result in an improvement in water quality as it drives the implementation of GMP and BMP practices. This will occur in the interim while the next phase of catchment-based limit setting process is being undertaken, i.e. through the NPSFM 2024 plan change process.

4. It is acknowledged that through the implementation of PC2 limits have not been designed to achieve the One Plan Schedule E water quality targets. However, it was not the intention of PC2 to create limits to meet water quality targets in Schedule E (Ms Patterson EIC, paragraph 58), rather the intention was to provide a step towards meeting them.

5. The NPSFM (2020) process requires community vision and value setting to inform freshwater outcomes and TAS. The water quality targets in Schedule E of the One Plan will need to be reviewed following this process, and then interim and long-term limits will be set to achieve the TAS. This will be the focus of the NPSFM 2024 plan development (Oranga Wai) currently being undertaken by Horizons, which will also require a detailed FMU specific modelling and limit setting approach.

6. Water quality modelling has been undertaken by Mr Easton (**Appendix A**) on behalf of HortNZ to:

    (a) estimate catchment nitrogen and sediment loads in the Manawatu-Whanganui region in relation to PC2. This modelling has focused on the Waiopehu FMU and the contribution of horticulture to contaminant loading.

(b) provide an estimate of the flux in cultivated land in the Horizons region between 1996 and 2018.

(c) Provides comment on the modelling outlined in Dr Snelder's EIC (paragraphs 56 to 71), in which a comparison is made between the potential water quality improvements under the provisions of the Decision Version of PC2 and the proposed Nitrogen Risk Scorecard for CVG.

7. Overall, the modelling completed by Mr Easton summarised in my evidence has shown that for N, P and sediment, the contribution of CVG as a proportion of total contaminant load is small, for example 0.7% of the N load, 0.4% of the P load and less than 0.5% of the total sediment load in the Region.

8. Based on these percentage contributions, the contaminant loss reductions achieved by CVG through the adoption of GMP and BMP practices, although important, will only ever be able to make a small contribution to reducing catchment contaminant loads.

9. I believe the potential water quality impacts of allowing rotation of CVG under PC2 will be minimal for a number of reasons, namely:

(a) The definition of the Baseline Commercial Growing Area within the Nitrogen Risk Scorecard which specifies that the growing area cannot increase under an existing consent, meaning there is no net change in load;

(b) The small size of the land being utilised for CVG in the region meaning the cumulative effect associated with the activity is small;

(c) In the case of the green vegetables within the Waiopehu FMU, the scarcity of suitable land meaning CVG tends to rotate on land previously cultivated;

(d) In the other TWMSZ, given the longer pasture phases CVG has similar N leaching to other activities that are likely to occupy suitable land; and

(e) Any change in localised effects being managed using the Freshwater Farm Plan (**FWFP**) with a Nitrogen Risk scorecard stating that the level of risk on the swapped lease land must be assessed and must not increase the overall risk level.

INTRODUCTION

Qualifications and experience

1. My full name is Gillian Margaret Holmes. I hold the position of Principal Consultant – Hydrology and Hydrogeology with SLR Consultancy NZ Ltd. I have been in this position since October 2021.

2. I am contracted to provide water quality expertise on the Proposed Waikato Regional Plan Change 2 to the Horizons One Plan (PC2) to Horticulture New Zealand (HortNZ).

3. I hold a Bachelor of Science (BSc) in Geography (2001) and a Master of Science Degree in Physical Geography (2004) from Otago University.

4. I have 19 years' experience in the field of hydrogeology and water resources. I started my career at MWH New Zealand Limited and worked for them between 2004 and 2007. From 2007 to 2021, I worked at Sinclair Knight Merz/Jacobs working up to an Associate Hydrogeologist role.

5. I have acted as an Expert Witness in groundwater-related consent hearings in New Zealand for the past ten years. I have provided expert evidence on behalf of HortNZ on the Proposed Water Conservation Order for the Ngaruroro River and Clive River, Hawke's Bay Regional Council Tutaekuri, Ahuriri, Ngaruroro and Karamu (TANK) Plan Change, as well as Block 1 and 2 hearings for the Waikato Regional Plan Change 1 in 2018-2019. I am currently engaged by HortNZ to provide water quality expert witness evidence to the Environment Court for Waikato Regional Councils PC1.

6. I have provided expertise in the fields of hydrogeology, water allocation and water quality to a range of local government clients including Bay of Plenty Regional Council and Far North District Council and other organisations such as HortNZ and Waka Kotahi.

7. I have knowledge of the Horizons region, particularly the Waiopehu FMU, as I have been involved in supporting several growers through

hydrogeological analysis, effects assessment and iwi consultation for inclusion in their groundwater consent renewals applications for the last 10 years.

Code of Conduct

8. I have been provided with a copy of the Code of Conduct for Expert Witnesses contained in the Environment Court's Practice Note dated 1 January 2023. I have read and agree to comply with that Code. This evidence is within my area of expertise, except where I state that I am relying upon the specified evidence of another person. I have not omitted to consider material facts known to me that might alter or detract from the opinions that I express.

Involvement in project

9. I have not been previously involved in the PC2 hearing or water quality conferencing. However, I have reviewed my colleague Dr Conwell's evidence before the Hearing Commissioners on behalf of HortNZ dated 25 September 2020, as well as the Catchment Water Modelling reports completed by Mr Easton appended to Dr Conwell's evidence.

10. I have been asked to prepare evidence outlining the water quality modelling undertaken by Mr Easton, providing my opinion on the current direction of PC2 with regards to water quality improvements, and the impact of crop rotation on water quality.

Scope of evidence

11. The scope of my evidence is to:

(a) Discuss the implications of PC2 on water quality in the Manawatu-Whanganui Region;

(b) Consider whether the Horizons One Plan and PC2 implement the National Policy Statement for Freshwater Management (NPSFM, 2020);

(c) Provide a summary of the water quality modelling completed for HortNZ by Mr Easton, with the latest, updated water quality modelling results appended to my evidence at **Appendix A**;

(d) Identify the scale and characteristics of commercial vegetable growing (**CVG**) as an Intensive Farm Land Use (**IFLU**) across the target Water Management Sub Zones (**WMSZ**); and

(e) Discuss the potential water quality impacts of allowing rotation of CVG that meets the requirements of the controlled activity rule, and as provided for in the definition of Baseline Commercial Growing Area, as referenced in Policy 14-5 (d)(iii) and Rule 14-1(iii).

THE IMPLICATIONS OF PC2 ON WATER QUALITY IN THE REGION

12. In my view the provisions within PC2 provide workable, regulatory pathways for IFLU's. From a water quality perspective, I think it is appropriate to provide alternative approaches for demonstrating nitrogen leaching is being appropriately managed.

13. In my opinion, the provisions in PC2 will result in an improvement in water quality as it drives the implementation of GMP and BMP practices. This will occur in the interim while the next phase of catchment-based limit setting process is being undertaken, i.e., through the NPSFM 2024 plan change process.

14. As outlined in paragraph 13 of Ms Patterson's EIC, the science and monitoring that was undertaken to inform the Horizons One Plan showed that the health of many of the region's waterways was poor and/or at risk of degradation, particularly with regards to nutrients, sediment and bacteria.

15. In order to manage the future water quality of the Horizons Region, the One Plan was developed with a framework which includes the management of diffuse sources of Nitrogen (**N**) and the regulation of intensive farming land use activities (**IFLU**). CVG has been identified as one of the IFLU activities within the One Plan.

16. In the One Plan, the management of diffuse sources of N are managed through the N load allocations outlined in Table 14.2 Cumulative Nitrogen Leaching Maximums (**CNLM**).

17. PC2 has provided updates to Table 14.2 for consistency with Overseer Version 6.2.3, as well as including an alternative regulatory pathway for IFLU's.

18. The evidence of Mr Ford (paragraph 18) outlines that the CNLM in Table 14.2 have come from modelling different intensities of dairy farming systems, and these do not correlate well to CVG, given the causes of N leaching differ considerably between the two land uses. In addition, as explained by Mr Ford in paragraph 20 of his EIC, the Overseer review has recommended that Overseer is not used to establish fixed numeric limits within regulation.

19. Given these concerns, I support the inclusion of the proposed Nitrogen Leaching Risk Scorecard outlined in Schedule [Y] for CVG as part of the PC2 framework as it takes into account more site-specific considerations than Table 14.2 and allows for targeted Good Management Practice (GMP) and/or Best Management Practice (BMP) to be developed for the CVG. Mr Barber provides a detailed analysis of the Nitrogen Risk Assessment Tool in his EIC, paragraphs 15 to 20.

20. GMP and BMP implementation is the key component for achieving water quality improvements from CVG, with this implementation driving improvements in farm practices (Mr Barber, paragraph 24).

21. From a water quality perspective, irrespective of any threshold of allocation of individual land parcels (the intensity KgN/ha as outlined in Table 14-2), it is the overall load of contaminants at a Water Management Sub-zone (**WMSZ**) or Freshwater Management Unit (**FMU**) scale, that influences water quality. The load at these scales represents the cumulative amount of a particular contaminant that is within a water body and flowing towards a sensitive downstream environment.

22. In addition, the consenting of landuse via solely CNLMs in Table 14-2, gives no consideration to the existing water quality, sensitivity of downstream environments, mitigations being undertaken on site or the contribution of the landuse to the WMSZ and FMU load. Overall, the management of the load will enable WMSZ and FMU improvements.

23. Recent monitoring by Horizons shows that improvement is possible and, in some locations, occurring, with a trend analysis across both 10-year and 20-year periods suggesting improvements in some water quality parameters across the region and WMSZs. Dr Snelder's EIC (paragraph 49) suggests there is some limited evidence that management actions are contributing to decreased river Soluble Inorganic Nitrogen (**SIN**) concentrations at the 20-year time scale (with 59% of sites showing a 'likely' improvement for SIN). I acknowledge that climatic variation is also having an impact on water quality in the short term.

24. As such, I believe that PC2 will lead to improvements in water quality as it drives the implementation of GMP and BMP practices.

WHETHER THE ONE PLAN AND PC2 IMPLEMENT THE NPSFM 2020

25. It is acknowledged that through the implementation of PC2, limits have not been designed to achieve the One Plan Schedule E water quality targets. However, it was not the intention of PC2 to create limits to meet water quality targets in Schedule E (Ms Patterson EIC, paragraph 58), rather the intention was to provide a step towards meeting them.

26. Within the One Plan and PC2, the term "limit" has been used to describe the numerical thresholds in Table 14.2, the CNLMs, and are divided between Land Use Capability Class (LUC I to VIII).

27. The CNLMs within Table 14.2 have not been set using the NPSFM limit setting process, i.e., it is not based on catchment modelling, is not linked to Target Attribute States (TAS) or the assimilative capacity of the downstream sensitive environment.

28. Further, it is effectivity allocating the CNLM to individual land parcels rather than the load at catchment or sub-catchment, which may have the effect of allowing some land uses to increase their N leaching in certain LUC classes.

29. I agree with the statement by Ms Patterson in paragraph 29 of her EIC, that "the desired outcomes for identified water body values, and achievement of water quality targets in Schedule E, are to be achieved through a range of mechanisms (both regulatory and non-regulatory) and not solely by regulating IFLUs".

30. The NPSFM (2020) process requires community vision and value setting to inform freshwater outcomes and TAS. The water quality targets in Schedule E of the One Plan will need to be reviewed following this process, and then interim and long term limits will be set to achieve the TAS. This will be the focus of the NPSFM 2024 plan development (Oranga Wai) currently being undertaken by Horizons, which will also require a detailed FMU specific modelling and limit setting approach.

SUMMARY OF WATER QUALITY MODELLING UNDERTAKEN BY HORTNZ

31. Water quality modelling has been undertaken by Mr Easton (**Appendix A**) on behalf of HortNZ to estimate catchment nitrogen and sediment loads in the Manawatu-Whanganui region in relation to PC2. This modelling has focused on the Waiopehu FMU and the contribution of horticulture to contaminant loading. The results of this modelling are discussed in paragraphs 45 to 61 of my evidence.

32. In addition, modelling has been undertaken to provide an estimate of the flux in cultivated land in the Horizons region between 1996 and 2018. This analysis has been used to support by discussion on water quality effects of crop rotation as discussed in paragraphs 62 to 74 of my evidence.

33. Finally, Section 4 of Easton (2023) provides comment on the modelling outlined in Dr Snelder's EIC (paragraphs 56 to 71), in which a comparison is made between the potential water quality improvements under the provisions of the Decision Version of PC2 (**DV-PC2**) and the proposed Nitrogen Risk Assessment Tool for CVG as discussed in paragraphs 52 to 58 of my evidence.

34. Several updates to the modelling have been undertaken during the PC2 process as more data has become available. Four water quality modelling reports are attached to my evidence as **Appendix A** showing the progression of the modelling updates over time. A summary of the modelling completed is provided below.

35. Easton (2020) entitled "Catchment Water Quality Modelling: supporting evidence of Dr Claire Conwell" was appended to Dr Conwell's Evidence in Chief during the PC2 Council Hearing. This memorandum details the calculation of estimates of catchment N

and sediment loads in the Manawatu-Whanganui region in relation to PC2, as well as calculating possible reductions in contaminants through the use of GMP and BMP.

36. The N modelling was based on supplied Contaminant Allocation and Simulation Model (**CASM**) model information (Snelder et al., 2020) and Page Bloomer Overseer modelling for CVG (Bloomer et al., 2020). Both the CASM and Page Bloomer modelling were used by Horizons to inform the PC2 process. The sediment modelling used the Revised Universal Soil Loss Equation (**RUSLE**) and loss-rates for CVG developed by Agrilink (Barber et al., 2019).

37. Eaton (2021) entitled "Land use and N load estimates – Pukekohe and Horowhenua" is a memorandum that summarises land use, annual N loss, Māori land, and Land Use Capability (**LUC**) for the Pukekohe and Horowhenua Specified Vegetable Growing Areas (SVGAs) as defined in the NPSFM (2020). This memorandum was Exhibit 1, attached to Ms Sands affidavit, for the judicial review of the Horowhenua Specified Vegetable Growing Area.

38. In Easton (2021) modelling, for the Horowhenua SVGA, N loss rates were once again based on supplied CASM model information (Snelder et al., 2020), however the land use mapping was based on Land Use and Carbon Analysis System (**LUCAS**) land use map for the year 2016. The LUCAS data was used in this modelling because it improves on the CASM mapping of CVG and provided a consistent land use map for similar analysis for Pukekohe.

39. Easton and Landers (2022) entitled "SCAMP modelling for Horticulture" is a memorandum that provides recommendations for improving the Horizons Simplified Contaminant Allocation and Modelling Platform **(SCAMP**) model for representation of urban and horticultural (including CVG) land uses. The SCAMP model has updated the CASM modelling completed for the PC2 process and will be used for simulating nutrient management options of the FMUs for the NPSFM plan process that will follow PC2, expected to be notified in 2024.

40. The recommendations within the Easton and Landers (2022) memorandum included considering the different CVG rotation types (i.e., Horowhenua Greens/Brassica, Horowhenua

Potato/Onion, Ohakune and Manawatu vegetable rotations) as modelled in Bloomer et al. (2020). GIS and N loss rate information were provided by Horizons Regional Council and the SCAMP modellers (Dr Cox and Dr Snelder).

41. Finally, Easton (2023) entitled "Catchment Modelling and Mapping – Horizons Plan Change 2" is the latest water quality modelling completed for the PC2 Environment Court hearing process. This memorandum updates the catchment modelling annual load estimates for N and Phosphorus (**P**) based on updated land uses using the SCAMP model GIS information received from Horizons in 2022, and updated Overseer modelling so all nitrogen leaching estimates were from Overseer version 6.2.3 or above.

42. The Easton (2023) modelling supersedes the previous modelling outlined in Easton (2020) and (2021) for N and P. It should be noted that the sediment calculations in Easton (2020) have not been updated as no further information is available to update these calculations. The calculated annual load estimates for N and P were used to provide an indication of the relative nutrient loading rates from different land uses.

43. The Easton (2023) memorandum also provides an estimate of the flux in cultivated land in the Horizons region between 1996 and 2018 using the Landcover Database (**LCDB**). This analysis has been used to support by discussion on water quality effects of crop rotation.

44. Finally, the Easton (2023) memorandum provides comment on the modelling outlined in Dr Snelder's EIC (paragraphs 56 to 71), in which a comparison is made between the potential water quality improvements under the provisions of the Decision Version of PC2 and the proposed Nitrogen Risk Assessment TOol for CVG.

SCALE AND CHARACTERISTICS OF CVG WITHIN THE HORIZONS REGION

45. Overall, the modelling completed by Mr Easton summarised in paragraphs 31 to 44 of my evidence, has shown that for N, P and sediment, the contribution of CVG as a proportion of total contaminant load is small, for example 0.7% of the N load, 0.4% of the P load and less than 0.5% of the total sediment load in the Region.

46. Based on these percentage contributions, the contaminant loss reductions achieved by CVG through the adoption of GMP and BMP practices, although important, will only ever be able to make a small contribution to reducing catchment contaminant loads.

47. Table 2 of Easton (2023) summarises the N and P loads for the entire Horizons Region. This information clearly shows that the N and P loads are dominated by pastoral farming, with 90% of the N load and almost 80% of P load estimated to come for Sheep and Beef or Dairy farms, collectively.

48. By comparison, Table 2 shows that Vegetable Cropping (i.e., CVG) makes up 0.2% of total area and is estimated to contribute only 0.7% of the N load and 0.4% of the P load in the Region.

49. Table 3 of Easton (2023) focuses on the N load within the Target WMSZs within PC2. Table 3 shows that with regards to Vegetable Cropping (i.e., CVG):

(a) There are 18 TWMSZ with no vegetable cropping and hence no associated N load;

(b) Vegetable Cropping contributes less than 1% of the N load in 7 TWMSZ, and between 1 - 5% of the N load in an additional 5 TWMSZs;

(c) In West 9b TWMSZ, Vegetable Cropping contributes 20.5% of the N load. However, it is only the third highest contributor after Sheep/Beef and/or deer farming and Dairy farming;

(d) In Hoki 1a TWMSZ, Vegetable Cropping contributes 25.5% of N load. However, it is still only the second biggest contributor after Dairy farming;

(e) Overall, across the TWMSZs, the N load is predominantly predicted to originate from Dairy farming.

50. Table 4 of Easton (2023) focuses on the P load within the Target WMSZs within PC2. Table 4 shows that with regards to Vegetable Cropping (i.e., CVG):

(a) There are 18 TWMSZ with no vegetable cropping and hence no associated P load;

(b) Vegetable Cropping contributes less than 1% of the P load in 8 TWMSZ, and between 1 - 5% of the P load in an additional 4 TWMSZs;

(c) In West 9b TWMSZ, Vegetable Cropping contributes 10.5% of the P load. However, it is only the fourth highest contributor after Dairy, Sheep/Beef and/or deer farming and other farming;

(d) In Hoki 1a TWMSZ, Vegetable Cropping contributes 15.9% of P load. However, it is still only the third equal biggest contributor with Dairy farming, and after Sheep/Beef and/or deer farming and Urban/Transport;

(e) Overall, across the TWMSZs, the P load is predominantly predicted to originate from Sheep/Beef and/or deer farming.

51. Easton (2023) modelling is conservative as it does not take into consideration any water quality improvements that will be made under PC2.

52. Water quality improvements were considered in Easton (2020), and as outlined in Easton (2023), the modelling predictions for water quality improvements presented in Easton (2020), are still sound and are unlikely to change significantly within the updates incorporated in the latest analysis.

53. As outlined in Section 2.1.1 of Easton (2023), the Easton (2020) memorandum calculated the reduction in N load predicted using the Bloomer (2020) Overseer modelling of three CVG rotations in the Horowhenua. As explained in the evidence of Mr Ford (paragraphs 57-58), the Overseer modelling compared two scenarios:

(a) A pre-2019 scenario to represent CVG practices at the time of the One Plan becoming operative; and

(b) A post-2019 scenario where GMPs and BMP consistent with the adoption of the GAP EMS were implemented.

54. The Easton (2020) modelling indicates that at the Waiopehu FMU scale, the effect of the adoption of GMPs and BMPs for the CVG rotations was a predicted reduction in N load of 34%.

55. The evidence presented by Dr Jolly, also predicted a reduction, although a higher estimate, which could be achieved with the adoption of GMP and BMP. I understand that the difference in reductions calculated relates to using different Overseer modelling approaches.

56. As outlined in the evidence of Mr Ford (paragraphs 72 to 74), Overseer is suitable to be used in catchment modelling, but it is not appropriate to take modelled estimates such as the 34% reduction predicted in the Easton (2020) and use this as the basis of a consent level limit, as was the case in the PC2 decision.

57. As outlined in Mr Barber's evidence (paragraph 65) the NRAT is designed to drive the uptake of GMPs and BMPs for nutrient management practices that were modelled by Bloomer (2019) and by Dr Jolly.

58. Therefore, the NRAT is likely to drive a similar water quality outcome as was predicted to be achieved with the Overseer budget approach within the PC2 decision. This statement is supported by the modelling completed by Dr Snelder's EIC (paragraph 71) in which he concluded that implementing PC2 with the proposed amendments would result in similarly modest water quality improvements in the target catchments of the Region to those predicted for the Decisions Version of PC2.As stated in my paragraph 42, the sediment calculations in Easton (2020) have not been updated in the Easton (2023) memorandum as no further information is available to update these calculations.

59. Table 16 of Easton (2020) provides the estimated sediment loss rate by FMU, with the combined CVG and cropping sediment load only making up 1% of the total load of the Waihepu FMU (named Horowheua in Table 16) and 0.5% of the total sediment load for the region. Overall, the majority of regional sediment load was predicted to be generated from pastoral farms.

