BEFORE THE HEARING COMMISSIONERS APPOINTED BY THE MANAWATŪ WANGANUI REGIONAL COUNCIL (HORIZONS)

IN THE MATTER	of the Resource Management Act 1991 (**the Act**)
AND	
IN THE MATTER	of Proposed Plan Change 2 to the Horizons One Plan

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STATEMENT OF EVIDENCE OF CLAIRE CONWELL (WATER QUALITY) ON BEHALF OF HORTICULTURE NEW ZEALAND

25 September 2020

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INTRODUCTION

Qualifications and experience

1. My full name is Claire Elaine Conwell.

2. I hold a PhD in marine ecotoxicology from the University of Melbourne (Australia, 2007), and First Class Honours in marine ecotoxicology from the Royal Melbourne Institute of Technology University (Australia, 2000) and a Bachelor of Science from Monash University (Australia, 1999). I am a member of Water New Zealand (including membership of the Stormwater Group) and the Society of Environmental Toxicology and Chemistry (SETAC Australasia Branch).

3. I work for Jacobs as an Associate Environmental Consultant (Water Resources). I have been employed at Jacobs since mid-January 2020. Prior to that, I was employed as a Senior Scientist with the Greater Wellington Regional Council (**GWRC**) where I was responsible for components of the Coastal State of the Environment Programme focusing on estuarine and subtidal sediment contaminants. I was Programme Manager for the Wellington Region's and Recreational Water Quality Monitoring Programme. I provided scientific technical advice for Environmental Regulation (consents) officers across a wide range of marine and freshwater quality issues, with specific focus on wastewater and stormwater discharges. I provided technical expert evidence on stormwater provisions for the proposed Natural Resources Plan. In my capacity at Jacobs, I continue to be engaged as technical expert for GWRC in these processes.

4. During January 2019 to June 2019 I was seconded to the Ministry for the Environment's Essential Freshwater Taskforce to assist the policy advisors with specific analysis and provisions in the Essential Freshwater Reforms, announced in September 2019. I championed the Envirolink Tools research project 'Monitoring water quality in urban streams and stormwater: Guidance for New Zealand practitioners' (NIWA 2019).

5. Prior to GWRC, I was employed as an environmental consultant for 5 years at the Cawthron Institute (Nelson), undertaking a range of Assessment of Environmental Effects for a variety of activities in near shore coastal environments around New Zealand. This commonly included an assessment

of contaminants in benthic sediments in urban coastal areas and port environments.

6. I have authored more than 50 technical reports in environmental management, produced more than 10 conference presentations in the field of ecotoxicology and water quality, and published several peer reviewed science papers and co-authored a book chapter in marine hydrocarbon pollution.

Expert Witness Code of Conduct

7. 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 December 2014. 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 the proceedings

8. I have been asked by Horticulture New Zealand (**HortNZ**) to present evidence in relation to water quality.

9. I took part in expert witness conferencing on 28 July and 13 August 2020 in respect to Water Quality provisions for PC2, with a focus on Table 14.2 Cumulative Nitrogen Leaching Maximums (**CNLM**s).

Purpose and scope of evidence

10. The purpose of my evidence is to provide an overview of the impact of PC2 on water quality in the Manawatū-Whanganui Region, with specific regard to the contribution of horticulture as an Intensive Farm Land Use (**IFLU**) across the target Water Management Sub Zones (**WMSZ**). I also present a summary of additional modelling scenarios appended to this evidence, as set out by Mr Stuart Easton (**Appendix A**).

11. In preparing my evidence I have reviewed the following documents and evidence:

    (a) Section 42A report of Christine Foster, on behalf of Manawatū-Whanganui Regional Council. Planning. 4 September 2020

(b) Section 42A report of Abby Matthews, on behalf of Manawatū-Whanganui Regional Council. Technical-Water Quality. 4 September 2020

(c) Section 42A report of Dr Antonius Snelder, on behalf of Manawatū-Whanganui Regional Council. Technical - Water Quality and Scenario Analysis. 4 September 2020

(d) Section 42A report of Dr Timothy Cox, on behalf of Manawatū-Whanganui Regional Council. Technical - Water Quality and Scenario Analysis. 4 September 2020

Summary of conclusions

12. The key conclusions of my evidence are:

(a) The proposed PC2 provides for a regulatory pathway for IFLUs that cannot meet the Table 14.2 Cumulative Nitrogen Leaching Maximum (**CNLM**). For Horticulture, this means that for the marginal contribution of overall catchment N-loads from this industry, horticultural farmers will be enabled to implement Best Management Practice (**BMP**) /Good Management Practice (**GMP**) under a regulatory framework to achieve improvements in water quality from their activity. Modelling of BMP shows this is achieving reductions in N and sediment.