60. Section 5 of Easton (2020) also modelled the difference in sediment loss rates for current practice and for potential BMP (such as high efficiency (80% effective) and low efficiency (20% effective) buffer strips. This modelling concluded that the current erosion and sediment control practices reduce average sediment loss by between 34% (low efficiency) and 56% (high efficiency) compared to unmitigated sediment loss rate.

61. Although the NRAT relates primarily to N, components of the NRAT related to soil health and practices between crops will drive the uptake of GMPs and BMPs for erosion and sediment management practices that were modelled by Easton (2020), and therefore in conjunction with the FWFPs, the NRAT approach is likely to drive a similar water quality outcome as was predicted to be achieved with the PC2 decision version of the provisions.

POTENTIAL WATER QUALITY IMPACTS OF ALLOWING ROTATION OF CVG

62. I believe the potential water quality impacts of allowing rotation of CVG under PC2 will be minimal for a number of reasons, namely:

    (a) The definition of the Baseline Commercial Growing Area within the NRAT which specifies that the growing area cannot increase under an existing consent, meaning there is no net change in load;

    (b) The small size of the land being utilised for CVG in the region meaning the cumulative effect associated with the activity is small;

    (c) In the case of the green vegetables within the Waiopehu FMU, the scarcity of suitable land meaning CVG tends to rotate on land previously cultivated;

    (d) In the other TWMSZ, given the longer pasture phases CVG has similar N leaching to other activities that are likely to occupy suitable land; and

    (e) Any change in localised effects being managed using the Freshwater Farm Plan (**FWFP**) with a NRAT stating that the level of risk on the swapped lease land must be assessed and must not increase the overall risk level.

63. I support the inclusion of the Baseline Commercial Growing Area under Rule 14-1 d(iii) as it ensures that the total area of CVG cannot expand, even if the location of CVG sought in the consent is different to where it was located in the baseline period (i.e., as occurs during crop rotation).

64. Crop rotation is an important component of CVG, with the concept described in the definition included in PC2 as below:

- ***Crop Rotation*** *is the systematic planting of different crops in sequence over multiple years within the same growing space, or across changing and parcels, and often includes a pasture phase. This process helps maintain nutrients in the soil, reduce soil erosion, and prevents plant diseases and pests*.

65. As outlined in the evidence of Mr Ford and Ms Sands, there are three main growing areas with the Horizons region, namely:

    (a) The northern part of the region, including Ohakune;

    (b) The central region located in the Manawatu and Rangitikei, including Opiki; and

    (c) The southern region, in the Horowhenua District, including the area around Levin.

66. Different rotations of vegetables are grown in different parts of the Region as outlined in Easton (2021) and EIC of Mr Ford (paragraphs 38-54), these rotations include different crops and have different nitrogen loss risks.

67. Easton (2023) provides an assessment of the CVG flux by comparing landuse change over time using data from the LCDB. This database has mapped landuses, including short-rotation cropland, for the years 1996, 2001, 2008, 2012 and 2018.

68. The assessment showed that for all the PC2 FMUs, there has been little change in short-rotation cropland area since 2008. It is expected that the majority of short-rotation cropland categorised by LCDB in the Waiopehu FMU will be CVG. For the Waiopehu FMU, the data showed that there had been a net decrease of 41 ha of short-rotation cropland since 2001.

69. This assessment shows that in the Waiopehu FMU, the rotational CVG systems tend to rotate to and from already cropped land without any net change in overall CVG area. However, there may be some instances where CVG land is returned to a pasture phase, or a pasture phase is returned to CVG.

70. In FMU's further north, the short-rotation crop area has not increased. However, given the CVG in these areas have longer pasture phases, it is difficult to distinguish CVG from arable cropping and cropping for animal feed from the LCDB GIS layer.

71. From a water quality perspective, crop rotation has a neutral effect on water quality at the FMU and TWMSZ scale due to CVG moving locations but not increasing in load. The area of CVP that will be rotated is also small i.e., CVG land equates to 0.2% of the total area of all FMU's (Easton, 2023). Further, the leaching rate from CVG further north is around 30.9 kg/N/ha/yr (as shown in Table 4 of Easton (2020) for Potato/Onion rotations). This load is similar to leaching rates for arable farming (30 kg/N/ha/yr) and dairy (43 kg/N/ha/yr) as outlined in Table 3 of Easton (2023).

72. Localised effects of crop rotation, i.e., the potential effect of rotating CVG closer to a sensitive downstream environment, can be managed through the NRAT produced as part of the FWFP, as outlined in paragraph 49 of Mr Barber's EIC.

73. The risk score card manages the risk associated with changing land (rotation) at the localised scale with the NRAT stating:

> "While the total land area cannot increase without consent, the location of leased land may change from year to year. The level of risk on all leased land must be assessed and must not increase the overall risk level."

74. In terms of PC2, the concept of Crop Rotation has been incorporated within the reference to Baseline Commercial Growing Area in Rule 14-1 d(iii). I support the inclusion of this definition as it takes into consideration the total area of land the growers were using in the baseline period (2012-2013) and enables rotation without the risk of an increased contaminant load at the broader scale.

Gillian Holmes

13 October 2023

APPENDIX A – UPDATED WATER QUALITY MODELLING RESULTS (STUART EASTON)

Subject:	Catchment Modelling & Mapping – Horizons Plan Change 2
Attention:	Gillian Holmes
From:	Stuart Easton
Date	11/10/2023
Copies to:	Michelle Sands

1 Introduction

This memorandum synthesises various analyses relevant to Cultivated Vegetable Growing (CVG) in relation to Horizons Plan Change 2 (PC2), comprising:

- A summary of three previous technical memorandums that modelled catchment water quality (**Section 2**);
- Update of annual load estimates for nitrogen (N) and phosphorus (P) based on provided SCAMP model information (**Section 3**);
- A comment on the analysis of Dr Snelder for the proposed amendments to the decisions version of PC2 for the Hoki_1a Water Management Subzone (WMSZ) (**Section 4**); and
- An estimate of the flux in cultivated land in the Horizons region between 1996 and 2018 using the Landcover Database (LCDB) (**Section 5**).

2 Previous analyses

The following sub-headings refer to three recent technical memorandums relevant to the assessment of water quality impacts from CVG in the Horizons region. The memorandums are included in the Appendices.

2.1 Catchment Water Quality Modelling: supporting evidence of Dr Claire Conwell (Easton, 2020)

This memorandum estimated catchment N and sediment loads in the Manawatu-Whanganui region in relation to PC2. The results showed that for both sediment and nitrogen, the contribution of CVG as a proportion of total contaminant load is small and subsequently that any contaminant loss reductions achieved by CVG are unlikely to significantly reduce catchment contaminant loads.

2.1.1 N modelling

N Modelling was based on supplied CASM model information (Snelder et al., 2020) and Page Bloomer Overseer modelling for CVG (Bloomer et al., 2020). The Page Bloomer overseer modelling predicted that through the implementation of Good Management Practice (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 (see Table 1). Based on the spatial distribution of CVG rotations in the Horowhenua (Waiopehu) Freshwater Management Unit (FMU), an overall 34% reduction in N load was predicted from pre-2019 to post-2019 practice (30% for target Waiopehu WMSZs only). This reduction was predicted to reduce Waiopehu FMU N load by approximately 5% (Table 2).

Table 1 Page Bloomer modelled title leaching rates for Horowhenua CVG rotations (reproduced from Table 4 in Easton, 2020).

Rotation	Leaching Rate (pre-2019) (kg/N/ha/yr)	Leaching Rate (post-2019) (kg/N/ha/yr)	Reduction from pre-2019 to post-2019 practice (%)
Intensive	81.0	44.0	-46%
Brassica	92.9	83.2	-10%
Potato/Onion	30.9	28.8	-7%

Table 2 Reduction in N loss from CVG GMP and BMP post-2019 for Horowhenua FMU WMSZs (reproduced from Table 9 in Easton, 2020).

Horowhenua FMU WMSZs	Target Catchment	CVG N load (pre-2019) (t/N/yr)	CVG N load (post-2019) (t/N/yr)	CVG N load change (%)	WMSZ N load (pre-2019 (t/N/yr)	WMSZ N load (post-2019) (t/N/yr)	WMSZ N load change (%)
Hoki_1a	Yes	34	24	-28.2%	125	115	-7.7%
Hoki_1b	Yes	0	0	0.0%	10	10	0.0%
West_8	Yes	3	2	-27.0%	36	35	-2.3%
West_9a	Yes	0	0	0.0%	54	54	0.0%
West_9b	Yes	4	2	-45.7%	48	46	-4.2%
Total for Target Catchments		**41**	**29**	**-30.0%**	**272**	**260**	**-4.6%**
Ohau_1a	No	0	0	0.0%	54	54	0.0%
Ohau_1b	No	36	22	-38.6%	182	168	-7.7%
West_7	No	0	0	0.0%	58	58	0.0%
Total for FMU		**77**	**51**	**-34.0%**	**566**	**540**	**-4.7%**

2.1.2 Sediment modelling

Sediment modelling used the Revised Universal Soil Loss Equation (RUSLE) and loss-rates for CVG developed by Agrilink (Barber et al., 2019). The Agrilink loss rates estimate that current erosion and sediment control practices reduce average sediment loss by between 34% (low efficiency) and 56% (high efficiency) compared to the unmitigated sediment loss rate[1]. The potential enhanced practice (BMP) achieves a 74% reduction in sediment.

[1] High and low efficiency of current practice relates to the effectiveness of buffer strips: high efficiency assumes buffer strips are 80% effective in removing transported sediment, low efficiency assumes 20%.

At a catchment scale, it was estimated that cultivated land (including but not limited to CVG) produces approximately 0.5% of the regional sediment load and 1% of the sediment load for the Waiopehu (Horowhenua) FMU[2]. Adoption of potential enhanced practices on CVG land were predicted to reduce total sediment load in the Waiopehu FMU by approximately 0.5% compared to unmitigated practice.

It is of the authors opinion that the sediment modelling in Easton (2020) is robust and remains relevant as it used the latest available LCDB information (2018 mapped year) to estimate land cover and predicted region wide sediment loads comparable to recent SedNetNZ modelling (8.7 Mt/year compared to 8.5 Mt/year in Vale et al., 2022).

2.2 Land use and N load estimates - Pukekohe and Horowhenua (Easton, 2021)

This memorandum summarised land use, annual N loss, Māori land, and Land Use Capability (LUC) for the Pukekohe and Horowhenua Specified Vegetable Growing Areas (SVGAs). For the Horowhenua, N loss rates were based on supplied CASM model information (Snelder et al., 2020) however the land use mapping was based on Land Use and Carbon Analysis System (LUCAS) land use map for the year 2016[3]. The N loss modelling results were very similar to Easton (2020).

2.3 SCAMP modelling for Horticulture (Easton & Landers, 2022)

This memorandum provided recommendations for improving the SCAMP model (which updated CASM) for representation of urban and horticultural (including CVG) land uses, including consideration of different CVG rotation types as modelled in Bloomer et al. (2020). GIS and N loss rate information were provided by Horizons Regional Council and the SCAMP modellers (Tim Cox and Ton Snelder).

3 Catchment N & P loads

This section estimates annual N and P loads from different land uses using the SCAMP model GIS data (based on Herzig et al., 2020) and N loss information (received 2022[4]). The load estimates are intended to provide an indication of relative nutrient loading from various land uses, not including point-source discharges. Nutrient loads are equivalent to unattenuated losses at the bottom of the root-zone. We have not attempted to replicate the full process and complexity of the SCAMP model. The information updates the CASM information used in Easton (2020) and Easton (2021), however the changes are relatively minor and results are expected to be very similar to the previous analyses at the FMU and WMSZ scale.

Table 3 shows the adopted nutrient loss rates and the mapped land use categories. Loss rates have been derived from the provided SCAMP model information and applied to the spatial land use layer. For Dairy and Sheep, beef, and/or deer farming, a single typology has been assumed. Further updates include the recommendations outlined in Easton (2022) (see **section 2.3**):

- Adoption of rotation-specific N loss rates for CVG based on location;

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[2] It is expected that the majority of cultivated land in the Waiopehu FMU is CVG.
[3] https://data.mfe.govt.nz/layer/52375-lucas-nz-land-use-map-1990-2008-2012-2016-v008/
[4] Dr Snelder personal communication (2022).

- Urban loss rates updated;
- Adoption of loss rates for Horticulture (other than veg) from 'Horticulture' in Drewry (2018).

Table 3 Adopted loss rates for N & P load estimates.

Cls_001	N loss class	N loss rate (kg/ha/year)	P loss rate (kg/ha/year)	Reference
SBD	**Sheep, beef, and/or deer farming**	14	0.8	SCAMP (SBD-Taranaki-Manawatu-Hill)
UKN	**Unknown - no data**	1.6	0.33	SCAMP (As per Conservation and amenity uses)
CON	**Conservation and amenity uses**	1.6	0.33	SCAMP
HYDR	**Hydro parcels**	0	0	SCAMP
TRAN	**Transport corridors**	11	1.1	SCAMP
FOR	**Forestry**	1.8	0.08	SCAMP
LIF	**Lifestyle blocks**	14	0.8	SCAMP (As per Sheep, beef and/or deer farming)
OTH	**Other land-uses**	1.6	0.33	SCAMP (As per Conservation and amenity uses)
DAI	**Dairy farming**	43	0.6	SCAMP (DAI-Warm/Low/Light/Dry)
URB	**Urban and other settlement areas**	11	1.1	SCAMP (Updated)
ARA	**Arable farming**	30	0.3	SCAMP
OAN	**Other animal farming**	14	0.8	SCAMP (As per Sheep, beef and/or deer farming)
HORT	**Horticulture (other than veg)**	9.9	0.17	Drewry (2018) 'Horticulture'
VEG	**Manawatu extensive**	31	1.6	Updated loss rate for 'Cash cropping – Rotation 1' in The Agribusiness Group (2014, 2017) *
VEG	**Horowhenua Potatoes/Onions**	31	1.6	Bloomer et al. (2020) 'Onion/Potato rotation'
VEG	**Horowhenua Intensive**	84.1	1.6	Bloomer et al. (2020) – area weighted average of 'Brassica dominant vegetables' and 'Intensive fresh vegetables' rotations
VEG	**Ohakune CVP**	35	1.6	Updated loss rate for 'Waimarino - Rotation 4' in The Agribusiness Group (2014) *

* Updated modelling to Overseer version 6.5 by Stuart Ford (personal communication)

3.1 Results

Table 4 summarises land use area and N and P loads for the Horizons region. N and P loads are dominated by pastoral farming with more than 90% of N load and almost 80% of P load predicted to originate from Sheep & Beef or Dairy farms collectively. CVG produces less than 1% of the regional N load and less than 0.5% of the regional P load. This is due to the relatively small CVG area; there is estimated to be 3,504 ha of CVG (just 0.2% of the region), of which 919 is within Target WMSZs.[5]

Table 5 and Table 6 estimate N and P load, respectively, for target WMSZs. N load is predominantly predicted to originate from Dairy farms in Target WMSZs, including in the Waiopehu FMU (previously named Horowhenua FMU). Similarly the majority of P load is from Sheep, beef, and/or deer farming in Target WMSZs, including in the Waiopehu FMU.

The results are comparable to the CASM modelling summary in Easton (2020), reflective of the relatively minor changes in land use area and nutrient loss rates when summarised at the regional, FMU or WMSZ scale. For example in Easton (2020) 15.2% of the N load in the Waiopehu target WMSZs is predicted to originate from CVG compared to 16.7% in this analysis. This suggests that the modelling in Easton (2020), including the analysis of future scenarios remains sound and is unlikely to change significantly with the updates incorporated in this analysis.

Table 4 Regional N and P loads (all FMUs).

Name	Area (ha)	Area (% of total)	N load (t/year)	N load (% of total)	P load (t/year)	P load (% of total)
Sheep, beef, and/or deer farming	1244773	55.8%	17426.8	62.2%	995.8	71.6%
Conservation and amenity uses	410443	18.4%	656.7	2.3%	135.4	9.7%
Dairy farming	183433	8.2%	7887.6	28.1%	110.1	7.9%
Forestry	151551	6.8%	272.8	1.0%	12.1	0.9%
Other land-uses	73842	3.3%	118.1	0.4%	24.4	1.8%
Lifestyle blocks	42346	1.9%	592.8	2.1%	33.9	2.4%
Unknown - no data	40072	1.8%	64.1	0.2%	13.2	1.0%
Transport corridors	35259	1.6%	387.9	1.4%	38.8	2.8%
Hydro parcels	19323	0.9%	0.0	0.0%	0.0	0.0%
Urban and other settlement areas	13735	0.6%	151.1	0.5%	15.1	1.1%
Arable farming	7476	0.3%	224.3	0.8%	2.2	0.2%
Other animal farming	4999	0.2%	70.0	0.2%	4.0	0.3%
Vegetable cropping	3504	0.2%	182.7	0.7%	5.6	0.4%
Horticulture (other than veg)	397	0.0%	3.9	0.0%	0.1	0.0%
Total	**2231152**		**28038.9**		**1390.7**	

[5] As discussed in Easton & Landers (2022), the CVG area as estimated by the SCAMP GIS information is likely to be an underestimate for the Ohakune area however within Target WMSZs it is expected to be correct.

Table 5 Target WMSZ N load (t/year). WMSZ proportion in parentheses.

FMU	Target Catchment Zone Code	N load (t/year)	Sheep, beef, and/or deer farming	Dairy farming	Vegetable cropping	Urban & Transport	Other Farming	Native, Forestry, & Other
					Manawatu extensive, Horowhenua Potatoes/ Onions, Horowhenua Intensive, Ohakune CVP	Transport corridors, Urban and other settlement areas	Lifestyle blocks, Arable farming, Other animal farming, Horticulture (other than veg)	Conservation and amenity uses, Forestry, Hydro parcels, Other land-uses
Manawatū	Mana_1a	671.4	417.6 (62.2%)	224.9 (33.5%)	0 (0%)	10 (1.5%)	14.3 (2.1%)	4.6 (0.7%)
	Mana_1b	164.6	71.5 (43.4%)	86.9 (52.8%)	0 (0%)	1.5 (0.9%)	2.7 (1.6%)	2.1 (1.2%)
	Mana_1c	312.2	305.3 (97.8%)	0 (0%)	0 (0%)	3.4 (1.1%)	2.7 (0.9%)	0.8 (0.2%)
	Mana_2a	83.9	64.6 (76.9%)	15.9 (19%)	0.3 (0.4%)	0.6 (0.7%)	2.4 (2.9%)	0 (0%)
	Mana_2b	273.5	69.7 (25.5%)	180.1 (65.8%)	0.2 (0.1%)	7.8 (2.9%)	15.4 (5.6%)	0.3 (0.1%)
	Mana_3	41.5	19 (45.8%)	19.8 (47.7%)	0 (0%)	0.3 (0.8%)	0.1 (0.3%)	2.2 (5.4%)
	Mana_4	16.8	1.6 (9.5%)	13.5 (80.4%)	0 (0%)	0.1 (0.7%)	0.3 (1.9%)	1.2 (7.4%)
	Mana_5a	265.2	174.8 (65.9%)	84.6 (31.9%)	0 (0%)	3.2 (1.2%)	2 (0.7%)	0.6 (0.2%)
	Mana_5b	112.1	22 (19.6%)	86.4 (77.1%)	0 (0%)	0.8 (0.7%)	1.3 (1.1%)	1.6 (1.4%)
	Mana_5c	121.0	5.7 (4.7%)	110.3 (91.1%)	0 (0%)	0.5 (0.4%)	4.3 (3.6%)	0.3 (0.2%)
	Mana_5d	141.8	11.9 (8.4%)	121.9 (86%)	0 (0%)	1 (0.7%)	4.4 (3.1%)	2.5 (1.8%)
	Mana_5e	115.0	17.7 (15.4%)	92.6 (80.6%)	0 (0%)	1.1 (1%)	2.1 (1.8%)	1.4 (1.2%)
	Mana_6	83.7	40 (47.8%)	42 (50.2%)	0 (0%)	1.3 (1.6%)	0.2 (0.2%)	0.2 (0.2%)
	Mana_8a	56.0	36.3 (64.9%)	12.5 (22.4%)	0 (0%)	0.9 (1.6%)	0.4 (0.6%)	5.8 (10.4%)
	Mana_8b	387.7	38.5 (9.9%)	341.4 (88%)	0 (0%)	5.8 (1.5%)	1.1 (0.3%)	1 (0.2%)
	Mana_8c	85.8	21.1 (24.5%)	50.3 (58.6%)	0.1 (0.2%)	5.7 (6.7%)	8.4 (9.8%)	0.2 (0.3%)
	Mana_8d	447.1	139.4 (31.2%)	292.8 (65.5%)	0 (0%)	7.8 (1.7%)	3.1 (0.7%)	4.1 (0.9%)
	Mana_9a	121.7	29.7 (24.4%)	88.8 (72.9%)	0 (0%)	2.2 (1.8%)	0.6 (0.5%)	0.4 (0.3%)
	Mana_9b	51.9	18 (34.6%)	29.6 (56.9%)	1 (1.9%)	1.2 (2.3%)	1.5 (2.9%)	0.7 (1.4%)
	Mana_9c	266.1	87.3 (32.8%)	165.9 (62.4%)	0.3 (0.1%)	6 (2.3%)	4.5 (1.7%)	2.1 (0.8%)
Rangitīkei-Turakina	Rang_4a	731.7	224.8 (30.7%)	456.1 (62.3%)	2.4 (0.3%)	8.5 (1.2%)	38.8 (5.3%)	1.1 (0.2%)
	Rang_4b	97.0	29.2 (30.1%)	58.4 (60.2%)	0.6 (0.6%)	1.4 (1.5%)	4.9 (5%)	2.5 (2.5%)
	Rang_4c	259.6	151.3 (58.3%)	96.3 (37.1%)	0.2 (0.1%)	4.1 (1.6%)	4.9 (1.9%)	2.8 (1.1%)

	Rang_4d	**276.7**	110.4 (39.9%)	133.6 (48.3%)	0.1 (0%)	8.7 (3.1%)	23.4 (8.4%)	0.6 (0.2%)
	West_5	**325.4**	134.7 (41.4%)	176.3 (54.2%)	0 (0%)	1.4 (0.4%)	4 (1.2%)	9 (2.8%)
	West_6	**375.2**	35.9 (9.6%)	325.3 (86.7%)	1.4 (0.4%)	2.7 (0.7%)	7.3 (1.9%)	2.6 (0.7%)
Waiopehu (Horowhenua)	**Hoki_1a**	**142.3**	21.9 (15.4%)	57.6 (40.5%)	36.3 (25.5%)	11.9 (8.4%)	13.3 (9.4%)	1.3 (0.9%)
	Hoki_1b	**13.2**	5.7 (43.3%)	6 (45.7%)	0 (0%)	0.4 (2.7%)	1 (7.7%)	0.1 (0.6%)
	West_8	**43.1**	12.5 (29%)	22.8 (52.9%)	2.6 (6%)	0.4 (0.8%)	4.1 (9.6%)	0.7 (1.7%)
	West_9a	**64.8**	4.5 (6.9%)	46.9 (72.5%)	2.9 (4.5%)	0.7 (1.2%)	4.9 (7.5%)	4.8 (7.5%)
	West_9b	**56.7**	16.5 (29.1%)	17.6 (31%)	11.6 (20.5%)	1.1 (2%)	8.8 (15.5%)	1.1 (1.9%)
Whanganui	**West_4**	**78.4**	57.7 (73.6%)	7 (8.9%)	0 (0%)	1.7 (2.2%)	8.9 (11.3%)	3.2 (4%)
Target WMSZ total		**6283.3**	**2396.7 (38.1%)**	**3464.2 (55.1%)**	**60 (1%)**	**104.4 (1.7%)**	**196.1 (3.1%)**	**61.8 (1%)**

Table 6 Target WMSZ P load (t/year). WMSZ proportion in parentheses.