(b) PC2 is regarded as an interim measure to allow for a consenting pathway – i.e. GMP/BMP to be implemented across IFLUs in the region, including horticulture where farms cannot meet the CNLMs in Table 14.2.

(c) Overall, for both sediment and nitrogen, the contribution of horticulture as a proportion of total contaminant load is small, given the relatively small area in production across the region. However due to the comparative small land area occupied by horticulture, the absolute reduction in the contribution to catchment contaminant load is also small.

(d) Despite the relatively small contribution, it is still recognised that through intensification and expansion of horticulture, there is the potential for contaminant loads to increase – however overall the reductions in contaminant loads are still demonstrably achieved via BMP, which will result in improvements in water quality. This is also consistent with the objectives of One Plan to improve water quality outcomes for the target WMSZ.

(e) PC2 and BMP alone will not achieve the water quality targets set out in One Plan Schedule E. Further reductions in contaminant loads requires the NPSFM limit setting process to be undertaken across the region; defining limits and action/management plans is required to provide a clear framework for water quality management in the region. The PC2 regulatory approach, along with other non-regulatory mechanisms, will serve to compliment this framework.

WATER QUALITY

13. Water quality in the region is described in detail in a number of technical science reports, including annual State of the Environment Monitoring, State and Trend Assessments (Fraser and Snelder 2018), catchment modelling assessments prepared for PC2 (Snelder 2020). A summary of the current state and trends is also set out in Appendix B of the s42A report of Dr Abby Matthews and Dr Ton Snelder.

14. Fraser and Snelder calculated 'compliance' statistics for the key water quality indicators listed in Schedule E of One Plan for State of the Environment (**SoE**) sites with the relevant data record. For key nutrients DIN and DRP, a high proportion of SoE sites both across the region, and within target WMSZ were assigned a 'fail' state compared against the Schedule E targets. (Snelder s42A)

15. Trend analysis across both the 10-year and 20-year periods suggested that, on the whole, there were improvements across the region and WMSZ. Snelder (2020), however, points to the influence of climatic variation as having a measurable impact on water quality. Thus, there is an element of caution expressed about inferring that changes in nitrogen management are responsible for the observed trends.

16. Snelder also notes that the improving trends are observed over both the 10-year and 20-year period, and given the widespread observation across sites, suggests there is some

limited evidence that the management actions are contributing to decreased river nitrogen concentrations.

17. In terms of improvement to water quality as a result of PC2, this evidence cross references the assessments of the s42A reports that reiterate that it has not been the intention of PC2 to meet water quality targets in Schedule E of One Plan. It is also noted in these reports that the implementation of PC2 will likely results in modest water quality improvements, bust most sites would still fail to comply with the Schedule E targets.

Contaminants

18. Key contaminants of concern for water quality management and contributing to Ecosystem Health and Human Health outcomes include *E. coli*, nutrients (Dissolved reactive Phosphorus (**DRP**) and Dissolved Inorganic Nitrogen (**DIN**)), and sediment. There are also other key contaminants, for the purpose of this discussion the main contaminants are referred to from the National Objectives Framework (**NOF**) setting out mandatory attributes for monitoring and reporting.

19. Sediment is widely regarded as a surface water contaminant due to the physical disturbance in water courses, reduced light penetration, smothering of habitat, and facilitating the transport of other contaminants down water courses. Site specific controls are largely sought via Erosion Sediment Control and Stormwater Management Plans. The NPSFM 2020 will now require management plans to be developed to monitor both suspended and deposited sediment in water courses.

20. The faecal indicator bacteria *E. coli* has long been used to assess the risk to human health of the likelihood of illness resulting from the use of water course for contact recreation. Although generally not considered to adversely impact on ecological health, the inclusion of E. coli in the NOF is used to drive improvements in water quality, reduce risk to human health, and to enhance cultural values such as mahinga kai. Generally elevated *E. coli* is not considered to incur an adverse ecological impact.

21. Nutrients such as DRP and DIN are recognised to exacerbate unwanted periphyton growth, algal blooms, and contribute to the risk of eutrophication of sensitive downstream receiving environments including lakes and estuaries. There are,

however, difficulties associated with prescribing attributes for DRP under the NOF that provide sufficient consistency across water body and land use types.