FMU	**Target Catchment Zone Code**	**P load (t/year)**	**Sheep, beef, and/or deer farming**	**Dairy farming**	**Vegetable cropping**	**Urban & Transport**	**Other Farming**	**Native, Forestry, & Other**
					Manawatu extensive, Horowhenua Potatoes/ Onions, Horowhenua Intensive, Ohakune CVP	Transport corridors, Urban and other settlement areas	Lifestyle blocks, Arable farming, Other animal farming, Horticulture (other than veg)	Conservation and amenity uses, Forestry, Hydro parcels, Other land-uses
Manawatū	**Mana_1a**	**29.77**	23.86 (80.2%)	3.14 (10.5%)	0 (0%)	1 (3.4%)	0.81 (2.7%)	0.96 (3.2%)
	Mana_1b	**5.99**	4.09 (68.2%)	1.21 (20.2%)	0 (0%)	0.15 (2.5%)	0.15 (2.6%)	0.39 (6.5%)
	Mana_1c	**18.03**	17.44 (96.7%)	0 (0%)	0 (0%)	0.34 (1.9%)	0.16 (0.9%)	0.09 (0.5%)
	Mana_2a	**4.14**	3.69 (89.2%)	0.22 (5.4%)	0.02 (0.4%)	0.06 (1.5%)	0.14 (3.3%)	0.01 (0.1%)
	Mana_2b	**8.23**	3.98 (48.4%)	2.51 (30.5%)	0.01 (0.1%)	0.78 (9.5%)	0.88 (10.7%)	0.06 (0.7%)
	Mana_3	**1.87**	1.09 (58.2%)	0.28 (14.8%)	0 (0%)	0.03 (1.7%)	0.01 (0.4%)	0.46 (24.8%)
	Mana_4	**0.56**	0.09 (16.3%)	0.19 (33.6%)	0 (0%)	0.01 (2.2%)	0.02 (3.2%)	0.25 (44.7%)
	Mana_5a	**11.69**	9.99 (85.5%)	1.18 (10.1%)	0 (0%)	0.32 (2.8%)	0.11 (1%)	0.08 (0.7%)
	Mana_5b	**2.92**	1.26 (43%)	1.21 (41.3%)	0 (0%)	0.08 (2.8%)	0.06 (1.9%)	0.32 (11%)
	Mana_5c	**2.04**	0.33 (16%)	1.54 (75.3%)	0 (0%)	0.05 (2.3%)	0.07 (3.6%)	0.06 (2.8%)
	Mana_5d	**3.25**	0.68 (20.9%)	1.7 (52.3%)	0 (0%)	0.1 (3%)	0.25 (7.8%)	0.52 (15.9%)
	Mana_5e	**2.82**	1.01 (35.8%)	1.29 (45.8%)	0 (0%)	0.11 (4%)	0.12 (4.3%)	0.28 (10.1%)

	Mana_6	**3.04**	2.28 (75.2%)	0.59 (19.3%)	0 (0%)	0.13 (4.4%)	0.01 (0.3%)	0.02 (0.7%)
	Mana_8a	**3.56**	2.08 (58.3%)	0.18 (4.9%)	0 (0%)	0.09 (2.6%)	0.02 (0.6%)	1.2 (33.6%)
	Mana_8b	**7.80**	2.2 (28.2%)	4.76 (61.1%)	0 (0%)	0.58 (7.4%)	0.06 (0.8%)	0.2 (2.5%)
	Mana_8c	**3.01**	1.2 (40%)	0.7 (23.3%)	0.01 (0.2%)	0.57 (19.1%)	0.47 (15.7%)	0.05 (1.7%)
	Mana_8d	**13.70**	7.96 (58.1%)	4.09 (29.8%)	0 (0%)	0.78 (5.7%)	0.18 (1.3%)	0.69 (5.1%)
	Mana_9a	**3.27**	1.7 (51.9%)	1.24 (37.9%)	0 (0%)	0.22 (6.7%)	0.04 (1.1%)	0.08 (2.4%)
	Mana_9b	**1.84**	1.03 (55.8%)	0.41 (22.4%)	0.05 (2.7%)	0.12 (6.4%)	0.09 (4.7%)	0.15 (8%)
	Mana_9c	**8.60**	4.99 (58%)	2.32 (26.9%)	0.02 (0.2%)	0.6 (7%)	0.26 (3%)	0.42 (4.9%)
Rangitīkei-Turakina	**Rang_4a**	**21.68**	12.85 (59.2%)	6.36 (29.4%)	0.12 (0.6%)	0.85 (3.9%)	1.31 (6%)	0.19 (0.9%)
	Rang_4b	**2.97**	1.67 (56.1%)	0.82 (27.4%)	0.03 (1%)	0.14 (4.8%)	0.1 (3.3%)	0.22 (7.4%)
	Rang_4c	**10.86**	8.65 (79.6%)	1.34 (12.4%)	0.01 (0.1%)	0.41 (3.8%)	0.28 (2.6%)	0.17 (1.5%)
	Rang_4d	**10.18**	6.31 (62%)	1.86 (18.3%)	0.01 (0.1%)	0.87 (8.5%)	1.03 (10.1%)	0.1 (1%)
	West_5	**11.00**	7.69 (69.9%)	2.46 (22.4%)	0 (0%)	0.14 (1.3%)	0.23 (2.1%)	0.48 (4.3%)
	West_6	**7.55**	2.05 (27.2%)	4.54 (60.1%)	0.07 (0.9%)	0.27 (3.6%)	0.42 (5.5%)	0.2 (2.7%)
Waiopehu (Horowhenua)	**Hoki_1a**	**5.06**	1.25 (24.8%)	0.8 (15.9%)	0.8 (15.9%)	1.19 (23.6%)	0.76 (14.9%)	0.25 (5%)
	Hoki_1b	**0.52**	0.33 (62.9%)	0.08 (16.2%)	0 (0%)	0.04 (6.9%)	0.06 (11.2%)	0.01 (2.8%)
	West_8	**1.47**	0.71 (48.5%)	0.32 (21.6%)	0.05 (3.3%)	0.04 (2.4%)	0.24 (16.1%)	0.12 (8.2%)
	West_9a	**2.15**	0.26 (11.9%)	0.66 (30.5%)	0.05 (2.6%)	0.07 (3.5%)	0.28 (13%)	0.83 (38.5%)
	West_9b	**2.11**	0.94 (44.6%)	0.25 (11.6%)	0.22 (10.5%)	0.11 (5.3%)	0.5 (23.8%)	0.09 (4.1%)
Whanganui	**West_4**	**4.29**	3.3 (76.8%)	0.1 (2.3%)	0 (0%)	0.17 (3.9%)	0.44 (10.3%)	0.29 (6.7%)
Target WMSZ total		**215.98**	**136.95 (63.4%)**	**48.34 (22.4%)**	**1.47 (0.7%)**	**10.44 (4.8%)**	**9.55 (4.4%)**	**9.23 (4.3%)**

4 Analysis of Dr Snelder

In the Statement of Evidence of Dr Snelder (6th October 2023), Dr Snelder assesses water quality outcomes for scenarios associated with implementation of the decisions version (DV-PC2), and proposed amendments to DV-PC2 associated with the adoption of the risk assessment tool. The analysis uses the CASM model information and a methodology similar to the annual load assessments presented in this memo and in Easton (2020), with additional consideration of in-stream Soluble Inorganic Nitrogen (SIN) concentrations.

For the Hoki_1a WMSZ, the analysis of Dr Snelder estimates that a 70% reduction in N loss from CVG would result in a 21% reduction in total load. This is predicted to improve mean SIN concentrations from 92% above the target to 90% above the target. Dr. Snelder concludes that the resulting water quality improvements are modest and that the same conclusion would be reached should more complex water quality modelling be undertaken.

The conclusions of Dr Snelder are consistent with the analysis in Easton (2020) as summarised in **Section 2.1.1**. Table 2 shows that a reduction in CVG load by 28.2% associated with the adoption of BMP and GMP achieves a 7.7% reduction in load for the Hoki_1a WMSZ. Extrapolating this table to a 70% decrease in CVG load results in an estimated 19% decrease in total WMSZ load (comparable to 21% in Dr Snelders analysis). The reason for the small difference in load reduction estimates is presumed to be related to the lack of load associated with urban land in Dr Snelders assessment (see discussion in Easton, 2020) and the adoption of updated CVG loss rates from Page Bloomer in Easton (2020) compared to CASM. Extrapolation of Table 5 in the same manner estimates that an 18% reduction in total load is achieved with a 70% reduction in CVG load for the Hoki_1a using the updated SCAMP land use mapping and loss rate information. Despite small differences in model inputs and results, the conclusion remains consistent that contaminant loss reductions achieved by CVG are likely to improve catchment water quality, but not significantly.

5 CVG flux

The flux in CVG land has been assessed using the Landcover Database (LCDB, version 5.0)[6]. The LCDB uses the 'short-rotation cropland' classification, which includes CVG as well as other cropping systems that comprise a period of cultivated bare ground such as extensive arable and seed cropping systems or cropping for animal consumption (e.g. fodder crops or winter grazing paddocks). LCDB land uses including short-rotation cropland are mapped for 1996, 2001, 2008, 2012, and 2018, which allows for land use change assessment across time.

Table 7 summarises the change in short-rotation cropland area since 1996 and shows that for all FMUs, there has been little flux since 2008. In general, there has been an expansion of short-rotation cropland from 1996 to 2008 and a relatively small change in area since then. From 1996 to 2012, each mapped year demonstrates some previously cultivated land is no longer cultivated and some

---

[6] https://lris.scinfo.org.nz/layer/104400-lcdb-v50-land-cover-database-version-50-mainland-new-zealand/ Accessed 31/05/2023.

uncultivated land comes into cultivation, likely due to crop rotation practices. For the Waiopehu FMU, where the majority of short-rotation cropland is expected to be CVG, expansion occurred to 2001, with a net decrease of 41 ha in short-rotation cropland observed since then. It is likely that the reason for the small change in area for the Waiopehu since 2008 is because there is little remaining land desirable for cropping and rotational CVG systems rotate within existing cultivated land.

In the Waiopehu (and likely elsewhere with relatively intensive CVG rotations), the LCDB shows good agreement with other estimates of CVG land (e.g. GAP EMS mapping, or Herzig et al., 2020) and the flux quantification is expected to be accurate. Elsewhere, where rotational cropping systems include longer pasture phases (i.e. spend only a short period of time as bare earth) as in the northern parts of the Horizons region it is unclear how accurate the LCDB information is for assessing flux in cultivated land, because satellite imagery may not be captured during the cropping phase of a rotation.

Table 7 Net flux in LCDB short-rotation cropland (SRC) by FMU (ha).

FMU	2012 - 2018		2008 - 2012		2001 - 2008		1996 - 2001	
	Into SRC	Out of SRC	Into SRC	Out of SRC	Into SRC	Out of SRC	Into SRC	Out of SRC
Kai Iwi	0	0	0	0	0	0	0	0
Manawatū	0	12	7	0	167	3	282	12
Puketoi ki Tai	0	0	0	0	0	0	0	0
Rangitīkei-Turakina	2	0	4	0	183	7	317	0
Waiopehu	0	0	10	5	21	67	133	2
Whangaehu	0	0	7	0	16	28	72	0
Whanganui	0	0	37	0	260	10	305	0
Total	**2**	**12**	**65**	**5**	**647**	**116**	**1109**	**14**

6 References

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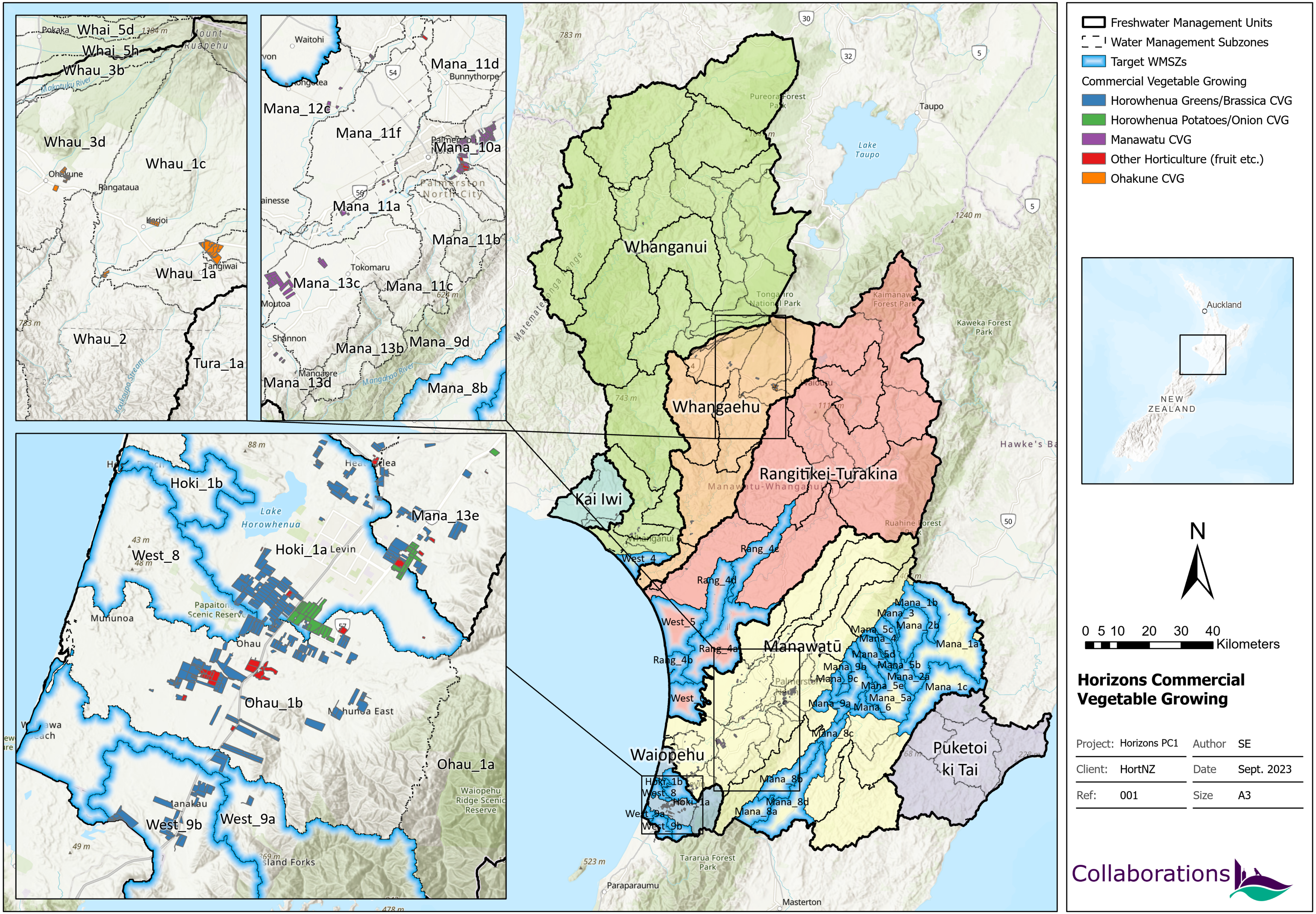
Appendix A Horizons CVG Map (A3)



Freshwater Management Units
Water Management Subzones
Target WMSZs
Commercial Vegetable Growing
Horowhenua Greens/Brassica CVG
Horowhenua Potatoes/Onion CVG
Manawatu CVG
Other Horticulture (fruit etc.)
Ohakune CVG
Whanganui
Whangaehu
Rangitīkei-Turakina
Kai Iwi
Manawatū
Waiopehu
Puketoi ki Tai
Whai_5d
Whai_5h
Whau_3b
Whau_3d
Whau_1c
Whau_1a
Whau_2
Tura_1a
Mana_11d
Mana_12c
Mana_11f
Mana_10a
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Hoki_1b
Mana_13e
West_8
Hoki_1a
Ohau_1b
Ohau_1a
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Mana_9b
Mana_5b
Mana_9c
Mana_2a
Mana_5e
Mana_1c
Mana_9a
Mana_5a
Mana_6
Mana_8c
Mana_8d
Mana_8a
Auckland
NEW ZEALAND
N
0 5 10 20 30 40 Kilometers
Horizons Commercial Vegetable Growing
Project: Horizons PC1
Author SE
Client: HortNZ
Date Sept. 2023
Ref: 001
Size A3
Collaborations

Appendix B Catchment Water Quality Modelling: supporting evidence of Dr Claire Conwell (Easton, 2020)

Jacobs

Memorandum

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Subject	**Catchment Water Quality Modelling: supporting evidence of Dr Claire Conwell**	**Project Name**	Horizons Plan Change 2
Attention	Dr Claire Conwell		
From	Stuart Easton		
Date	September 24, 2020		
Copies to	Tim Baker, Michelle Sands		

1. Overview

This report estimates catchment Nitrogen (N) and sediment loads in the Manawatu-Whanganui region in relation to Horizons proposed Plan Change 2 (PC2), with a focus on the Horowhenua Freshwater Management Unit (FMU) and the contribution of Commercial Vegetable Growing (CVG) to contaminant loading.

Nitrogen leaching rates for CVG are derived from Page Bloomer Overseer modelling[1]. For other land uses, N leaching estimates are based on GIS modelling of supplied CASM input information[2]. A brief discussion of the CASM model architecture, baseline modelling and scenario results is provided. Sediment load estimates use the Revised Universal Soil Loss Equation (RUSLE) and loss-rates for CVG developed by Agrilink[3].

1.1 Limitations

The analysis in this memo is based on provided data from different sources which are assumed to be correct and accurate. Catchment N loss estimates are equivalent to loss rates at the bottom of the root zone; the full process and complexity of the CASM model is not replicated. Estimates of in-stream concentrations for N or sediment are not provided. The discussion of the CASM model is based on the authors best knowledge and relies on information disseminated during the PC2 pre-hearing meetings, and the s42A reports from Tim Cox and Ton Snelder.

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[1] Bloomer, D., Posthuma, L., O'Brien, G. 2020. Modelled Loss of Nutrients from Vegetable Growing Scenarios in Horowhenua. Report for Pattle Delamore Partners.
[2] Snelder, T., Cox, T., Kerr, T., Fraser, C., Collins, S. 2020. Manawatū-Whanganui Region Catchment Nitrogen Models Supporting Regional Plan Change 2.
[3] Barber, A., Stenning, H., Hicks, M. 2019. Don't Muddy the Water Final Summary Report. Prepared for: MPI SFF Project 407925.

2. CASM modelling and representation of horticulture

This section comments on the CASM modelling more generally and specifically on the representation of CVG for the current state 'baseline'. A discussion and comparison of the CASM scenario modelling to the analysis in this report is provided in section 4.5.

2.1 CASM architecture

CASM estimates N loss rates based on Overseer modelling in Bright et al. (2018), which are combined and routed through a representation of the stream network to provide an estimate of in-stream N concentration. N-loss rates are lumped within each catchment by a combination of land use, climate, soil, land use class, and irrigation; i.e. all farms in a given WMSZ that are characterized by the same bio-physical factors will have the same estimated N loss-rate.

CASM adopts attenuation factors that are representative of potential mass losses occurring from the point of export or leaching to the point of discharge to the receiving stream. As attenuation factors are applied equally across each WMSZ, where loading rates change, as tested in this document for land use change and mitigation implementation, an equivalent change in in-stream N concentration would be predicted by CASM.

2.2 Baseline representation

Table 1 summarises CASM inputs by land use category for all WMSZs, as calculated from the provided CASM input spreadsheet and GIS files.

The area weighted average export coefficient for horticulture is 67 kg/ha/year across the total modelled area (all catchments) with a range between 16 and 71 kg/N/ha/year. Representation of horticulture in CASM is representative of different systems across the region and does not nominally differentiate between rotation types. The range in leaching rates are equivalent to the CVG rotation types modelled by Ford (2017)[4]. The average leaching rate is lower than, but comparable to that modelled in Overseer by Page Bloomer for intensive Horowhenua rotations (see section 4.1). In general, the relativity in leaching rates are representative of the configuration of CVG systems in the Manawatu-Whanganui region, with predominantly less-intensive rotations (i.e. the 'cash cropping' potato rotation in Ford, 2017) in the north of the region and more intensive market garden type rotations predominantly in and around the Horowhenua.

The area modelled as horticulture is 2,413 ha, of which 548 ha is in the Horowhenua FMU. This is an underestimate of the actual CVG footprint in the FMU, which is estimated at 1007 ha from the grower mapping undertaken during Environment Management System (EMS) workshops. Across the region, the area in CVG is somewhat uncertain due to lack of mapping and inconsistent definitions; Plant and Food estimates approximately 3,700 ha (2019)[5], while the Land Cover Database version 5 (LCDB5) estimates 17,139 ha of 'short-rotation cropland' across all catchments. Of the area estimated by the LCDB, 1,132 ha

[4] Ford, S. 2017. Farm Scale Economic Impact Analysis of One Plan Intensive Land Use Provisions. Prepared for Horizons. The AgriBusiness Group.
[5] Plant and Food. 2019. Fresh Facts. https://www.freshfacts.co.nz/files/freshfacts-2019.pdf

are in the Horowhenua FMU and approximately 1,500 ha in the Ohakune area, with the remaining area within the central part of the Region. Note that the short-rotation cropland definition is broad and includes arable cropping systems, winter grazing, extensive, and intensive vegetable production.

Table 1 CASM Land use and diffuse N load (all WMSZs)

Land use	Area (ha)	Area (% of total)	N Load (t/N/yr)	N load (% of total)	Area weighted average export coefficient (kg/N/ha/yr)
Builtup/Parks/Others	11860	0.5%	0	0.0%	0.0
Cropping	6919	0.3%	96	0.4%	13.9
Dairy	133423	6.0%	4967	18.2%	37.2
Exotic Cover	156277	7.0%	523	1.9%	3.3
Horticulture	2413	0.1%	160	0.6%	66.5
Native Cover	688901	30.8%	2089	7.7%	3.0
Other	48837	2.2%	100	0.4%	2.0
Sheep and/or Beef	1180000	52.8%	19277	70.8%	16.3
Water Body	4838	0.2%	0	0.0%	0.0
Total	2233466	100%	27218	100%	12.2

For Urban land uses ('Builtup/Parks/Others' in Table 1), CASM assumes no N load is produced. In the literature, estimates for urban loss rates vary between 10 and 15 kg/N/ha/year (see section 3.1). While the urban area is small (only 0.5% of the total) for some catchments urban load may be not insignificant.

Updates to the CASM representation of CVG in the Horowhenua, and the application of an urban N loss rate are described in section 3.

2.3 Authors comment on CASM

CASM is a 'steady state' model that does not simulate stream flows in time, providing only an (calibrated) estimate of mean in-stream N concentration. While the model is fit for purpose to estimate catchment-scale changes in N load and mean concentration due to PC2 and related scenarios, the model architecture makes CASM unsuited to testing changes in hydrology or providing statistical measures derived from output water quality timeseries (e.g. median or 95th percentile concentrations) that would be required for understanding the impact of PC2 or other policy in regards to the National Policy Statement for Freshwater Management (NPS-FM).

With regard to the Horowhenua FMU specifically, section 2.2 explains that the CASM representation of both CVG and urban land uses is poor. Furthermore, there are no water quality stations utilised for calibration within the Lake Horowhenua catchment (Hoki_1a), and all water quality stations in the Horowhenua FMU are predominantly upstream of the primary agricultural land. Given the known complexity of the surface and ground water systems in the Horowhenua and the relatively small catchment sizes in comparison to elsewhere in the region, the applied CASM attenuation coefficients are therefore likely to be uncertain. Additional monitoring and process-based modelling (e.g. a daily tie-step coupled surface-groundwater model), alongside a dedicated lake model is required to increase the reliability of water quality assessments in the catchment.

3. CASM data updates

This section outlines updates made to the provided CASM data to improve the representation of urban and CVG land uses for assessment in section 4.

3.1 Urban leaching update

Table 1 shows that CASM assumes no N load from urban land uses. Australian literature estimates N loss from urban land uses at 10 kg/ha/year[6], while stormwater monitoring data from the Kapiti coast was used to estimate average urban N loss of 15 kg/ha/year during the Porirua Whaitua water quality limit setting modelling for Greater Wellington Regional Council[7], and NIWA modelling for Waikato Plan Change1 estimated Urban N loss at 12 kg/ha/year.

Table 2 estimates the N loading from urban land use for Horowhenua WMSZs, assuming a conservative loss rate of 10 kg/ha/yr. For the Hoki_1a WMSZ, the urban area is greater than Horticulture, and produces a significant N load of almost 8,000 kg/year, equivalent to 8% of the total N load for the WMSZ. Furthermore, attenuation of Urban N load is likely to be reduced in comparison to other land uses, as impervious surfaces and channelised waterways reduce the time of concentration to the receiving environment, reducing denitrification and biological uptake potential.

An N loss rate of 10 kg/ha/year has been applied to all urban land in the following analysis.

Table 2 Estimate of Urban N load for Horowhenua WMSZs

Horowhenua FMU WMSZs	Target Catchment	CASM Urban Area (ha)	Urban load at 10 kg/ha/yr (kg)	Urban load as % of total WMSZ load
Hoki_1a	Yes	794	7936	8%
Hoki_1b	Yes	16	161	2%
West_8	Yes	9	89	0%
West_9a	Yes	25	250	0%
West_9b	Yes	25	250	1%
Ohau_1a	No	0	0	0%
Ohau_1b	No	25	250	0%

[6] Fletcher, T., Monash University. Cooperative Research Centre for Catchment Hydrology, & Fletcher, T. (2004). Stormwater flow and quality and the effectiveness of non-proprietary stormwater treatment measures: a review and gap analysis. Australia: CRC for Catchment Hydrology.
[7] Moores, J., Easton, S., Gadd, J., Sands, M. (2017) Te Awarua-o-Porirua Collaborative Modelling Project Customisation of urban contaminant load model and estimation of contaminant loads from sources excluded from the core models. Prepared for Greater Wellington Regional Council.

Horowhenua FMU WMSZs	Target Catchment	CASM Urban Area (ha)	Urban load at 10 kg/ha/yr (kg)	Urban load as % of total WMSZ load
West_7	No	68	677	1%
Total		961	9613	2%

3.2 CVG land use and leaching update

Figure 1 shows that for the Horowhenua and Opiki vegetable production areas, large areas of CVG land as mapped by growers through the EMS programme are misclassified in CASM, predominantly as Dairy, Sheep & Beef, and Cropping.

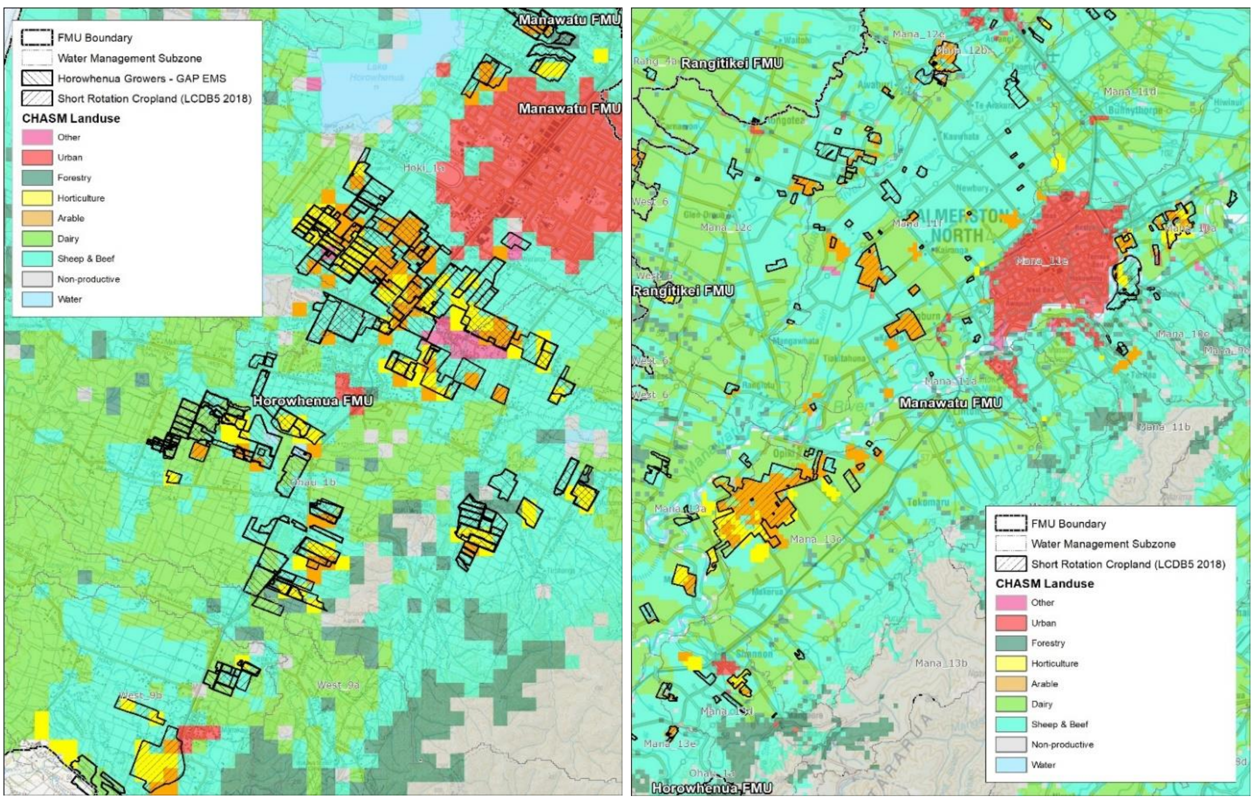

Figure 1 Comparison of CASM land use inputs for Horowhenua (left) and Opiki (right)

To provide a more accurate estimate of the CVG footprint, the CASM data has been updated using the grower provided mapping through the EMS in Horowhenua. Table 3 summarises the changes in CASM land area and N load estimates resulting from the land use update for CVG for WMSZs in the Horowhenua FMU. The increased area and leaching rate compared to CASM results in a subsequent increase in N load.

CVG mapping outside of the Horowhenua FMU is not currently available (the LCDB lacks differentiation between CVG and arable and winter grazing systems). The provided CASM data for CVG has been used in the following analysis for all other FMUs. The total CVG area at different scales in the Manawatu-Whanganui region is provided in Table 7 in section 4.2.

Table 3 CVG area update for Horowhenua WMSZs

Horowhenua FMU WMSZs	Target Catchment	CASM Horticulture Area (ha)	Updated CVG Area (ha)	Change in WMSZ N load (kg/N/yr)*	Change in WMSZ N load (%)*	Total Updated CVG N load (kg/N/yr)*	Updated CVG load as % of total WMSZ load*
Hoki_1a	Yes	227	472	+19177	+18%	33847	27%
Hoki_1b	Yes	0	0	0	0%	0	0%
West_8	Yes	0	35	+2453	+7%	3001	8%
West_9a	Yes	1	0	0	0%	0	0%
West_9b	Yes	86	55	+2786	+6%	4434	9%
Ohau_1a	No	0	0	0	0%	0	0%
Ohau_1b	No	234	445	+21636	+13%	36105	20%
West_7	No	0	0	0	0%	0	0%
Total		548	1007	46051	9%	77387	14%
*WMSZ N load accounts for updated Urban loads (Table 2) and uses pre-2019 leaching rates for CVG (see 4.1)							

4. Nitrogen

This section estimates the catchment N loading rate at the WMSZ scale under baseline conditions, with best management practice implemented for Horticulture, under PC2, and under alternative future land management scenarios, with a focus on the Horowhenua where the majority of intensive vegetable production occurs.

The analysis utilises the provided CASM input GIS files, updated to provide an improved estimate of CVG area and N leaching in the Horowhenua and Urban N leaching rate for all WMSZs (see section 2).

The analysis gives an estimate of the unattenuated catchment loading rate. Changes in loading rate can be expected to result in equivalent changes in in-stream N concentration assuming a constant attenuation factor as in CASM.

4.1 Leaching rates

The N leaching rate modelled by Page Bloomer for three CVG rotations is given in Table 4. Note that the estimated loads from the potato/onion rotation are greater than that predicted by the CASM ‘potato’ scenarios 9c, 9d, and 9e, which models an expansive one in five-year potato rotation, similar to that modelled by Ford (2017), referred to as cash cropping. The cash cropping rotation is representative of the potato rotations grown north of Horowhenua.

Table 4 Page Bloomer title leaching rate

Rotation	Leaching Rate (pre-2019) (kg/N/ha/yr)	Leaching Rate (post-2019) (kg/N/ha/yr)	Reduction from pre-2019 to post-2019 practice (%)
Intensive	81.0	44.0	-46%
Brassica	92.9	83.2	-10%
Potato/Onion	30.9	28.8	-7%

The implementation of Good Management Practice (GMP), Best Management Practice (BMP), and elements of system change (e.g. retirement of land) by growers in the Horowhenua has resulted in a decrease in predicted N loss, reflected by the reduction in N loss rate from pre- to post-2019 in Table 4. Table 4 shows that the intensive rotation was predicted to reduce N leaching by 46% following the adoption of both GMP and BMP with system change, while improvements for the brassica and potato/onion rotations are only 10% and 7%, respectively for GMP and BMP adoption.

4.2 Leaching load estimate

The Page Bloomer modelled rotations are broadly representative of three individual enterprises in the Horowhenua. Table 5 estimates the enterprise area of the modelled rotations in the Horowhenua FMU, which represent around 69% of the total CVG area. Based on grower advice, the most applicable leaching rate for the remaining 31% of the CVG area (309 ha) is likely to be best represented as a mixed-crop combination of the Brassica and Intensive rotations.

Table 5 Modelled CVG rotation types in the Horowhenua FMU

Rotation	Area (ha)	Area (%)	Title leaching Rate (pre-2019) (kg/N/ha/yr)	Title leaching Rate (post-2019) (kg/N/ha/yr)
Intensive	488	48%	81.0	44.0
Brassica	76	8%	92.9	83.2
Potato/Onion	134	13%	30.9	28.8
Other (not modelled)	309	31%		
Total	1007	100%		

Table 6 estimates the N load from CVG in target catchments in the Horowhenua FMU for pre-2019 and post-2019 practice. Three leaching rate estimates are provided for 'other' land not modelled by Page Bloomer: equivalent to the intensive rotation, equivalent to the brassica rotation, and equivalent to a 50:50 combination of the two. For pre-2019 practice, the total estimated N load generated from CVG is between 72.1 and 75.6 t/ha/year. For post-2019 practice, the difference between the upper and lower load estimates, 46.1 and 57.7 t/ha/year, is greater than pre-2019 due to the increased representation of the brassica rotation which has limited capacity to reduce leaching. The average reduction in leaching rate across the three modelled rotations is 30%, significantly greater than achieved by the brassica or potato/onion rotation alone (Table 4).

Table 6 Estimated N load from CVG in Horowhenua FMU target catchments

Rotation	Area (ha)	Title leaching Rate (pre-2019) (kg/N/ha/yr)	Title leaching Rate (post-2019) (kg/N/ha/yr)	N load (pre-2019) (t/N/yr)	N load (post-2019) (t/N/yr)	Reduction from pre-2019 to post-2019 practice (%)
Intensive	202	81	44	16.4	8.9	-46%
Brassica	75	92.9	83.2	7.0	6.2	-10%
Onion Potato	118	30.9	28.8	3.6	3.4	-7%
Other as Intensive	166	81	44	13.5	7.3	-46%
Other as 50:50 Intensive: Brassica		87.0	63.6	14.5	10.6	-27%
Other as Brassica		92.9	83.2	15.5	13.9	-10%
Total (Other as Intensive)	561	72.1	46.1	40.5	25.9	-36%
Total (Other as 50:50 Intensive: Brassica)		73.9	51.9	41.5	29.1	-30%
Total (Other as Brassica)		75.6	57.7	42.5	32.4	-24%

Table 7 estimates total catchment N load and CVG contribution for target and non-target catchments in the Horowhenua. Leaching rates for CVG in the Horowhenua follow Table 6, assuming the 'other' rotation is a 50:50 mix of intensive and brassica crops. Loads for other land uses are based on CASM, except urban which has been updated (see section 3.1). Note all following analyses also makes these assumptions except where explicitly stated.

Table 7 Estimated CVG area and N loss

Catchment group	Total Area (ha)	Existing CVG Area (ha)	Existing CVG Area (% of total)	Total N load (t/N/yr)	Existing CVG N load (t/N/yr)	Existing CVG N load (% of total)
Horowhenua target catchments	17,134	561	3.3%	272	41.3	15.2%
Horowhenua FMU	39,411	1007	2.6%	566	77.4	13.7%

As discussed in section 2.2, the area of CVG outside of the Horowhenua FMU is not mapped. To provide an estimate of the N loading contribution from CVG at a regional scale, Table 8 below replicates Table 1, with the CVG area increased to match the Plant and Food estimate of 3700 ha of CVG in the region. The additional CVG area has been removed from the Dairy area to maintain a consistent total area. N loading from CVG follows Table 7 for Horowhenua, and CASM elsewhere. The applied leaching rate for the additional modelled area (829 ha) is 66.5 kg/N/ha/year, equivalent to the CASM area weighted average leaching rate. Note that urban N losses have also been updated, following section 3.1.

This scenario can be considered conservative, as the majority of CVG outside of the Horowhenua FMU are extensive rotation systems that would be expected to leach at a lower rate than 66.5 kg/N/ha/year. Under this scenario, the proportion of total N load attributed to CVG increases from 0.6% in CASM to 0.9%. The area-weighted average leaching rate for CVG increases slightly to 68.7 kg/N/ha/year due to the adopted increased leaching rates in the Horowhenua (section 4.1).

Table 8 Proportion of N load under an increased CVG area scenario

Land use	Area (ha)	Area (% of total)	N Load (t/N/yr)	N load (% of total)	Area weighted average export coefficient (kg/N/ha/yr)
Builtup/Parks/Others	11860	0.5%	119	0.4%	10.0
Cropping	6919	0.3%	96	0.4%	13.9
Dairy	132135	5.9%	4919	18.0%	37.2
Exotic Cover	156277	7.0%	523	1.9%	3.3
Horticulture	3700	0.2%	256	0.9%	68.7
Native Cover	688901	30.8%	2089	7.6%	3.0
Other	48837	2.2%	100	0.4%	2.0
Sheep and/or Beef	1180000	52.8%	19277	70.4%	16.3
Water Body	4838	0.2%	1	0.0%	0.2
Total	2233466	100%	27380	100%	12.3

Table 9 estimates total catchment N load for WMSZs in the Horowhenua FMU. Leaching rates for other land uses follow CASM, except urban which is assumed to leach at 10 kg/ha/year (see section 3.1).

An overall reduction of 34% in N lost from CVG in the Horowhenua FMU is achieved from pre- to post-2019 practice, equivalent to a 5% reduction in N load for the FMU.

Table 9 Reduction in N loss from CVG GMP and BMP post-2019 for Horowhenua FMU WMSZs

Horowhenua FMU WMSZs	Target Catchment	CVG N load (pre-2019) (t/N/yr)	CVG N load (post-2019) (t/N/yr)	CVG N load change (%)	WMSZ N load (pre-2019 (t/N/yr)	WMSZ N load (post-2019) (t/N/yr)	WMSZ N load change (%)
Hoki_1a	Yes	34	24	-28.2%	125	115	-7.7%
Hoki_1b	Yes	0	0	0.0%	10	10	0.0%
West_8	Yes	3	2	-27.0%	36	35	-2.3%

Horowhenua FMU WMSZs	Target Catchment	CVG N load (pre-2019) (t/N/yr)	CVG N load (post-2019) (t/N/yr)	CVG N load change (%)	WMSZ N load (pre-2019 (t/N/yr)	WMSZ N load (post-2019) (t/N/yr)	WMSZ N load change (%)
West_9a	Yes	0	0	0.0%	54	54	0.0%
West_9b	Yes	4	2	-45.7%	48	46	-4.2%
Total for Target Catchments		**41**	**29**	**-30.0%**	**272**	**260**	**-4.6%**
Ohau_1a	No	0	0	0.0%	54	54	0.0%
Ohau_1b	No	36	22	-38.6%	182	168	-7.7%
West_7	No	0	0	0.0%	58	58	0.0%
Total for FMU		**77**	**51**	**-34.0%**	**566**	**540**	**-4.7%**

4.3 Alternative reduction scenarios

Table 10 shows the change in WMSZ N load under two alternative reduction scenarios for the intensive, brassica, and 'other' rotation: 20% and 35%; the reduction for the potato/onion rotation follows Table 6 (-7%). These scenarios are intended to quantify the catchment-scale reductions achieved by the on-farm reduction scenarios discussed in the PC2 expert evidence of Stuart Ford.

The reduction in catchment load achieved by the scenarios is small (<5%). The 35% reduction scenario produces a similar catchment N load reduction as the pre- to post-2019 practice modelled in Table 9.