22. NIWA (2007)[1] summarises the issues regarding nitrogen (**N**) as the limiting nutrient in Horizons region. It is generally regarded as more cost effective to manage for the limiting nutrient, rather than for both N and DRP. Similarly, with DRP, the aim of managing N loads in catchments is to minimise the impacts at the bottom of the catchment sensitive receiving environments, such as estuaries, and lakes, and to prevent macroalgae bloom eutrophication in these systems.

23. In terms of water quality, the overall **load** of contaminants, at a sub-catchment scale, influences water quality. This represents the overall amount of a particular contaminant (N), as a cumulative amount, that has entered the water course, and is transported to downstream receiving environments. Thus, it is irrespective of any threshold of allocation of that load, which can be described as an intensity (i.e. kgN/ha) for an individual land parcel.

24. Assessment of a particular sub-catchment contaminant load over a year requires the average concentration to be converted to a load to assess water quality impacts. But for wet weather events, the maximum load of a contaminant is delivered to a downstream receiving environment in these wet weather events, rather than being expressed as averaged over time.

25. The focus on the ***intensity*** of a potential contaminant (i.e. as a measure of kgN/ha) has led to limited improvement in reducing overall catchment load of N.

26. For the Horizons regions, the focus for managing N load has been to implement the nutrient management framework of the One Plan, namely the allocations prescribed in Table 14.2. (Horizons, 2007). This has meant that greater than 50% of the N load is not being managed. Instead, the focus has been on the land use types defined as IFLU – of which CVG contributes only 1% of the total N load. (Easton, 2020. Appendix A)

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[1] Wilckck, B., Biggs, B., Death, R., Hickey, C., Larned, S., Quinn, J. (2007) Limiting nutrients for controlling undesirable periphyton growth. NIWA Client report HAM2007-006. Report prepared for Horizons Regional Council. 43p

27. The division, or allocation of that load, whether this be from the current landuse and investment (i.e. grandparenting) or the productive potential of the land (i.e. natural capital) are not directly a water quality management tool, rather these practices are largely a result of social and economic mechanisms, as well as cultural values, and efficiency.

28. In terms of achieving water quality targets – management of the load will drive catchment and sub-catchments improvements.

29. In terms of setting targets, these are ideally driven by the sensitivity of the downstream receiving environment – whereby the bottom of the catchment, as being the final sink for the bulk of the load, will be required to be protected for under a limit setting process. This approach is also explicitly set out in the NPSFM 2020.

30. Thus, a blanket approach of allocating a maximum load, such as the CNLM, on the basis of its natural capital cannot take the relative sensitivities of downstream receiving environments into account when determining the maximum load a contaminant can be discharged at from an individual site.

Hydrology implications on water quality

31. The Manawatū-Whanganui Region is a large and diverse area across which the hydrology varies greatly.

32. The hydrology of each of these catchments, and even of their sub-catchments will vary greatly, and as a result hydrology has a significant role in influencing the water quality of a catchment. Hydrology is influenced by interactions between rainfall variability in space and time and catchment characteristics. Catchment characteristics morphology, climatic factors, vegetation and land use, soils and geology. Across the region these characteristics vary greatly, and include high altitude volcanic catchments, de-vegetated steep mudstone country, flat coastal and riverine plains and standalone coastal lake catchments.

33. Creating models that represent this regional hydrological variance, and therefore water quality variability, is a complex and difficult process. Horizons have adopted Streamlined Environmental Limited's regional scale model called

Contaminant Allocation and Simulation Model (**CASM**) to inform the PC2 process.

34. This model has been described by Streamlined as a flexible and usable generalised modelling tool for simulating diffuse and point source contamination at a catchment scale. It would appear to be fit-for-purpose for this type of regional scale approach where relative change in water quality (through the re-distribution of loads) is more important than absolute measures.

35. In the CASM modelling undertaken the region has been characterised by four main river basins:

(a) The Manawatū (including Horowhenua and Coastal Tararua catchments),

(b) The Rangitikei,

(c) The Whanganui, and

(d) The Whangehu.

36. The modelling does not treat lake catchments any differently from river catchment. No lake processes are included in the model, rather the lake catchments are assumed to behave like river catchments and are calibrated in the same way. For example, Hokio Stream which is the outlet of Lake Horowhenua, was calibrated to a water quality monitoring site located in the Ohau River, rather than actual WQ data from the Hokio Stream or the lake.