Table 10 Change in CVG and WMSZ N load under 20% and 35% reduction scenarios

Horowhenua FMU WMSZs	Target Catchment	Existing N Load (t/N/yr)	Change in catchment load with 20% reduction in Brassica & Other rotation leaching rate (%)	Change in catchment load with 35% reduction in Brassica & Other rotation leaching rate (%)
Hoki_1a	Yes	125	-5.1%	-8.7%
Hoki_1b	Yes	10	0.0%	0.0%
West_8	Yes	36	-1.7%	-2.9%
West_9a	Yes	54	0.0%	0.0%
West_9b	Yes	48	-1.8%	-3.2%
Total for Target Catchments		**272**	**-2.9%**	**-4.9%**
Ohau_1a	No	54	0.0%	0.0%
Ohau_1b	No	182	-3.9%	-6.9%
West_7	No	58	0.0%	0.0%
Total for FMU		**566**	**-2.6%**	**-4.6%**

4.4 CVG expansion and rotation

Table 11 estimates the marginal leaching rate of CVG horticulture under an expansion scenario. Suitable CVG land is defined as LUC 1 or 2, with an existing land use of Dairy, Sheep & Beef, or Cropping. The existing average leaching rate for suitable CVG land ranges between 19.3 and 22.3 kg/N/ha/year, depending on the current configuration of land uses in the catchment or catchments. Additional N leaching assumes a conversion to a green vegetable rotation based on the post-2019 brassica rotation in Table 4 (83.2 kg/N/ha/year), as a conservative assumption.

Conversion to CVG would leach an additional ~63 kg/N/ha/year for a brassica rotation. Conversion to a system compliant with the table 14.2 leaching maximum would increase leaching between 13.8 and 20.4 kg/N/ha/year.

Table 11 Marginal leaching rates for brassica rotation CVG expansion

Catchment group	Existing CVG Area (ha)	Suitable CVG Area (ha)	Area weighted N leaching rate for suitable CVG land (kg/N/ha/yr)	Additional N leaching from conversion to post-2019 average rotation (kg/N/ha/yr)	Additional N leaching from conversion to controlled activity, compliant with table 14.2 (kg/N/ha/yr)
Horowhenua target catchments	561	2127	19.3	63.9	20.4
Horowhenua FMU	1007	4339	22.3	60.9	16.4
All target catchments	693	62401	22.1	61.1	13.8
All catchments	2871	192780	20.7	62.5	15.6

Table 12 estimates the change in catchment load following an expansion of brassica rotations, using the marginal leaching rates from Table 11. An expansion of 10% is modelled, equivalent the projected population growth for the Wellington region[8].

The additional N load from brassica expansion is small in comparison to the total catchment loads, with less than 1% increase in catchment load predicted at all modelled scales.

Table 12 Catchment N load change following brassica CVG expansion

Catchment group	Existing Load (t)	Additional N load from 10% expansion of post-2019 brassica rotation (t/N/yr)	Additional N load from 10% expansion of post-2019 brassica rotation (% of total)
Horowhenua target catchments	272	+3.6	+1.32%

[8] Statistics New Zealand medium population growth scenario estimates a 10% increase for the Wellington region from 2018 to 2038.

Catchment group	Existing Load (t)	Additional N load from 10% expansion of post-2019 brassica rotation (t/N/yr)	Additional N load from 10% expansion of post-2019 brassica rotation (% of total)
Horowhenua FMU	566	+6.1	+1.08%
All target catchments	5423	+4.2	+0.08%
All catchments	27395	+17.9	+0.07%

Table 13 estimates the change in catchment load for the scenario where 20% of the existing CVG land rotates from within the target catchments to the non-target catchments in the Horowhenua FMU, after 2019. It is assumed that in the target-catchments, the replacement leaching rate for rotated CVG is equivalent to the average for suitable CVG land and in the non-target catchments CVG replaces the average suitable land use. Because the average existing leaching rate for suitable CVG land in non-target catchments (25.1 kg/N/ha/year) is higher than that for the target catchments (19.3 kg/N/ha/year), a net benefit of 0.1% reduction in FMU load is achieved.

Table 13 Change in catchment N load following 20% rotation from target to non-target catchments

Catchment group	CVG Area (ha)	CVG Area with 20% rotation from target to non-target catchments (ha)	Total catchment N load post-2019 (t/N/yr)	N Load following 20% rotation (t/N/yr)	Change in load following 20% rotation (%)
Horowhenua target catchments	561	449 (-112)	259.7	252.1	-2.9%
Horowhenua non-target catchments	445	558 (+112)	280.2	287.2	2.5%
Horowhenua FMU	1007	1007	539.9	539.2	-0.1%

4.5 Discussion

The N loading estimates in this report are conservative compared to CASM due to increased CVG footprint and increased leaching rate adopted. However, the contribution of CVG as a proportion of total N load remains small, with 256 tonnes of N estimated to leach from CVG across all target catchments, representative of less than 1% of the total N load Table 8. As such, reductions in the leaching rate from CVG produce only minor reductions in catchment N load, and the expansion of green vegetable rotations by 10% has a similarly small impact on catchment N load increase. The expansion of extensive root vegetable rotations can occur with neutral impacts on water quality; the average leaching rate of suitable CVG land (Table 11) is comparable to the leaching rate of the 'cash cropping' potato rotation in Ford (2017).

4.5.1 Comparison to CASM scenario modelling

The load increase predicted by the CASM horticulture expansion scenarios A & B is greater for the Horowhenua catchments than predicted in this analysis (section 4.4). The CASM scenarios model all Dairy or Sheep and Beef LUC 1, 2, and 3 land as a one in five-year CVG rotation (scenario A) and all LUC 1, 2, and 3 land regardless of current land use as a one in five-year CVG rotation (scenario B). For the Horowhenua FMU this is representative of an additional permanent CVG area of 2,236 ha in the A scenario (i.e. one-fifth of the 11,180 ha of LUC 1, 2, and 3 land currently in Dairy or Sheep and Beef), and 2,546 ha in the B scenario, equivalent to an 222% (A), and 253% (B) increase on the current 1007 ha footprint. Given that only 5% of current CVG land is on LUC 3 or higher, and the lack of change in CVG footprint in the region between 2012 and 2018[9], these scenarios can be considered unrealistic.

The CASM 'potato' scenarios A, B, and C show little increase or a net-decrease in in-stream N concentration following extensive potato expansion. The modelled potato system, a one in five-year rotation, is comparable to the 'cash cropping' potato rotation modelled in Ford (2017). While the modelled increase in area is similarly unrealistic as the CVG expansion scenarios, the results are reasonable. Table 11 shows that the average leaching rate for suitable CVG land is approximately 20 kg/N/ha/year; the expansion of any CVG system that leaches less than this rate will reduce catchment N loading, on average (e.g. CASM Potato scenarios B & C).

The scenarios which model a reduction in horticulture export coefficients, 'Horticulture Mitigation A' and 'Horticulture Mitigation B', use percentage reductions (36% and 55% for the two scenarios, respectively) derived from the s42a report by Dr Anne Maree Jolly, which are greater than that predicted by Page Bloomer. However, comparison between the leaching estimates and reduction potential is difficult as the modelling of Dr Jolly is representative of part-rotations rather than the full-rotations of Page Bloomer[10].

5. Sediment

Annual sediment loss rates from CVG in Horowhenua have been calculated by Agrilink, based on the Revised Universal Soil Loss Equation (RUSLE). Sediment loss rates for current practice, and for potential BMP ('potential enhanced rate') have been calculated (see Table 14). High and low efficiency of current practice relates to the effectiveness of buffer strips: high efficiency assumes buffer strips are 80% effective in removing transported sediment, low efficiency assumes 20%.

Table 14 Sediment loss rates for CVG land in Horowhenua

Loss rate metric	Unmitigated sediment loss rate (t/ha/yr)	Current sediment loss rate (t/ha/yr) – low efficiency	Current sediment loss rate (t/ha/yr) – high efficiency	Potential enhanced sediment loss rate (t/ha/yr)
Average	0.85	0.56	0.38	0.22
Maximum	15.25	9.80	6.07	3.92
Minimum	0.06	0.01	0.01	0.02

Table 14 shows that current erosion and sediment control practices reduce average sediment loss by between 34% (low efficiency) and 56% (high efficiency) compared to the unmitigated sediment loss rate. The potential enhanced practice achieves a 74% reduction in sediment. The improvements in erosion and sediment control represent that, over time, there is a combination of more mitigations being implemented and that both existing and new mitigations are delivered more effectively (primarily less channelising).

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[9] No change in area for 'short-rotation cropland' between 2012 and 2018 in LCDB4 in the Horowhenua FMU.

[10] Stuart Ford, personal communication (September 2020)

Table 15 applies the average sediment loss rates from Table 14 to the CVG area in Horowhenua WMSZs. Assuming high efficiency of buffer strips, current erosion and sediment control practices mitigate 480 tonnes of sediment loss across the FMU (860 t total compared to 380 t).

Table 15 Estimated sediment loss from CVG land in Horowhenua

Horowhenua WMSZ	CVG Area (ha)	Unmitigated sediment loss (t/yr)	Current sediment loss (t/yr) – low efficiency	Current sediment loss (t/yr) – high efficiency	Potential enhanced sediment loss (t/yr)
Hoki_1a	472	403	267	178	104
Hoki_1b	0	0	0	0	0
West_8	35	30	20	13	8
West_9a	0	0	0	0	0
West_9b	55	47	31	21	12
Ohau_1a	0	0	0	0	0
Ohau_1b	445	381	252	168	98
West_7	0	0	0	0	0
Total	**1007**	**860**	**569**	**380**	**221**

5.1 Catchment sediment loads

A GIS based implementation of the RUSLE has been used to estimate sediment loss rates for the remainder of the Horowhenua FMU catchment, and all other FMUs in the Manawatu/Whanganui region. Table 16 provides the estimated total sediment loads for land uses within each FMU from surficial (hillslope) erosion. Note that the land use data used is the Land Cover Database version 5 (LCDB5), which does not differentiate between pastoral land uses (i.e. between dairy and sheep and beef) or between arable cropping systems, extensive, and intensive vegetable production. Landslide, earthflow, or gully erosion processes are not modelled.

At the regional scale, the RUSLE estimates of sediment loading are comparable to the Suspended Sediment Yield Estimator (SSYE). For all catchments, the RUSLE method predicts 31% lower sediment loss compared to the SSYE, within generally accepted range for annual sediment estimates. Of all FMUs, estimates for the Horowhenua FMU are most dissimilar between the RUSLE and the SSYE; a 63% higher load is estimated following the RUSLE compared to the SSYE. The advantage of the RUSLE over the SSYE is that it provides a consistent methodology to quantify the relative effects of sediment and erosion control measures or land use change on catchment sediment loading, and it provides the ability to assess the relative contribution to total sediment load by different land uses.

Table 16 shows that the combined CVG and cropping sediment load makes up just 1% of the total load for the Horowhenua FMU, and 0.5% of the total sediment load for the region. The majority of regional sediment load is predicted to be generated from pastoral farms.

Table 16 Estimated sediment loss rate by FMU

FMU	Total sediment load (t)	Estimated sediment load by land use (t), % of FMU load in brackets					
		Native	Forestry	Other	Pasture	Urban	CVG / Cropping
Horowhenua	129035	66639 (52%)	15816 (12%)	30488 (24%)	15006 (12%)	22 (<0.1%)	1064 (1%)
Manawatu	2342994	496481 (21%)	92613 (4%)	421049 (18%)	1326066 (57%)	238 (<0.1%)	6546 (0.3%)
Rangitikei	1492567	293625 (20%)	32795 (2%)	615376 (41%)	539033 (36%)	161 (<0.1%)	11578 (1%)
Turakina/Whangaehu	1084318	59533 (5%)	101132 (9%)	25518 (2%)	886545 (82%)	86 (<0.1%)	11505 (1%)
Whanganui	3031348	922300 (30%)	366200 (12%)	170326 (6%)	1562462 (52%)	373 (<0.1%)	9688 (0.3%)
East Coast	634106	42903 (7%)	106756 (17%)	65881 (10%)	418542 (66%)	18 (<0.1%)	5 (<0.1%)
Total	8714368	1881480 (22%)	715313 (8%)	1328637 (15%)	4747653 (54%)	899 (<0.1%)	40386 (0.5%)

Table 17 summarises the sediment loading results for CVG in the Horowhenua FMU. To provide context, the bottom-two rows provide an estimate of proportion of total load compared to catchment estimates made using the SSYE and the RUSLE. The current proportion of sediment load attributable to CVG in the FMU is less than 1% assuming high buffer strip efficiency.

Table 17 Sediment load summary for Horowhenua horticulture

Loss rate metric	Unmitigated sediment loss	Current sediment loss – low efficiency	Current sediment loss – high efficiency	Potential enhanced sediment loss
Average loss rate (t/ha/yr)	0.85	0.56	0.38	0.22
Load from CVG (t)	845	559	373	217
Load from CVG - % of FMU (RUSLE)	0.7%	0.4%	0.3%	0.2%
Load from CVG - % of FMU (SSYE)	1.8%	1.2%	0.8%	0.5%

The RUSLE methodology adopted here simulates that cultivated land for CVG is more erodible than pasture by a factor of 16.5 (C factor of 0.33 for CVG and 0.02 for pasture), however soil type, rainfall, and slope are also important factors that determine sediment loss rates. While cultivation is a large risk factor for sediment loss, CVG operations are generally small, and located on shallow slopes compared to the hill country where the majority of catchment sediment load is generated.

6. Conclusion

For both sediment and nitrogen, the contribution of CVG as a proportion of total contaminant load is small, due to the relatively small area in production. Subsequently, where large reductions in contaminant generation occur (e.g. under BMP scenarios), the reduction in catchment contaminant load is small. The reductions modelled in this analysis are representative of the average however it should be noted that half of the modelled area will be beneath the average, and half above, both in terms of contaminant loss and ability to reduce.

Appendix C Land use and N load estimates - Pukekohe and Horowhenua (Easton, 2021)

Jacobs

Memorandum

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Subject	**Land use and N load estimates - Pukekohe and Horowhenua**	**Project Name**	NPS-FM Judicial Review - Specified Vegetable Growing Areas
Attention	Michelle Sands		
From	Stuart Easton		
Date	February 18, 2021		

1. Overview

This memo presents a Geographic Information System (GIS) based summary of the Specified Vegetable Growing Areas (SVGAs) in Pukekohe and Horowhenua as described in the National Policy Statement for Freshwater Management 2020 (NPS-FM). Patterns of land use, annual Nitrogen (N) loss, Māori land, and Land Use Capability (LUC) class are estimated using national and regional scale data. A national scale summary of vegetable production and land suitability for vegetable growing is also provided.

1.1 Data and limitations

Land use data is derived from the Land Use and Carbon Analysis System (LUCAS) land use map[1] for the year 2016. LUCAS is comparable to the Land Use Cover Database (LCDB) however is preferred for its differentiation between Dairy and other grazed pasture systems.

Land use categories from LUCAS have been matched to those used in local scale N-loss modelling for Pukekohe (MPI Modelling to reduce nitrogen in Pukekohe (Whangamaire stream)[2]) and Horowhenua (CASM water quality model developed for Horizons Plan Change 2[3]). The underlying land use data is therefore consistent, however the land use categories used in the tables and maps in this memo are different between the two regions as they have been maintained from the local scale modelling.

Māori land has been estimated from LINZ property parcel information[4]. LINZ caveats the data that it is known to contain omissions and errors and is indicative only.

The public GIS data, statistics, and local scale N-loss modelling used in this memo are assumed to be representative and accurate.

[1] https://data.mfe.govt.nz/layer/52375-lucas-nz-land-use-map-1990-2008-2012-2016-v008/
[2] MPI, 2021. Modelling to reduce nitrogen in Pukekohe (Whangamaire stream). https://www.mpi.govt.nz/dmsdocument/42078/direct. Accessed 6/02/2021.
[3] Snelder, T., Cox, T., Kerr, T., Fraser, C., Collins, S. 2020. Manawatū-Whanganui Region Catchment Nitrogen Models Supporting Regional Plan Change 2.
[4] https://data.linz.govt.nz/table/51567-nz-property-titles-list/

2. Pukekohe SVGA

2.1 Pukekohe SVGA boundary

Figure 1 outlines the Pukekohe SVGA boundary as described in Appendix 5 of the NPS-FM.

The NPS-FM SVGA description for Pukekohe provides an incomplete boundary; the western and eastern boundaries terminate at the border of the Auckland and Waikato regions without meeting the southern SVGA boundary (Waikato river north bank). A straight line has been extrapolated between the southern-most ends of the western and eastern boundaries and the southern boundary in Figure 1. Furthermore, the Pukekohe SVGA boundary does not follow hydrological catchments. The described boundary dissects the existing sub-catchments defined in the Waikato Regional Council (WRC) Healthy Rivers Plan Change 1 limit-setting.

The tables in this section provide statistics for all hydrological catchments that are intersected by the boundary as described in the NPS-FM, except the Wairoa river (i.e. all catchments displayed in Figure 1). The Wairoa has been excluded as it is the largest catchment, drains to the east, has very little horticultural land, and is only partially intersected by the SVGA boundary.

2.2 Land use and Nitrogen loading

Land use within the Pukekohe SVGA has been estimated using the LUCAS land use map for the year 2016. Land use categories from LUCAS have been matched to those used in the MPI modelling of the Whangamaire stream to provide an estimate of N loading and the relative contribution from the different land uses. Data is unavailable to differentiate between arable cropping and Cultivated Vegetable Production (CVP); all land classified as “Cropland – annual” is therefore assumed to be CVP.

Figure 1 shows the Pukekohe SVGA extent and land use within the intersecting catchments. Land use area and estimated annual N loss using MPI loading rates are provided in Table 1 and Table 2.

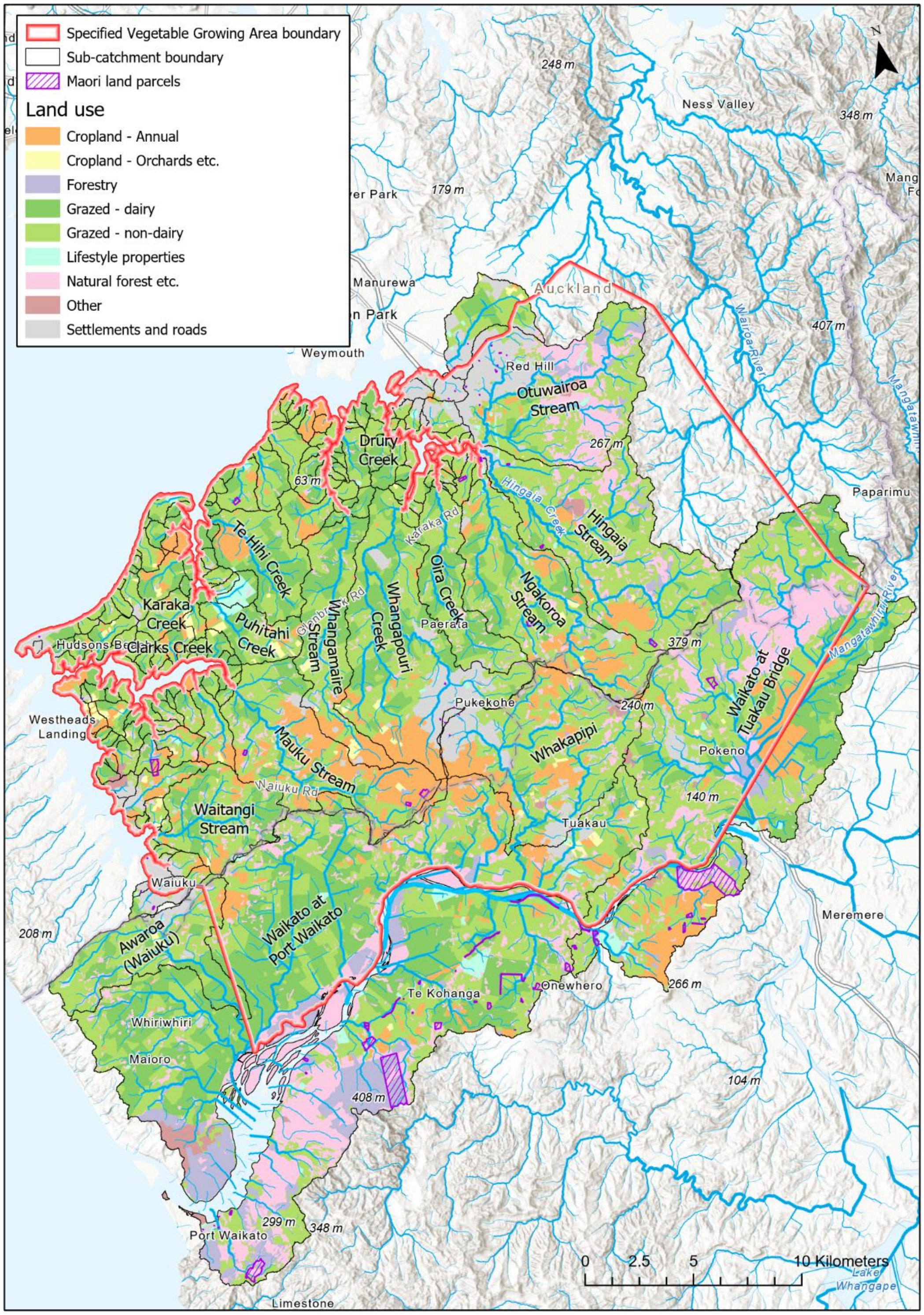

Figure 1 Pukekohe SVGA land use

Table 1 Land use area and N load for all catchments in Pukekohe SVGA

Land use*	Area (ha)	Area (% of total)	MPI N loss rate (kg/N/ha/year)	N load (kg/year)	N load (% of total)
Cropland – Annual (assumed to be CVP)	10211	11%	65	663726	35%
Cropland - Orchards and vineyards (perennial)	829	1%	11	9117	0%
Grazed - dairy	20842	22%	30	625259	33%
Grazed - non-dairy	39126	41%	12	469508	25%
Lifestyle properties	896	1%	10	8960	0%
Natural forest, water, and grassland with woody biomass	13217	14%	4	52867	3%
Other	543	1%	4	2172	0%
Forestry	4516	5%	4	18063	1%
Settlements and roads	4346	5%	9	39117	2%
Total	**94526**			**1888790**	
* MfE LUCAS land use (2016) applied to MPI modeling land use categories					