Hydrology of lake catchments and impact on quality.

37. The Lake Horowhenua catchment has unique hydrology that is unlike any other catchment in the region, and perhaps in New Zealand. The surface water and groundwater catchments are different, which adds to the complexity.

38. The surface water catchment extends from the foothills of the Tararuas in the east, across the midway between Lake Horowhenua and the coast in the west. In the middle of the catchment is Lake Horowhenua.

39. The groundwater catchment is larger than the surface water catchment, and less well defined. Groundwater recharge occurs in permeable alluvium between the base of the foothills and somewhere in the vicinity of State Highway 1 but

extends westward beneath the Lake and out to the Coast. Surrounding the Lake catchment, in the wider Horowhenua Water management Subzone, there are complex interactions with Lake Papitonga and the Ohau river.

40. The Lake acts as a basin, with the main surface water inflows coming in from the north (Mangaroa and Pataki Streams), the east (Queen Street Drain including all urban run-off) and the south (Arawhata Drain).

41. Unlike a typical costal plan aquifer system where groundwater flows from the foothills and discharges to the coast, a large basement high (Faultline) beneath the lake drives a proportion of groundwater flow to the surface and is thought to emerge in both the Arawhata Drain and directly into the lake.

42. The potential range of groundwater inflow to the lake has been estimated by PDP to be in the order 36 and 62% of total flow (PDP, 2019), however there is uncertainty in these estimates, in where the inflow occurs and how it varies in space and time. The is also little information on the role groundwater plays in maintaining lake health.

43. The Lake is in poor health. For many years it received the Levin wastewater discharge and continues to receive significant nutrient and sediment loading from the Levin urban area and surrounding agricultural land.

44. The relative proportions of nitrogen load in the Horowhenua WMSZ have been calculated by my colleague Mr Easton (included in **Appendix A**). They are:

(a) 8% Urban

(b) 27% Horticulture

(c) 65% Pastoral farming and other.

45. Horticulture occurs mainly in the Arawhata sub-catchment of the Horowhenua WMSZ. The Arawhata is a highly modified catchment, with an extensive drainage network originally developed as a Water Race by the local Water Board, but then decommissioned and modified by various parties to act as land drainage scheme.

46. This drainage network captures a range of land use including pastoral land, outer residential/lifestyle, SH1 and the

horticultural growing area. It has flooding and capacity issues, which are known to drive sediment erosion when the networks capacity is exceeded.

47. The nitrogen concentration in the Arawhata drain is high, with a median total nitrogen concentration of 10.9 mg/L over the last 5 years (LAWA, 2020). As the drainage network rarely flows, it is assumed this nitrogen is coming from groundwater upwelling into the drain.

48. The complexities of the Horowhenua catchment described above are an example of where a regional scale model is not an appropriate tool for catchment scale water quality modelling, or for driving water quality improvement. Rather, a proper catchment scale limit setting process must be followed that acknowledged individual complexities of catchment.

NPSFM and whether the One Plan and PC2 implement NPSFM 2020

49. In the NPSFM, the term 'limit' can refer to a limit on a resource use, or a water take limit. A limit on resource use means the maximum amount of a resource use (e.g. land use) that is permissible while still achieving a relevant target attribute state (see clauses 3.12 and 3.14, NPSFM 2020).

50. For PC2, the term 'limit' has been used to describe the numerical thresholds in Table 14.2 that are otherwise also known as Cumulative Nitrogen Leaching Maximum (CNLM) and are divided between Land Use Capability Class (LUC I to VIII).

51. Table 14.2 maximums have not been set using the NPSFM limit setting process, i.e. it is not based on catchment modelling, rather a high-level approach to setting maximum leaching rates for land use classes, primarily using Overseer as a tool to do this (ref).

52. The partitioning between land use classes is effectively allocating these CNLM to individual land parcels – rather than setting catchment, or sub-catchment, loads. The setting of catchment-based limits is the approach mandated in the NPSFM, but has not been the approach adopted for establishing Table 14.2.

53. Thus, for smaller land use parcels in a sub-catchment this sets the practice whereby one farm can exceed the CNLM, if another is under the CNLM. In effect, Table 14.2 seeks to

improve the current state in some LUC, whist accommodating degradation of water quality in some LUC.