Table 2 N load (kg/year) per catchment (catchment percentage in parentheses)

Catchment Name	Region	Cropland - Annual (assumed to be CVP)	Cropland - Orchards and vineyards (perennial)	Grazed - dairy	Grazed - non-dairy	Lifestyle properties	Natural forest, water, and grassland with woody biomass	Other	Forestry	Settlements and roads
Other*	Auckland	280011 (41.8%)	4794 (0.7%)	171491 (25.6%)	181361 (27.1%)	3372 (0.5%)	9913 (1.5%)	520 (0.1%)	1551 (0.2%)	16290 (2.4%)
Clarks Creek	Auckland	1516 (58.3%)	288 (11.1%)	141 (5.4%)	656 (25.2%)	0 (0%)	1 (0%)	0 (0%)	0 (0%)	0 (0%)
Drury Creek	Auckland	20 (0.5%)	0 (0%)	3662 (92.6%)	246 (6.2%)	7 (0.2%)	19 (0.5%)	0 (0%)	0 (0%)	0 (0%)
Hingaia Stream	Auckland	23232 (28.2%)	142 (0.2%)	11383 (13.8%)	42432 (51.5%)	144 (0.2%)	3262 (4%)	247 (0.3%)	718 (0.9%)	803 (1%)
Karaka Creek	Auckland	3030 (39.7%)	54 (0.7%)	2184 (28.6%)	2292 (30.1%)	8 (0.1%)	39 (0.5%)	0 (0%)	0 (0%)	16 (0.2%)
Mauku Stream	Auckland	92042 (73.9%)	241 (0.2%)	14416 (11.6%)	16218 (13%)	54 (0%)	1234 (1%)	0 (0%)	42 (0%)	380 (0.3%)

Catchment Name	Region	Cropland - Annual (assumed to be CVP)	Cropland - Orchards and vineyards (perennial)	Grazed - dairy	Grazed - non-dairy	Lifestyle properties	Natural forest, water, and grassland with woody biomass	Other	Forestry	Settlements and roads
Ngakoroa Stream	Auckland	48742 (49.8%)	604 (0.6%)	22296 (22.8%)	24101 (24.6%)	120 (0.1%)	1221 (1.2%)	9 (0%)	200 (0.2%)	608 (0.6%)
Oira Creek	Auckland	970 (2.8%)	0 (0%)	22488 (65.6%)	9966 (29.1%)	45 (0.1%)	484 (1.4%)	0 (0%)	157 (0.5%)	157 (0.5%)
Otuwairoa Stream	Auckland	6531 (13.8%)	94 (0.2%)	4121 (8.7%)	21747 (46.1%)	376 (0.8%)	5620 (11.9%)	200 (0.4%)	1262 (2.7%)	7217 (15.3%)
Puhitahi Creek	Auckland	5373 (27.8%)	815 (4.2%)	8286 (42.9%)	4142 (21.4%)	537 (2.8%)	102 (0.5%)	0 (0%)	32 (0.2%)	43 (0.2%)
Te Hihi Creek	Auckland	13472 (32.3%)	56 (0.1%)	21986 (52.7%)	6029 (14.4%)	24 (0.1%)	153 (0.4%)	0 (0%)	4 (0%)	27 (0.1%)
Waitangi Stream	Auckland	15558 (33.4%)	229 (0.5%)	20919 (44.9%)	8885 (19.1%)	122 (0.3%)	801 (1.7%)	0 (0%)	15 (0%)	46 (0.1%)
Whangamaire Stream	Auckland	23073 (38.1%)	729 (1.2%)	25410 (42%)	10436 (17.2%)	0 (0%)	538 (0.9%)	0 (0%)	0 (0%)	356 (0.6%)
Whangapouri Creek	Auckland	45024 (37.6%)	618 (0.5%)	43629 (36.4%)	23332 (19.5%)	220 (0.2%)	667 (0.6%)	0 (0%)	83 (0.1%)	6136 (5.1%)
Awaroa (Waiuku)	Waikato	4683 (10.9%)	429 (1%)	18909 (43.8%)	16926 (39.3%)	164 (0.4%)	668 (1.5%)	0 (0%)	156 (0.4%)	1188 (2.8%)
Waikato at Port Waikato	Waikato	93931 (20.4%)	1116 (0.2%)	228573 (49.7%)	98636 (21.5%)	2650 (0.6%)	20341 (4.4%)	1092 (0.2%)	11566 (2.5%)	1864 (0.4%)
Waikato at Tuakau Bridge	Waikato	117625 (41%)	249 (0.1%)	73196 (25.5%)	76506 (26.7%)	1568 (0.5%)	12702 (4.4%)	190 (0.1%)	3073 (1.1%)	1634 (0.6%)
Whakapipi	Waikato	62158 (60%)	417 (0.4%)	5159 (5%)	28468 (27.5%)	45 (0%)	1545 (1.5%)	170 (0.2%)	321 (0.3%)	5347 (5.2%)

*Other is the sum of all other sub-catchments. It is mostly comprised of small first and second-order catchments draining to the Manukau Harbour.

2.2.1 Land use capability

Table 3 summarises the land area within the Pukekohe SVGA catchments by LUC class. Figure 2 shows the distribution of LUC class across the Pukekohe SVGA catchments.

Table 3 LUC class in Pukekohe SVGA catchments

LUC class	Area (ha)	Area (% of total)
1	4933	5%
2	29882	32%
3	19820	21%
4	9872	10%
5	0	0%
6	21603	23%
7	6000	6%
8	30	0%
Lake	52	0%
Quarry	204	0%
Town	1811	2%
Total	**94207**	

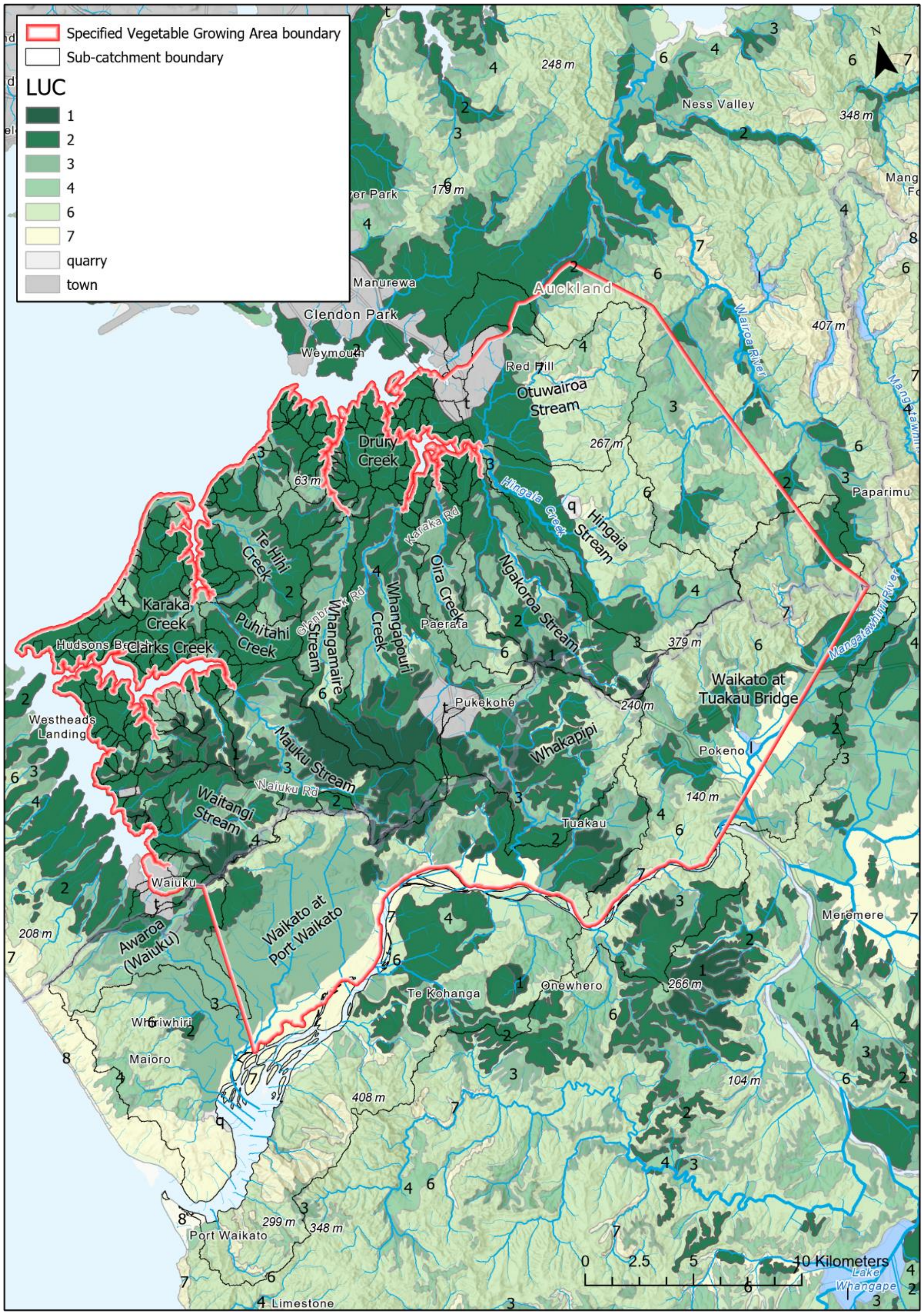

Figure 2 Pukekohe LUC class

2.2.2 Māori land

There is an estimated 628 ha of Māori land within the catchments that intersect the Pukekohe SVGA, accounting for 0.7% of the total area of the SVGA catchments. The majority of Māori land is south of the Waikato river in the Waikato at Port Waikato and Waikato at Tuakau catchments (Figure 1), which contain 301 and 265 ha of Māori land, respectively. Table 4 summarises the Māori land area by Land Use Capability (LUC) class within the SVGA catchments. Table 5 summarises the Māori land parcels by land use.

Table 4 LUC class of Māori land in Pukekohe SVGA

LUC class	Area (ha)	Area (% of total)
1	9	1%
2	98	16%
3	11	2%
4	12	2%
5	0	0%
6	456	73%
7	40	6%
Town	2	0%
Total	**628**	

Table 5 Land use of Māori land in Pukekohe SVGA

Land use	Area (ha)	Area (% of total)
Cropland - Annual	35	6%
Forestry	175	28%
Grazed - dairy	9	1%
Grazed - non-dairy	141	22%
Natural forest, water, and grassland with woody biomass	266	42%
Settlements and roads	3	1%
Total	**628**	

3. Horowhenua SVGA

3.1 Land use and Nitrogen loading

Land use within the Horowhenua SVGA has been estimated using LUCAS for the year 2016. Land use categories from LUCAS have been matched to those used in the CASM water quality model developed for Horizons Plan Change 2[5] to provide an estimate of N loading and the relative contribution of the different land uses.

The LUCAS land use category 'Orchards and vineyards (perennial)' has been matched to the CASM category 'Cropping', which provides the most appropriate estimate of N loss rate. All short rotation cropland in LUCAS is labelled as 'Horticulture' and assumed to be CVP.

Figure 3 shows the extent and land use within the Horowhenua SVGA. Land use area and estimated annual N loss using average annual N loss rates from CASM are provided in Table 6. Small differences in estimated N loads between Table 6 and those estimated directly from CASM[6] are the result of the different underlying land use data. The LUCAS data used here has increased spatial resolution to the regional CASM model and can be considered more representative.

Table 6 Land use area and N load for all catchments in Horowhenua SVGA

CASM Land use*	Area (ha)	Area (%)	CASM N loss rate (kg/N/ha/year)	N load (kg)	N load (% of total)
Builtup/Parks/Others	1026	15%	10	10260	7%
Cropping**	36	1%	13.9	507	0%
Dairy	1355	19%	37.2	50391	35%
Exotic Cover	290	4%	3.3	957	1%
Horticulture***	504	7%	66.5	33541	23%
Native Cover	204	3%	3	612	0%
Other	119	2%	2	239	0%
Sheep and/or Beef	2960	43%	16.3	48253	33%
Water Body	467	7%	0	0	0%
Total	**6963**			**144759**	

***** MfE LUCAS land use (2016) applied to CASM land use categories
** Orchards and vineyards (perennial) in LUCAS
*** Short rotation cropland in LUCAS

[5] Snelder, T., Cox, T., Kerr, T., Fraser, C., Collins, S. 2020. Manawatū-Whanganui Region Catchment Nitrogen Models Supporting Regional Plan Change 2.
[6] Easton, S. 2020. Catchment Water Quality Modelling: supporting evidence of Dr Claire Conwell. Horizons Plan Change 2 expert evidence.

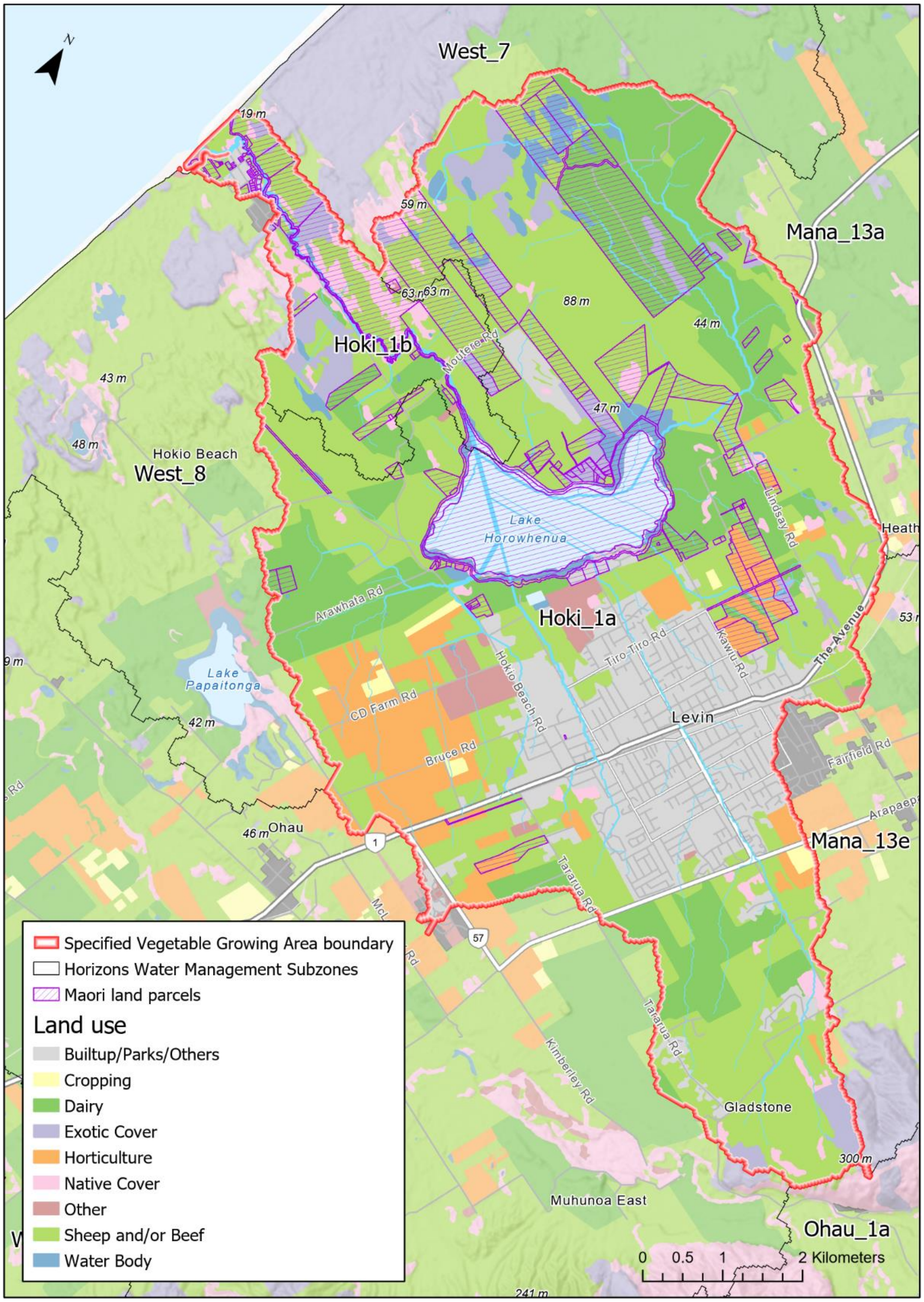

Figure 3 Horowhenua SVGA land use

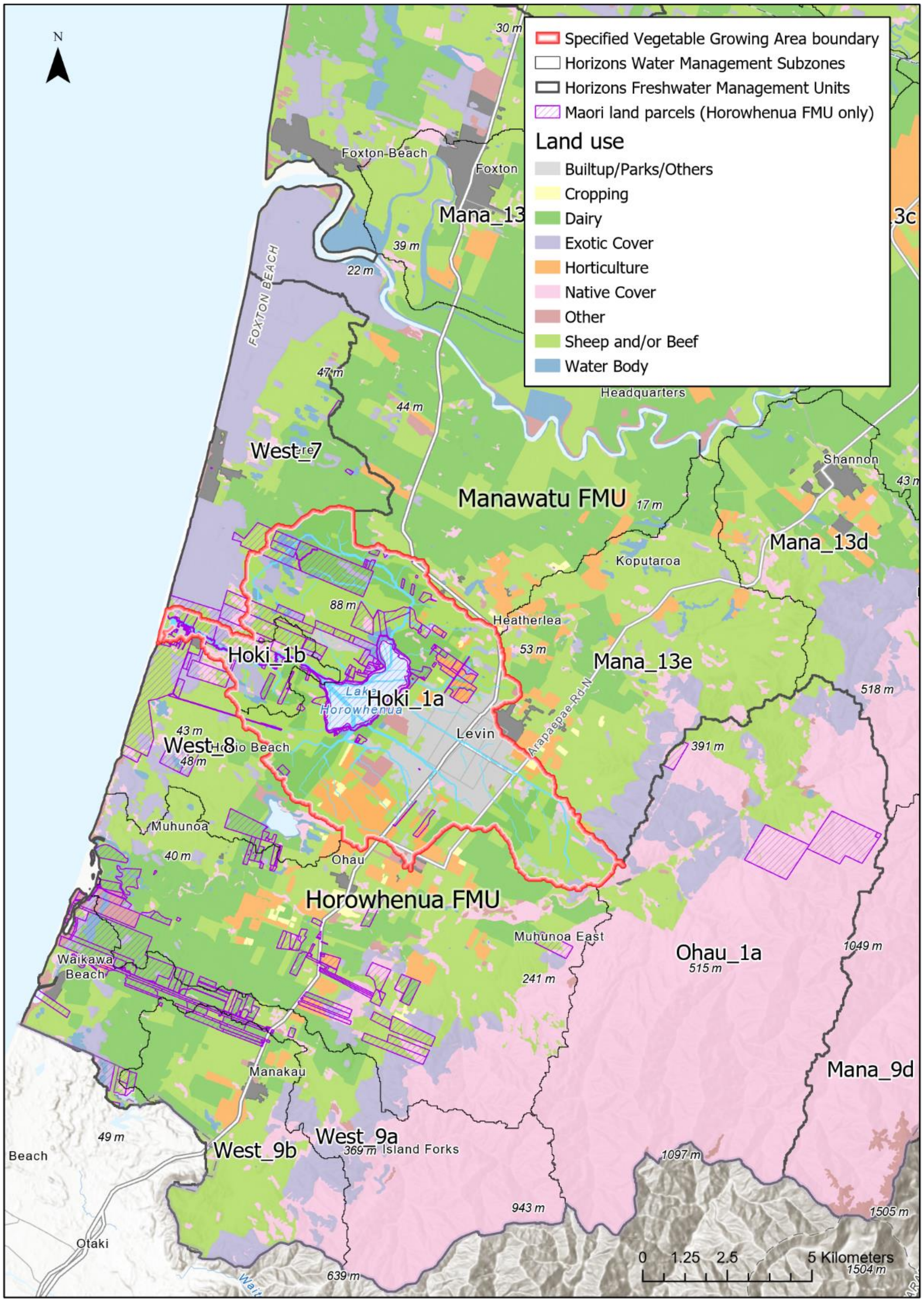

Figure 4 Horowhenua FMU land use

3.1.1 Land use capability

Table 7 summarises the land area within the Horowhenua SVGA and Freshwater Management Unit (FMU) by LUC class. Figure 5 shows the distribution of LUC class across the Horowhenua FMU.