54. By contrast, Policy 5 of the NPSFM requires regional councils to manage freshwater via the National Objectives Framework (NOF) to '*ensure the health and well-being of degraded water bodies and freshwater ecosystems is improved, and the health and well-being of all other water bodies and freshwater ecosystems is maintained and (if communities choose) improved*.'

55. The process requires councils to identify target attribute states and objectives via a limit setting process, with the aim of improving water quality if it is in a degraded state, and where it is improved, to be maintained is a desired state is already reached.

56. This applies where there are nutrient sensitive downstream receiving environments – such as wetlands, lakes, and estuarine receiving environments, and outcomes desired for these downstream receiving environments must be accounted for in the upstream limit setting criteria.

57. It is clear in the wording of the NPSFM and the NOF that the intent of the NPSFM prescribes a 'maintain' status and if desired by the community, to 'improve'. There is no accommodation in the NPSFM wording to allow a water body to degrade.

58. The One Plan and PC2 acknowledges that this NPSFM implementation and limit setting process has not been done under the NPSFM (2017) when PC2 was in development, nor under NPSFM (gazetted August 2020).

59. Modelling undertaken by Snelder, Cox, and Kerr (2020) for PC2 has been undertaken for a range of scenarios, impacts of PC2, and outcomes for IFLUs. Findings from that modelling has indicated that management of nitrogen leaching proposed under PC2 will lead to *modest* water quality improvements in the target catchments, but may allow some IFLU land to increase its nitrogen leaching rates up to CNLM in recalibrated Table 14.2.

60. This provision for a theoretical increase in N leaching is acknowledged in the evidence of Abby Matthews, thus again emphasising the point that the thresholds set out in PC2 Table

14.2 cannot be regarded as limits according to NPSFM, as the One Plan framework allows for an increase in N loss.

61. This will also mean that for currently unregulated IFLUs, improvements via the consenting pathway will most likely lead to longer term improved outcomes for water quality, including for those located outside target catchments.

SUMMARY OF "CATCHMENT WATER QUALITY MODELLING" (S. EASTON, 2020, APPENDIX A) APPENDED REPORT

62. The work undertaken by Mr Easton (Appendix A**)** estimates catchment nitrogen and sediment loads in the Manawatū-Whanganui region in relation PC2, with a focus on the Horowhenua Freshwater Management Unit (**FMU**) and the contribution of horticulture to contaminant loading. The following sections summarise key findings of Appendix A.

Regional

63. The estimates of total catchment N load and horticulture contribution for WMSZ in the Manawatū-Wanganui region are set out in Table 1 (Appendix A).

64. The total area occupied by horticulture land across all WMSZ is around 0.1% of the total area. The Horowhenua FMU has the highest proportion of this, and is where the majority of intensive vegetable production occurs.

65. The contribution of horticulture, as a proportion of total N load remains small, with 66.5 tonnes of N estimated to leach from horticulture across all target catchments - representative of just 0.6% of the total N load.

66. It is noted in Appendix A that the CASM analysis has underestimated the total land occupied by horticulture. Using updated land information, the total proportion of N leaching from horticulture is estimated to be 0.9% (see Table 8).

GMP and BMP adoption scenarios

67. S. Easton (Appendix A) indicates that the modelled rotations set out by Bloomer, Posthuma, and O'Brien (2020) are broadly representative of three individual enterprises (intensive, brassica, potato/onion) in the Horowhenua. These modelled rotations in the Horowhenua FMU, represent around 69% of the total Horticultural area.

68. The N load from horticulture in target catchments in the Horowhenua FMU for pre-2019 and post-2019 practice was modelled based on the leaching rates provided for by Page Bloomer (see Table 5 and 6, App A).

69. For pre-2019 practice, the total estimated N load generated from horticulture is between 72.1 and 75.6 t/ha/year.

70. 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.

71. 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 which achieved a 7% reduction (Table 4, App A).

72. The effect on N leaching from a controlled pathway reduction of a 20% or a 35% reduction of crop rotation (where crop rotation was brassica and mixed crop), was also tested to quantify catchment scale reductions that could be achieved by implementation of on-farm reduction scenarios.

73. The reduction in catchment load achieved by the two scenarios is small (~5% for a 35% reduction, and ~3% for a 20% reduction, see Table 10 in Appendix A). The 35% rotation reduction scenario produces a similar overall catchment N load reduction as the pre- to post-2019 (i.e. GMP/BMP implementation) outcome, which was a 5% reduction in N-load across the FMU from horticulture GMP/BMP.