Table 7 LUC classes in Horowhenua

LUC class	Area in SVGA (ha)	Area in SVGA (% of total)	Area in FMU (ha)	Area in FMU (% of total)
1	1145	16%	2517	6%
2	561	8%	2646	7%
3	2412	35%	8215	21%
4	154	2%	1604	4%
5	0	0%	0	0%
6	1311	19%	9332	24%
7	181	3%	7661	19%
8	21	0%	6030	15%
Lake	308	4%	366	1%
Town	870	12%	1008	3%
Total	**6963**		**39379**	

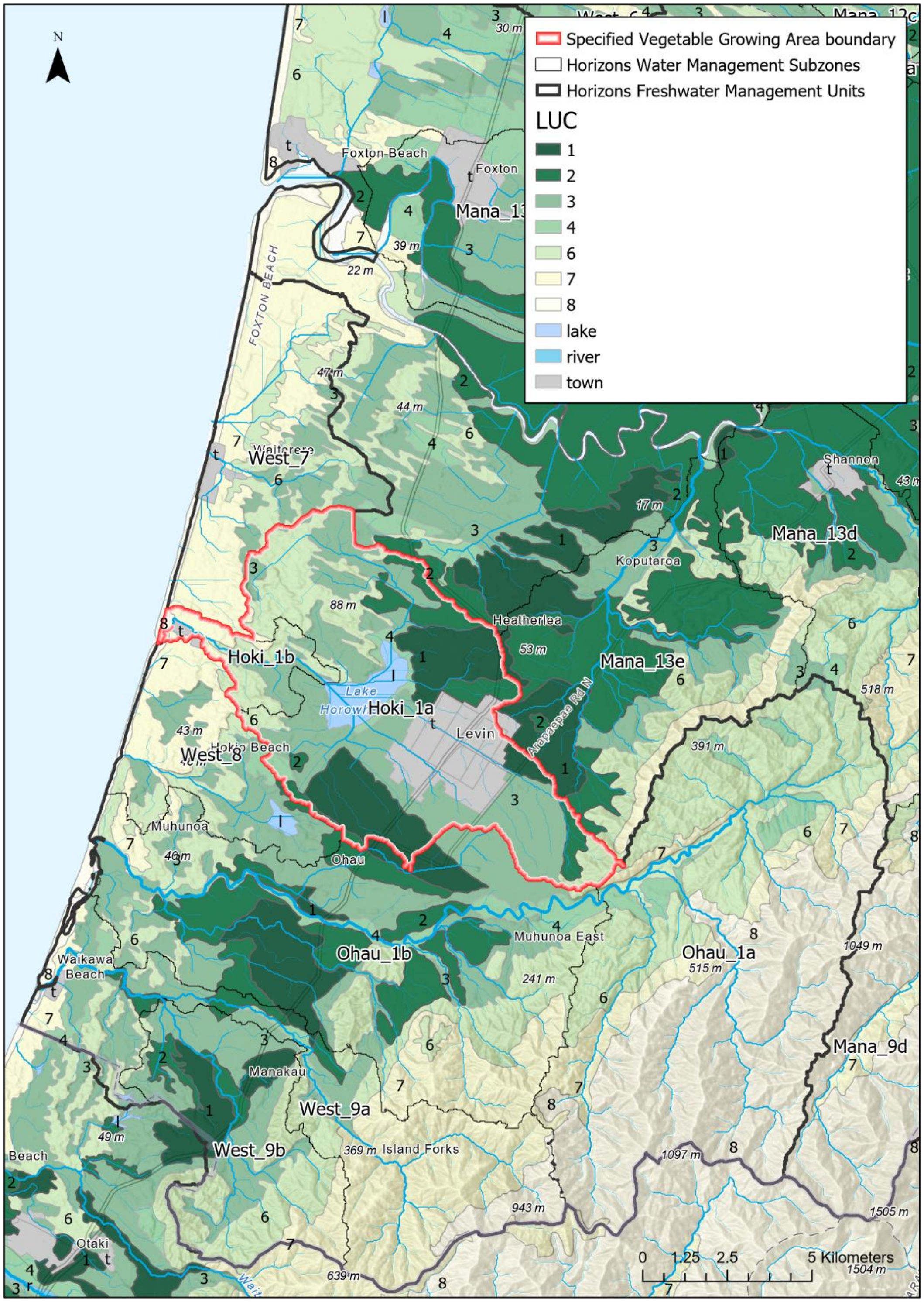

Figure 5 Horowhenua LUC class

3.1.2 Māori land

Māori land parcels within the Horowhenua SVGA total 1450 ha (21% of the total SVGA area), 308 ha of which covers Lake Horowhenua. Table 8 summarises the Māori land in the Horowhenua SVGA and within the wider Horowhenua FMU by LUC. Table 9 summarises the Māori land in the Horowhenua SVGA and within the Horowhenua FMU by land use.

Table 8 LUC of Māori land in Horowhenua

LUC class	Area in SVGA (ha)	Area in SVGA (% of total)		Area in Horowhenua FMU (ha)	Area in Horowhenua FMU (% of total)
1	98	7%		177	4%
2	51	4%		208	5%
3	343	24%		1166	29%
4	76	5%		196	5%
5	0	0%		0	0%
6	424	29%		896	22%
7	137	9%		908	23%
8	7	1%		166	4%
t	7	0%		9	0%
l	308	21%		308	8%
Total	**1450**			**4034**	

Table 9 Land use of Māori land in Horowhenua

CASM land use	Area in SVGA (ha)	Area in SVGA (% of total)		Area in Horowhenua FMU (ha)	Area in Horowhenua FMU (% of total)
Sheep and/or Beef	524	36%		1264	31%
Native Cover	85	6%		676	17%
Exotic Cover	96	7%		351	9%
Dairy	237	16%		1041	26%
Horticulture	82	6%		118	3%
Builtup/Parks/Others	19	1%		22	1%
Other	4	0%		106	3%
Water Body	404	28%		457	11%
Total	**1450**			**4034**	

4. National scale vegetable production

4.1 Vegetable production statistics

The 2017 agricultural production survey[7] describes the distribution of vegetable production in New Zealand. Figure 6**Error! Reference source not found.** summarises the total area used for growing outdoor vegetables by regional council. The largest producing areas are Canterbury, Hawke's Bay, Auckland (Pukekohe SVGA), Waikato (Pukekohe SVGA), Gisborne, and Manawatu-Whanganui (Horowhenua SVGA). The vegetable producing area in Canterbury and Hawke's Bay is dominated by process-vegetables such as peas and beans and extensive vegetable rotations of onions, potatoes, and squash. The growing areas in Pukekohe (Auckland and Waikato regions) and Horowhenua (Manawatu-Whanganui region) are particularly important for the production of brassicas (broccoli, cauliflower, and cabbage), lettuce and other leafy vegetables (spinach, silverbeet, bok choy, etc.), potatoes, and onions (Figure 7).

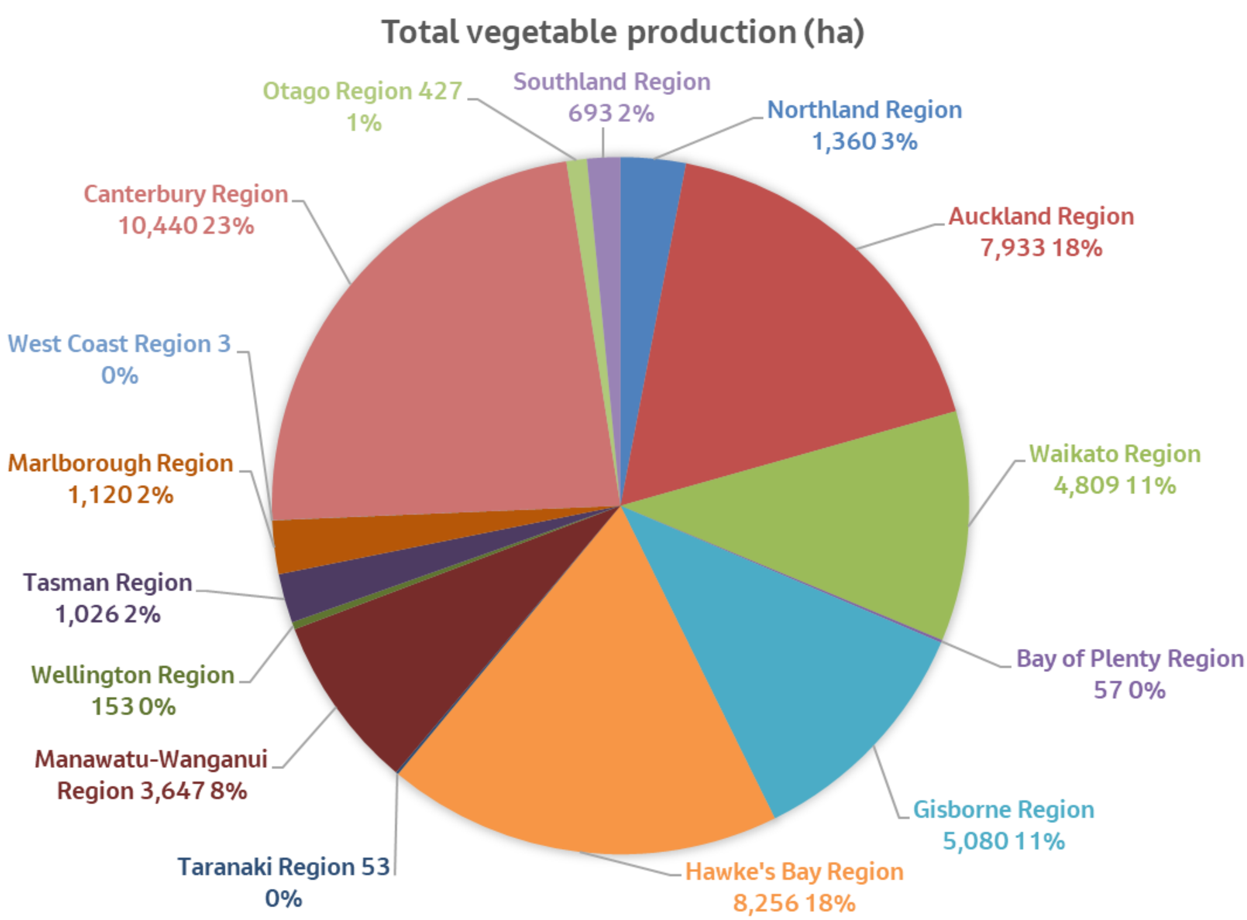

Figure 6 Outdoor vegetable production by regional council (2017)

[7] https://www.stats.govt.nz/information-releases/agricultural-production-statistics-june-2017-final

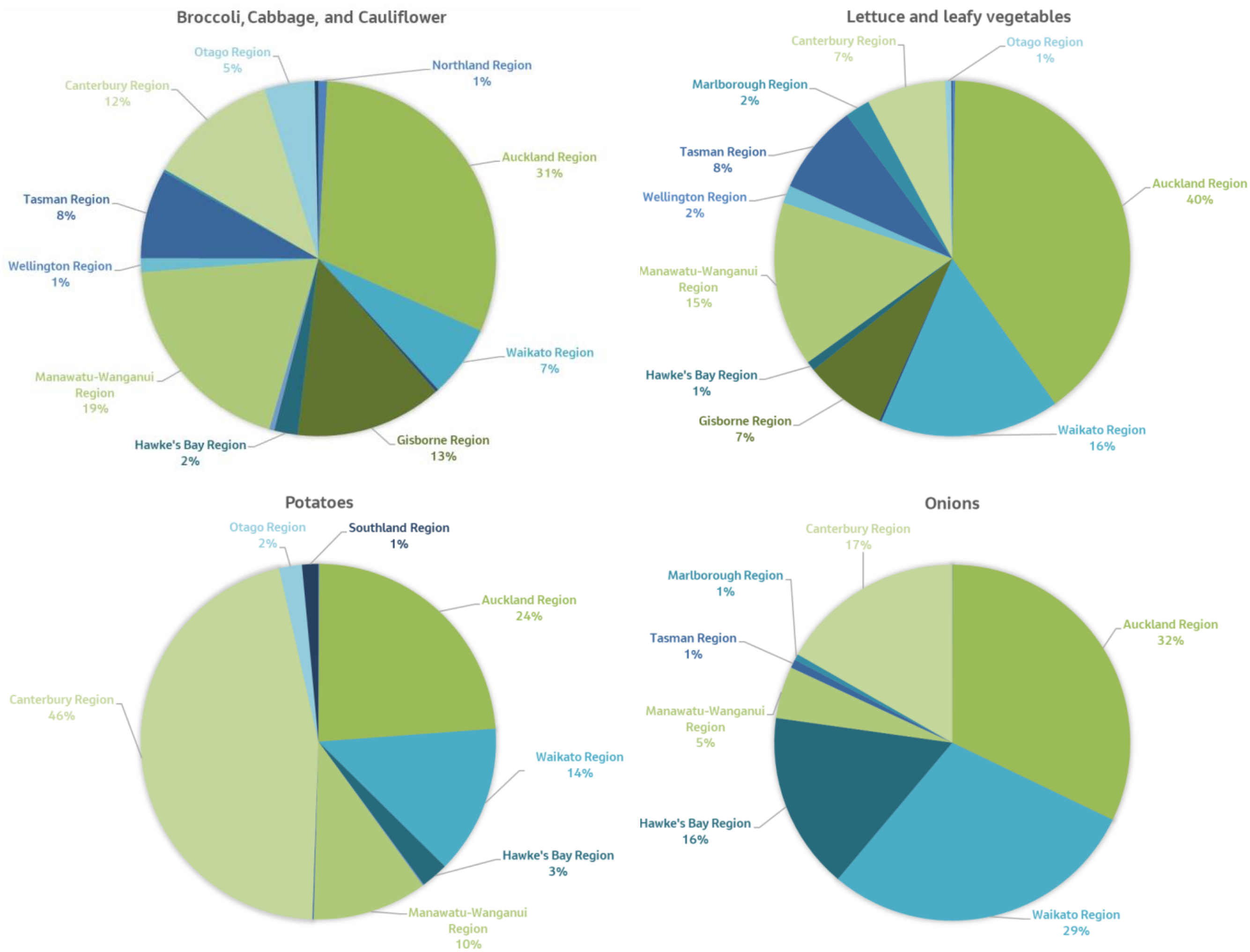

Figure 7 National production area for selected vegetables by regional council (2017)

4.2 Distribution of suitable land for CVP

LUC classes 1 and 2 are generally considered to be versatile[8] and therefore suitable for CVP. Another estimate of suitable food-producing land is 'high-class land'[9]. This definition is similar to class 1 and 2 land in the LUC classification, but with differences in the thresholds for climate, erosion, and drainage class, among others. High-class land has been mapped by the Ministry for the Environment[10]. Table 10

[8] Andrew, R., & Dymond, J. R. (2013). Expansion of lifestyle blocks and urban areas onto high-class land: An update for planning and policy. Journal of the Royal Society of New Zealand, 43(3), 128-140.
[9] Webb T, Jessen M, McLeod M, Wilde R 1995 . Identification of high-class land. Broadsheet November 1995: 109 – 114
[10] https://data.mfe.govt.nz/layer/52830-high-class-land-for-food-production-north-island-2012/

summarises the distribution of high-class land and LUC class 1 and 2 land by regional council. Figure 8 maps the high-class land across New Zealand.

Climatic limitations such as frost prevalence and Growing Degree Days (GDDs) further limit the suitability of some high-class land and LUC class 1 and 2 land for commercial vegetable production. Plant and Food[11] estimate 671,000 ha across New Zealand meet the criteria of LUC class 1 or 2, greater than 800 10-degree GDDs, <= 5 degrees slope, and has 180 days frost free: approximately half of the total LUC 1 & 2 land.

Table 10 High class land and LUC class 1 & 2 by regional authority

Regional Authority	Area (ha)	High Class Land (ha)	High Class land (% of region)	LUC 1 & 2 (ha)	LUC 1 & 2 (% of region)
Northland Region	1250425	27754	2%	36569	3%
Auckland Region	494107	63183	13%	59243	12%
Waikato Region	2390036	286631	12%	298806	13%
Bay of Plenty Region	1207181	37221	3%	56065	5%
Gisborne Region	838533	40749	5%	21046	3%
Manawatū-Whanganui Region	2222058	148357	7%	205460	9%
Hawke's Bay Region	1413801	92672	7%	44005	3%
Taranaki Region	725447	87081	12%	92017	13%
Wellington Region	804860	36290	5%	34857	4%
Marlborough Region	1045782	37735	4%	13843	1%
Tasman Region	961613	15975	2%	9642	1%
Nelson Region	42219	304	1%	695	2%
Canterbury Region	4450428	319426	7%	293160	7%
West Coast Region	2324524	322	0%	0	0%
Otago Region	3118633	87915	3%	50335	2%
Southland Region	3119612	183950	6%	172930	6%
Total	**26,409,260**	**1,465,566**	**6%**	**1,388,673**	**5%**

[11] Clothier B, Müller K, Hall A, Thomas S, van den Dijssel C, Beare M, Mason K, Green S, George S. March 2017. Futures for New Zealand's arable and horticultural industries in relation to their land area, productivity, profitability, greenhouse gas emissions and mitigations. A Plant & Food Research report prepared for: New Zealand Agricultural Greenhouse Gas Research Centre.

Figure 8 High class land distribution

Appendix D SCAMP modelling for Horticulture (Easton & Landers, 2022)

Subject:	SCAMP modelling for Horticulture
Attention:	Ton Snelder, Tim Cox, Maree Patterson, Amy Lennard
From:	Stuart Easton, Jordyn Landers
Date	01 June 2022

1 Introduction

This memo provides recommendations for improving the SCAMP model representation of horticulture for typical Commercial Vegetable Production (CVP) rotations and fruit growing. Section 2 recommends updated loss rates and mapping. Section 3 outlines general model limitations regarding horticulture and the Horowhenua primary growing area (Waiopehu FMU).

It is agreed that the recommendations given in this memo are unlikely to significantly affect the calibration of the SCAMP model given the small areas of horticulture relative to the average catchment sizes across the region. However, with regard to model scenarios and testing of potential mitigations it is important to accurately represent horticulture within the baseline model.

The views and analysis expressed in this memo are based on our current understanding of the SCAMP model and its inputs – we welcome any clarification. We appreciate the data and assistance provided to date.

2 Current state model inputs

2.1 Nutrient loss rates

The following sub-sections recommend updated Nitrogen (N) and Phosphorus (P) loss rates for SCAMP land use types.

2.1.1 Vegetable cropping

The current SCAMP 'Vegetable cropping' (synonymous with CVP) loss rates of 71 kg N/ha/yr and 1.6 kg P/ha/year are derived from the average of three different Horowhenua rotations modelled in Bloomer et al. (2020)[1]. These loss rates are applied to all parcels defined as Vegetable cropping across the entire model domain (Horizons region). Other land use categories have loss rates similarly applied at the regional scale except 'Dairy' and 'SBD' (Sheep, beef and/or deer farming) which are

[1] Bloomer D, Posthuma L, O'Brien G (2020): Modelled Loss of Nutrients from Vegetable Growing Scenarios in Horowhenua. Report prepared for Pattle Delamore Partners.

further classified into ‘typologies’ based on climate, slope, drainage, and soil moisture, (Dairy) and farm type and slope (SBD). We request that Vegetable cropping systems are also further classified to better represent the different rotations present across the region (further described in Appendix A):

1. Southern Region - Horowhenua
    a. Horowhenua Greens/Brassica vegetable rotations
    b. Horowhenua Potato/Onion vegetable rotations
2. Northern Region – Ohakune vegetable rotations
3. Central Region – Manawatu vegetable rotations

Table 1 summarises the recommended vegetable cropping typologies and their N loss rates. Current P loss rates are suggested to be maintained (1.6 kg/P/ha/year) as there is limited P loss rate information available for vegetable cropping systems. Appendix C summarises the described rotations at WMSZ scale using the existing SCAMP land use polygons for ‘Vegetable cropping’ (VEG) with the intention of simplifying any model updates. A map is provided in Appendix D. The underlying spatial data is available at request.

Table 1 Recommended nutrient loss rates for CVP types

Rotation	Location Description	Loss rate data source	Proposed N loss rate (kg N/ha/year)	Recommended area (at FMU scale)
Horowhenua Greens/Brassica Vegetable Rotation	Waiopehu FMU largely in Hoki_1a and Hoki_1b WMSZs. Also in the Manawatu FMU south of the Manawatu river (Mana_13a and Mana_13e WMSZs).	Bloomer et al. (2020) – area weighted average of ‘Brassica dominant vegetables’ and ‘Intensive fresh vegetables’ rotations (see Appendix B)	84.1	1077 ha (89%) of VEG land in Waiopehu FMU. 288 ha (18%) of VEG land in Manawatū FMU.
Horowhenua Potato/Onion Vegetable Rotation	Largely within the Waiopehu FMU in Hoki_1a and Ohau_1b WMSZs, along Kimberley Road. Limited area in Manawatu FMU south of the Manawatu River in the Mana_13a and Mana_13e WMSZs.	Bloomer et al. (2020) ‘Onion/Potato rotation’	31	139 ha (11%) of VEG land in Waiopehu FMU. 35 ha (2%) of VEG land in Manawatū.
Ohakune vegetable rotations	Ohakune area in Whangaehu FMU (not including Whau_3a and Whau_4 WMSZs).	Updated loss rate for ‘Waimarino - Rotation 4’ in The Agribusiness Group (2014) *	TBC*	405 ha (95%) of VEG land in Whangaehu FMU.

Manawatu vegetable rotations	Manawatu, Rangitikei-Turakina, Whanganui, and Whangaehu (Whau_3a and Whau_4 WMSZs) FMUs. Majority is located within the Mana_10a and Mana_13c WMSZs.	Updated loss rate for 'Cash cropping – Rotation 1' in The Agribusiness Group (2014, 2017) *	TBC*	1324 ha (80%) of VEG land in Manawatu FMU, 19 ha (5%) of VEG land in Whangaehu FMU, All VEG land in Rangitikei-Turakina, Kai Iwi, and Whanganui FMUs
* HortNZ have engaged Stuart Ford to update the relevant rotations modelled described in the Agribusiness Group (2014)[2] and The Agribusiness Group (2017)[3] to Overseer version 6.3.				

2.1.2 Other Horticulture

Loss rates in SCAMP for the land use category 'Horticulture (other than veg)' are taken from Drewry (2018)[4], from the median loss rates for 'Vegetables' (54 kg N/ha/year and 0.3 kg P/ha/year). In Drewry (2018) the 'Vegetables' loss rate is derived from studies from across NZ (predominantly Pukekohe and Tasman but not including Manawatu-Whanganui), for a range of rotation types (including potatoes, brassicas, and leafy greens) i.e vegetable leaching information is being applied to fruit, flower, nursery and viticulture land uses.

It is strongly recommended that the Drewry loss rates for 'Horticulture' are adopted instead; 9.9 kg N/ha/year and 0.17 kg P/ha/year. These are derived from estimates for fruit production systems (including viticulture, apples, and kiwifruit) that better represent the 'Horticulture (other than veg)' category which is mapped from the Agribase 'Flower', 'Fruit', 'Nursery', and 'Viticulture' categories and the LCDB category 'Orchards and Vineyards' (Herzig et. al 2020[5]).