74. The actual reduction in N catchment load that can be achieved by controlled reduction pathways is likely to be around these values set out in Table 10. As demonstrated in the modelling of Page Bloomer there are already growers who have exceeded the BMP standard and have undertaken systems change and have reduced more than 35%.

75. Also, as identified in the modelling of Page Bloomer and the evidence of Stuart Ford, some growers (Brassica rotations, which had higher N-leaching) are unlikely to be able to access the controlled pathway if the threshold at set at 20%, and will likely need to seek a discretionary consent for a shorter duration, that achieve GMP and BMP reductions appropriate to their rotation.

76. However, setting a threshold at a level which is unachievable for too many growers may drive lesser uptake of GMP and BMP than an ambitious but achievable threshold, because it will drive more growers though the discretionary or exit pathway.

77. From a water quality perspective, the difference between achieving a 5% reduction in N load or 3% reduction in N load is minimal in the context of the long-term goal of achieving freshwater outcomes following implementation of other non-regulatory mechanisms as well as the NPSFM.

Expansion scenarios

78. Snelder (S42A) sets out two Horticulture Expansion scenarios. However, the simulations are considered unrealistic in terms of assessing that the land as LUC I, II, or III currently in Dairy Farming or Sheep and Beef would be converted to horticulture and accompanied by 5 year crop rotations. The higher end scenario assumed horticulture expansion across all LUC I, II and III land.

79. These scenarios are unrealistic to consider in terms of viable outcomes for the PC2 process, and a more realistic expansion scenario is included in modelling assessment provided in Appendix A.

80. 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).

81. In terms of potential expansion, estimates of changes to catchment load following a 10% expansion (based on domestic food supply demand) of horticultural rotations was assessed (See Table 12, App A).

82. This expansion assessment indicated the additional N load from Horticultural expansion is small in comparison to the total

catchment loads, with less than 1% increase in catchment load predicted at all modelled scales.

Crop rotation scenarios

83. In terms of rotation, changes in catchment N loads were also examined where 20% of the existing horticulture land rotates from within the target catchments to the non-target catchments (see Table 13, App A).

84. Although the average existing leaching rate for suitable horticulture land in non-target catchments is higher than that for the target catchments a net benefit of 0.1% load reduction was still achieved.

Other findings

85. Several updates to the CASM data were implemented for the modelling scenarios set out in Appendix A. This included grower provided mapping through the EMS in Horowhenua, as well as inclusion of urban N leaching estimates. The increased area and leaching rate compared to CASM results in a subsequent increase in N load.

86. Overall, for both sediment and nitrogen, the contribution of horticulture 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.

Sediment load

87. On average, modelling shows the current erosion and sediment control practices reduce average sediment loss by between 34% (current practice, low efficiency, assuming 20% buffer strips) and 56% (current practice, high efficiency, assuming 80% buffer strips) compared to the unmitigated sediment loss rate. The BMP achieves a 74% reduction in sediment.

88. These modelled improvements in erosion and sediment control show that over time as BMP becomes more widespread, both existing and new mitigations are reducing sediment loss rates.

89. For the WMSZ in Horowhenua, modelling BMP also demonstrates the 74% reduction in sediment loss rate (as assumed the average loss rate from the Horowhenua FMU).

90. At an FMU catchment scale, the combined horticulture 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.

91. Similarly for the Horowhenua FMU, current proportion of sediment load attributable to horticulture in this FMU is less than 1% (assuming high efficiency, i.e. 80% buffer strip).

92. CVG contributes a very small proportion of the sediment load, and therefore these improvements, while worthwhile, won't be sufficient to achieve freshwater outcomes. Thus the NPSFM process will be required to set limits that achieve outcomes. Those future limits will have to seek reductions from land uses other than CVG, given that 99% of the sediment load discharged to receiving waters in the Horowhenua FMU is from other land uses.

Impact of what is proposed by HortNZ on existing state compared with PC2 over the next 10 years

93. Overall, for CVG the impact of setting the weighted average percentage reduction at 20% compared to 35% in minimal, given the total proportion of IFLUs occupied by CVG.

94. The key mechanism for realising improvements to water quality from CVG is to implement improvements in farm practices via GMP/BMP, and to work towards the next plan which will be looking to implement NPSFM outcomes on a catchment and sub-catchment basis.

95. It is recognised that the One Plan nutrient management framework does not seek to reduce N leaching to the degree that water quality Schedule E targets would be met (Matthews s42A, para 80).

96. PC2 is regarded as a component of a 'tiered' response that this provides for the regulation of nutrients, with the aim of reducing nutrient input over time from IFLUs. It is also recognised that this is also only one regulatory mechanism being used to drive improvements in water quality (Foster s42A, para 10).

97. PC2 is generally regarded by Council as a 'transitional' plan change, that it is not proposed to give effect to either the 2017 or 2020 NPSFM (ref. Rather, PC2 can be regarded as enabling GMP/BMP to be implemented via a regulatory pathway for IFLUs that can't meet Table 14.2).

98. PC2 will not prevent Horizons from giving effect to NPSFM, but it is also recognised that the nutrient management framework will be central to subsequent reviews, for the purpose of establishing catchment limits and/or action plans as required by the NPSFM (Matthews, para 81).

99. The broad scale approach of the PC2 is also recognised as being based on the surface water catchment monitoring network, i.e. it does not account for catchment groundwater or lake loads.

100. The CASM model while somewhat useful, needs significant investment and improvement to inform the NPSFM processes.

101. Cox (s42A, 2020) describes the sources of uncertainty in undertaking the modelling for PC2. Cox also states that given these uncertainties, and that these are unavoidable, the models are better suited for predicting relative changes in basin water quality rather than absolute values in N loads themselves.

102. This was also recognised by the Water Quality Joint Witness Statements, that despite the sources of uncertainty, these models have been able to be used to assess changes in catchment N loads from PC2, and to also examine alternative scenarios of interest.

103. As outlined in the evidence of Andrew Barber, the NZG EMS FEP, enables the collection of information about CVG and the adoption of GMP and BMP. This data would be very valuable for the calibration and scenario testing of future modelling.

104. The PC2 approach (as an allocation process, and one which can result in increased N loads), and restrictions of the modelling to describe relative change all point to the need for a detailed FMU specific modelling and limit setting approach, as per the requirements of the NPSFM. This will require the further development of the catchment contaminant load models to test catchment-based scenarios, and to inform the limit setting process.

105. This limit setting process, and other key provisions set out in the NPSFM such as key management plans and delineation of wetland areas, provide for other mechanisms of improving water quality that cannot be achieved under PC2 alone.

106. The One Plan, PC2 (as notified), the proposed S42a and the proposed approach from HortNZ, will not achieve the scale of Nitrogen reductions in the Hokio 1a catchment required to meet the freshwater outcomes. A NPSFM process will be required to set limits that achieve outcomes. Those future limits will have to also seek reductions from land uses other than CVG, given that 70% of the N load in that catchment is from other landuses.

107. Achieving outcomes in Hokio 1a is unlikely to be achieved with limits alone. It is also likely to require additional catchment scale mitigation projects such as the proposed constructed wetland project to improve the assimilative capacity of the catchment.

108. The proposed constructed Arawhata Wetland is one such mitigation being considered. Horizons is currently investigating the feasibility of a large-scale treatment wetland that would capture flow form the Arawhata Drain and drainage network and treat it before it enters Lake Horowhena. Engineered treatment wetlands of this scale have been known to reduce nitrogen concentrations similar to that of the Arawhata Drain (~10 mg/L) to less than 1 mg/L.

109. The proposal from Horizons acknowledges the difficulties faced by landowners in improving water quality when many of the natural characteristics of the catchment have been modified or removed i.e. increased drainage, natural wetland removal. It also acknowledges that removing horticulture form high quality soils is not the only way to drive water quality improvements.

CONCLUSIONS AND RECOMMENDATIONS

110. The proposed PC2 and assessments set out in the s42A reports recognise that PC2 provides for a regulatory pathway to be implements for IFLUs that cannot meet the Table 14.2 CNML. For Horticulture, this means that for the marginal contribution of overall catchment N-loads from this industry, CVG will be enabled to implement BMP/GMP under a regulatory framework to achieve improvements in water quality from

their activity. Modelling of BMP shows this is achieving reductions in N and sediment.

111. It is widely recognised that NPSFM has not been implemented, and that PC2 is an interim measure to allow for a consenting pathway – i.e. GMP/BMP to be implemented across IFLUs in the region

112. Overall, for both sediment and nitrogen, the contribution of horticulture as a proportion of total contaminant load is small, given the relatively small area in production.