2.1.3 Urban

Urban loss rates in SCAMP have been mis-assigned at 1.1 kg N/ha/year and 0.1 kg P/ha/year from Moores et al. (2017)[6]. The median loss rates presented in Moores et al. (2017) Table 3-9 (URQIS database) are instead 11.0 kg N/ha/year and 1.1 kg P/ha/year.

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[2] The Agribusiness Group. 2014. Nutrient Performance and Financial Analysis of Horticultural Systems in the Horizons Region. Prepared for Horticulture NZ.
[3] The Agribusiness Group. 2017. Farm Scale Economic Impact Analysis of One Plan Intensive Land Use Provisions. Prepared for Horizons.
[4] Drewry, J. 2018. Nitrogen and phosphorus loss values for selected land Uses. Manaaki Whenua Landcare research. Contract Report: LC3367. Prepared for: AgResearch (Sources and Flows, Our Land and Water).
[5] Herzig, A., Manderson, A., Baish, L. 2020. Opportunities and constraints on intensive land-use expansion in the Horizons Region – Land-Use Mapping
[6] Moores, J, Easton, E, Gadd, J, Sands, M: (2017) Te Awarua-o- Porirua Collaborative Modelling Project Customisation of urban contaminant load model and estimation of contaminant loads form source excluded form the core models, NIWA client report WRC1710

For the Hoki_1a Water Management Sub-zone (WMSZ), where Urban is the 3rd largest land use by area after Sheep, Beef, and Deer and Dairy the change in loss rate will increase the estimated catchment loading rate by 9,741 kg N/ha/year, equivalent to more than ¼ of the total estimated N loss from vegetable cropping in the same WMSZ.

2.1.4 Septic Tanks

Septic tanks are not currently represented in SCAMP, however it is likely that they contribute a significant N load in the Waiopehu FMU and elsewhere where rural housing is dense. For example, groundwater isotope analysis by McLarin et at. (1999)[7] found that septic tank effluent is likely the main source of nitrate contamination of groundwater in the Manakau village.

Lifestyle block loss rates in SCAMP are deemed to be equivalent to SBD, ranging from 14 – 30 kg N/ha/year depending on the property slope. In the Waiopehu FMU It is likely that the majority of Lifestyle blocks are of low slope; it is assumed they are matched to the loss rates for the Taranaki-Manawatu Finishing SBD class (16 kg N/ha/year). SPASMO modelling presented in the Section 42a report by Brent Clothier for the Horizons One Plan (2009) estimated leaching rates from 25 to more than 40 kg N/ha/year from Lifestyle blocks fitted with septic tanks in Levin (3-bedroom dwellings on 1250-5000 m^2 sections without animals), indicating the current SPASMO loss rate underestimates the N load from Lifestyle blocks where housing density is greater than one house per hectare.

Furthermore, the underlying land use mapping does not differentiate between urban land uses that are serviced by the wastewater network and those that use septic tanks, i.e., Manakau and Ohau villages have the same N loss rate as Levin. The average property size in the Ohau village is approximately 1500 m^2, suggesting a loss rate greater than 35 kg N/ha/year. Where septic tanks are undersized, broken, or poorly maintained it would be expected loss rates are even greater. We believe further investigation and explicit consideration of septic tanks within SCAMP is necessary.

2.2 Land use mapping

This section compares the SCAMP land use data to HortNZ estimates of growing area. SCAMP land use is derived from mapping undertaken by Manaaki Whenua Landcare Research for Horizons Regional Council (Herzig et. al 2020). Land use classification is for the year 2018, from a combination of different sources, including Agribase, the Landcover Database (LCDB), Horizons Consents and SLUI programme information, valuation data, and LINZ datasets.

It is acknowledged that it is difficult to accurately represent rotational horticultural systems on a static map. However, it is important that the total area within each sub-catchment or FMU is approximately correct so that in-stream nutrient load estimates are accurate and scenario testing can provide realistic guidance. Table 2 compares the Vegetable cropping area in SCAMP and HortNZ estimates for where estimates are available for the main CVP production areas of Horowhenua and Ohakune.

[7] McLarin, W., Bekesi, G., Brown, L., & McConchie, J. (1999). Nitrate contamination of the unconfined aquifer, Manakau, Horowhenua, New Zealand. Journal of Hydrology (New Zealand), 211-235.

Table 2 Estimated Vegetable cropping area for primary CVG areas

Growing Area	FMU	SCAMP Vegetable cropping area	HortNZ estimated CVG area	Note
Horowhenua	Waiopehu	1216 ha	1007 ha	HortNZ estimate based on GAP EMS grower mapping. Spatial data available.
Ohakune	Whangaehu	424 ha	863 ha	HortNZ estimate based on non-spatial grower estimates.

In general, the representation of Horticulture is reasonable for a regional scale model however the Vegetable cropping area in Ohakune (Whangaehu FMU) is significantly lower than estimated from grower correspondence. Elsewhere, including in Horowhenua, the area of Vegetable cropping is likely to be overestimated. This is due to the inclusion of Orchards from ratings/valuation data into the Vegetable category (this is particularly evident around the Whanganui area), and the way the classification method prioritises vegetable cropping over other rural land uses, so in the case of a classification conflict from the different data sources used, parcels have been classified as Vegetables by default.

We acknowledge the additional work required to update the land use data and baseline model, and the relatively small scale of change expected for total catchment loads. However, for the Ohakune growing area where the difference in areal estimates is significant, we recommend that model interpretation or scenario design account for the increased area

Other comments on land use mapping:

- Vegetable (and arable) systems are rotational – this means that the spatial location on a map is not static and changes year on year (however the total area remains reasonably consistent). This is important to keep in mind when using the land use mapping information.
- The Arable classification includes ‘Feed Crops (includes Pastures)’ from the consents information. It is uncertain as to whether these parcels would be more appropriately classified as Dairy and may overestimate the area of arable cropping and underestimate nutrient loss rates where they are grazed.

3 Note on model limitations

We acknowledge that the SCAMP model is a regional scale model intended to assess relative change between scenarios. However, based on our understanding of the SCAMP model and previous scenario design (for Plan Change 2 modelling) we are concerned that the model architecture may limit its ability to appropriately model Horticulture and the Waiopehu FMU.

In the model, nutrient loads from individual properties are combined at the catchment scale. Where in-stream loads are lower, for example due to catchment size, the loading rate from each land use or property will provide a greater proportion of the total load and therefore be of greater influence on total load and ability to reduce. Similarly, at smaller catchment sizes attenuation factors can be expected to remove a smaller load mass. This has the effect of predicting an unequal influence on water quality for enterprises within smaller reporting catchments (WMSZs). In the Waiopehu FMU which includes the Horowhenua CVP area, the average catchment size is significantly smaller than for the other FMUs (Table 3). We recognise that this is partly a function of the location of water quality monitoring sites on the lowland streams in the Waiopehu FMU, however elsewhere in the model domain multiple small coastal catchments are grouped together, for example the Northern Manawatu lakes and Southern Wanganui lakes WMSZs. Furthermore, the discussion of the annual load estimation method (Fraser & Snelder 2020[8]) indicates that in general, total in-stream loads are likely to be under-estimated due to a lack of monitoring data at high flows and the Flow Duration Curve (FDCs tendency to under-estimate high flows, particularly in the Tararua ranges[9]. This serves to compound the relative influence of enterprises within these catchments on total loads.

Table 3 Water management subzones within each FMU

FMU	WMSZ count	WMSZ average size (ha)
Puketoi ki Tai	5	24,405
Manawatū	49	12,025
Waiopehu	8	4,925
Rangitīkei-Turakina	19	27,456
Kai Iwi	3	11,328
Whanganui	29	25,050
Whangaehu	11	18,124

A further source of uncertainty for predictions of current and future water quality in the Waiopehu FMU is the lack of water quality calibration sites downstream of the main Horowhenua growing area (assuming that the water quality sites used for SCAMP calibration have been maintained from the CASM model (Snelder et. al, 2020[10])).

N loss rates and their physical pathway representation are another source of potential bias in model interpretation. The average annual N loss rates are derived from Overseer modelling, which is recognised to have limited accuracy, especially for CVP where crops and management practices change significantly temporally and spatially within a given year or growing season. The 'Rootzone reality' project has shown that N losses from CVP occur predominantly in response to drainage events (Norris et al. 2017[11]). As drainage volumes are not simulated in the model, the relative contribution

[8] Fraser, C. & Snelder, T. 2020. Load calculations and spatial modelling of state, trends, and contaminant yields. Report No. 2020EXT1672. Prepared for Horizons Regional Council.

[9] It is unclear as to whether the 6 Tararua sites mentioned with very poor performance are on the eastern (Manawatu) or western (Waiopehu) side of the range.

[10] Snelder, T., Cox, T., Kerr, T., Fraser, C., Collins, S. 2020. Manawatū-Whanganui Region Catchment Nitrogen Models Supporting Regional Plan Change 2.

[11] Norris, M., Johnstone, P., Green, S., Clemens, G., van den Dijssel, C., Wright, P., & Halliday, A. 2017. ROOTZONE REALITY–A NETWORK OF FLUXMETERS MEASURING NUTRIENT LOSSES UNDER CROPPING ROTATIONS.

and ability to mitigate N load from CVP (or other enterprises) during baseflow conditions (where periphyton growth is expected to occur) is uncertain.

Given the model uncertainties, we encourage sensible scenario design and interpretation, for example:

- Any modelled expansion of CVP is limited to appropriate horticultural land (i.e., based on LUC, current land use, frost occurrence etc.),
- Changes in N and P loading are expressed as a net-change (e.g., the expansion of extensive Potato rotations at 31 kg N/ha/year into current Dairy pasture at 60 kg N/ha/year (Warm/Low/Light/Moist typology) will result in an increase in CVP load but a net decrease in catchment load).
- Recognition that the ability to mitigate N loss for many CVP enterprises may be limited. For example, the Bloomer et al. (2020) modelling predicted that reductions achieved by the Intensive rotation were significantly greater than the Brassica rotation, driven largely by a modelled reduction in cropping footprint which may be unachievable elsewhere, given a reduction in cropping foot print is associated with an equivalent increase elsewhere, or an overall reduction in vegetable production.

We would appreciate the opportunity to comment further on the limitations of modelling and to provide input into scenario design.

4 Summary of recommendations

We recognise the challenges of water quality modelling and appreciate the opportunity to comment. We recommend the following to improve the current model inputs:

1. Vegetable cropping N yields are updated to reflect actual/typical rotations based on location and crop type. We can provide a GIS shapefile of the proposed rotation sub-categories and N-loss estimates following the completion of the updated Overseer modelling.
2. ‘Horticulture (other than veg)’ loss rates are changed to ‘horticulture’ in Drewry (2018) across all FMUs.
3. Urban N and P loss rates are updated.
4. Consideration of losses from septic tanks.
5. Model scenarios are realistic, and results acknowledge limitations in the model, including accounting for the increased Vegetable cropping area in the Whangaehu FMU (Ohakune).

In addition to the recommendations listed above, we are concerned that an annual average regional scale model designed for- and calibrated to- larger, pasture-dominant catchments may not adequately predict water quality dynamics in the Waiopehu catchment. We welcome further opportunities to provide input.

Appendix A Typical vegetable growing rotations/typologies in the Horizons Region

HortNZ have provided the following summary of the key vegetable growing areas in the Horizons regions.

Northern Region – Ohakune Vegetable Rotations

FMU (based on indicative boundaries):	Mostly Whangaehu (some area in the Rangitīkei-Turakina FMU)
Growing area description:	Ohakune has long been associated with supplying the North Island's winter vegetable crops. It has friable volcanic soils and a cool climate. It is an ideal vegetable growing area. This area is important for the winter supply of vegetables. The Ohakune autumn/winter harvesting season complements the other growing regions in the North Island, filling this important gap that would otherwise exist when these vegetable types would not be available to the fresh market in the quantities required to meet domestic consumer demand. Key crops in this area include carrots, potatoes, onions and brussels sprouts. Growers in Ohakune typically specialise in growing only 1 or 2 vegetable types, e.g, carrots and potatoes, brussels sprouts and parsnips etc. Only one crop per year is grown, being planted in spring growing over summer and mature ready for harvest in autumn and winter. These crops are grown in quite extensive rotations of 6-10 years in pasture followed by a rotation of vegetables of 3-5 years. While the total growing area remains reasonable static year on year, the location varies due to rotational practices and shifts within/between water management zones annually. Rotation is important to maintaining the soil health.
Previous modelling:	2014 modelling by The Agribusiness Group described as Waimarino (Rotation 4).

Central Region – Opiki/Manawatu/Rangitikei

FMU (based on indicative boundaries):	Rangitīkei-Turakina and Manawatu
Growing area description:	This growing area is important for the supply of fresh and process potatoes and for seed potatoes. Process peas are also grown in this part of the Region. Potato production in the Opiki District occurs within a mix of maize, dairy cattle, and potato production rotated on a shorter term due to the soil.

	As with the northern region described above, rotation means that the land parcels used for vegetable growing are not static year on year e.g., a land parcel may be in arable for 1-2 years, then pastoral for 5 years before being in vegetables for a year.
Previous modelling:	2014 modelling by The Agribusiness Group described as cash cropping (Rotation 1), and subsequent 2017 report.

Southern Region – Horowhenua

FMU (based on indicative boundaries):	Waiopehu
Growing area description:	The climate in Horowhenua is also ideal for the growing of vegetable crops - this growing area is important for the year-around supply of green vegetables. A very wide range of crops are grown, over 38 vegetable crops – including, brassicas, leafy greens, Chinese greens, salad crops, potatoes and onions. These growing systems are less integrated with pastoral farming, than the vegetable type rotations found in the northern and central part of the Region. The intensive market garden systems many crops in the same field with up to three crops a year in a continuous rotation. The location of CVG is more stable than the rotations in the norther and central parts of the Region, but the locations do change over time as lease land arrangements alter and as land is periodically rested. The NPSFM 2020 identifies Horowhenua as a specified vegetable growing area – specifically Lake Horowhenua (Hoki_1a) Water Management Subzone and Hokio (Hoki_1b) Water Management Subzone.
Previous modelling:	“Modelled Loss of Nutrients from Vegetable Growing Scenarios in Horowhenua – May 2020” (Bloomer) report – identified three main rotation types. The Agribusiness Group 2014 and 2017 reports – as intensive vegetables and Market Garden.

Appendix B Horowhenua intensive N loss rate estimation

Table 4 summarises the leaching rates from Bloomer et. al (2020) to estimate the area-weighted average leaching rate for CVP not including Potato/Onion rotations in the Waiopehu FMU (i.e to determine the 'Horowhenua Greens/Brassica Vegetable Rotation' typology referred to). Rotation area is based on the HortNZ Good Agricultural Practice (GAP) Environmental Monitoring System (EMS) survey results. The growing area of unknown rotation type (Other) are assumed to be a 50:50 mix of Intensive and Brassica.

Table 4 Bloomer et al. (2020) N leaching rates and estimated rotation area in the Waiopehu FMU

Rotation	Area (ha)	N Leaching Rate (kg N/ha/year)
Intensive	488	81
Brassica	76	93
Other (50:50 Intensive Brassica assumed)	309	87
Combined	**873**	**84.1**

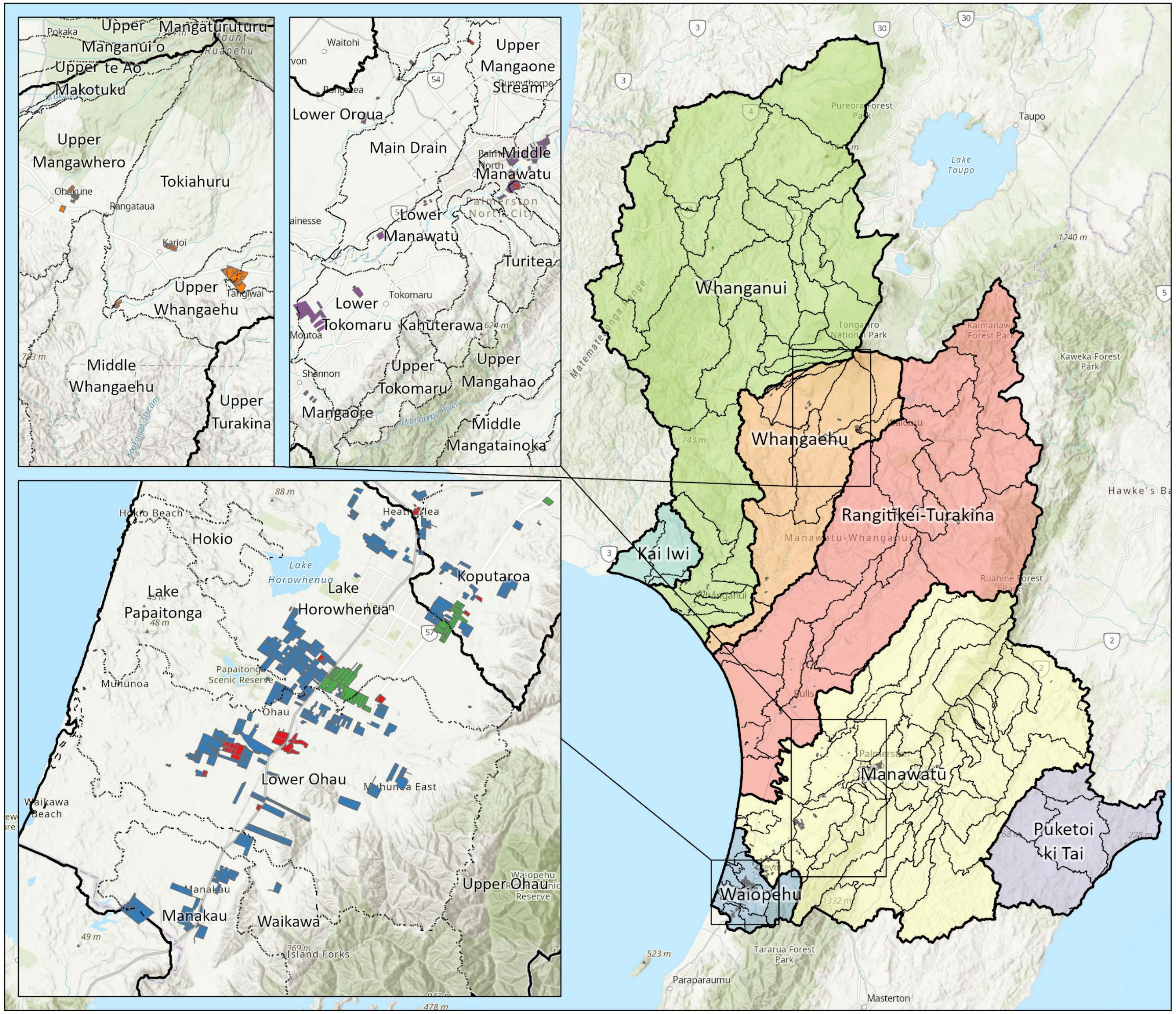
Appendix C Vegetable rotation areas

FMU	WMSZ Zone Code	Total VEG Area (currently in SCAMP)	Recommended area of Vegetable rotation 'typologies' to be adopted (ha)			
			Horowhenua Potatoes/ Onions Vegetable rotations	Horowhenua Greens/ Brassica Vegetable rotations	Ohakune Vegetable rotations	Manawatu vegetable rotations
Kai Iwi	West_3	11	0	0	0	11
Manawatū	Mana_13c	390	0	0	0	390
	Mana_11a	55	0	0	0	55
	Mana_13a	152	0	112	0	40
	Mana_10e	47	0	0	0	47
	Mana_10a	483	0	0	0	483
	Mana_13e	212	35	176	0	0
	Mana_10d	29	0	0	0	29
	Mana_11f	15	0	0	0	15
	Mana_13f	38	0	0	0	38
	Mana_12a	18	0	0	0	18
	Mana_12c	56	0	0	0	56
	Mana_9b	32	0	0	0	32
	Mana_12d	19	0	0	0	19
	Mana_2a	11	0	0	0	11
	Mana_13d	31	0	0	0	31
	Mana_12e	18	0	0	0	18
	Mana_2b	6	0	0	0	6
	Mana_11e	6	0	0	0	6
	Mana_12b	4	0	0	0	4
	Mana_9c	10	0	0	0	10
	Mana_10c	4	0	0	0	4
	Mana_11b	2	0	0	0	2
	Mana_8c	5	0	0	0	5
	Mana_11d	2	0	0	0	2
	Mana_11c	2	0	0	0	2
Rangitīkei-Turakina	West_6	44	0	0	0	44
	Rang_4a	77	0	0	0	77
	Rang_4b	19	0	0	0	19
	Tura_1b	17	0	0	0	17
	Rang_4c	7	0	0	0	7
	Rang_4d	4	0	0	0	4
Waiopehu	Ohau_1b	511	28	484	0	0

	West_9b	138	0	138	0	0
	West_8	31	0	31	0	0
	West_9a	34	0	34	0	0
	Hoki_1a	501	111	390	0	0
Whangaehu	Whau_1a	143	0	0	143	0
	Whau_1b	125	0	0	125	0
	Whau_3c	21	0	0	21	0
	Whau_3d	75	0	0	75	0
	Whau_3a	19	0	0	0	19
	Whau_1c	42	0	0	42	0
Whanganui	Whai_7a	22	0	0	0	22
	Whai_7b	11	0	0	0	11
	Whai_2a	2	0	0	0	2
	Whai_4d	1	0	0	0	1

Collaborations

Appendix D CVP types map



Proposed Vegetable Rotations

For SCAMP water quality model. See attached explanatory memo

Project:	Horizons Model Advice	Author	SE
Client:	HortNZ	Date	May 2022
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Collaborations