113. However due to the comparative small land area occupied by horticulture, the absolute reduction in the contribution to catchment contaminant load is also small.

114. Despite the relative small contribution, it is still recognised that through intensification and expansion of horticulture, there is the potential for contaminant loads to increase – however overall the reductions in contaminant loads are still demonstrably achieved via BMP, which will result in improvements in water quality. This is also consistent with the objectives of One Plan to improve water quality outcomes for the target WMSZ.

115. A catchment based NPSFM limit setting process, defining limits and action/management plans, is required to provide a clear framework for water quality management in the region. The PC2 regulatory approach, along with other non-regulatory mechanisms, will serve to compliment this framework.

Claire Conwell

25 September 2020

APPENDIX A – CATCHMENT WATER QUALITY MODELLING – STUART EASTON

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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

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[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.

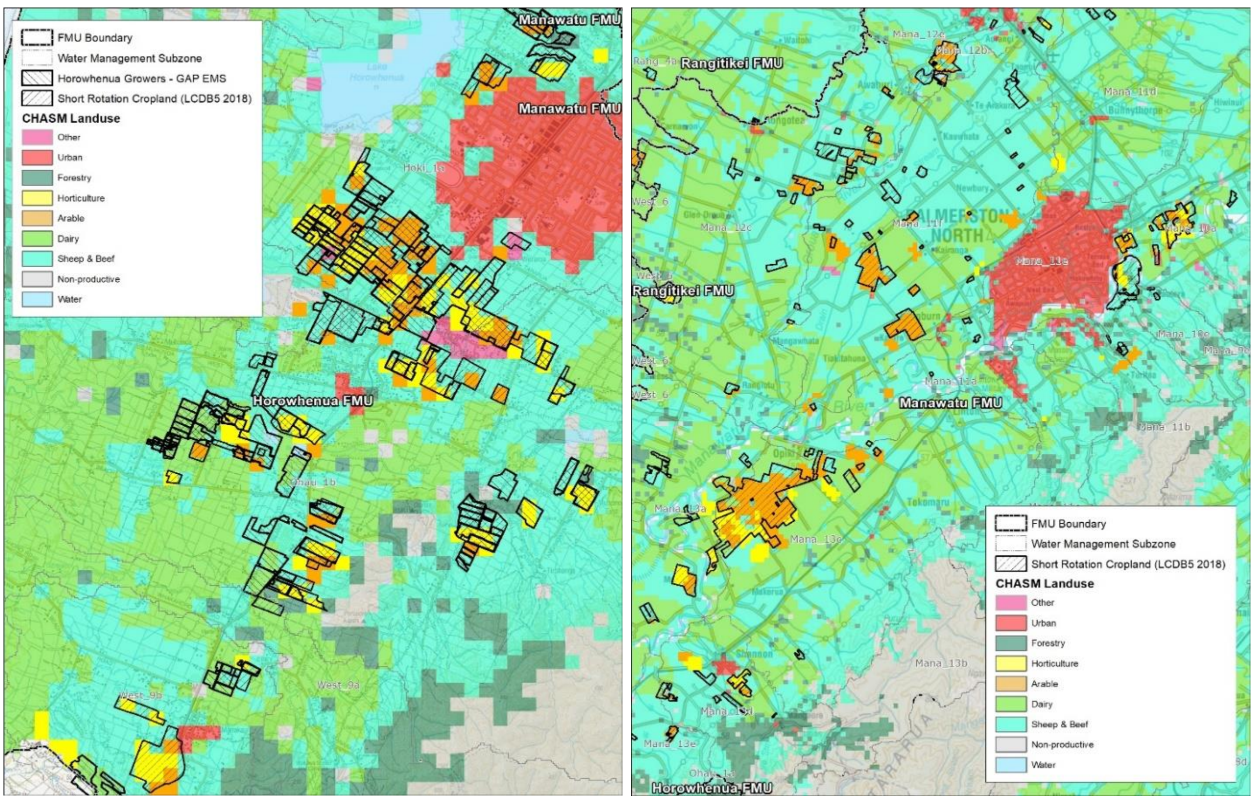

Figure 1 Comparison of CASM land use inputs for Horowhenua (left) and Opiki (right)

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		81	44	13.5	7.3	-46%
Other as 50:50 Intensive: Brassica	166	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)		72.1	46.1	40.5	25.9	-36%
Total (Other as 50:50 Intensive: Brassica)	561	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).

[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.