BEFORE THE ENVIRONMENT COURT

In the matter of	appeals under clause 14 of the First Schedule to the Resource Management Act 1991 concerning proposed One Plan for the Manawatu-Wanganui region.
between	**FEDERATED FARMERS OF NEW ZEALAND ENV-2010-WLG-000148**
and	**MINISTER OF CONSERVATION ENV-2010-WLG-000150**
and	**HORTICULTURE NEW ZEALAND ENV-2010-WLG-000155**
and	**WELLINGTON FISH & GAME COUNCIL ENV-2010-WLG-000157**
	Appellants
and	**MANAWATU WANGANUI REGIONAL COUNCIL** *Respondent*

STATEMENT OF TECHNICAL EVIDENCE BY ASSOCIATE PROFESSOR RUSSELL DEATH ON THE TOPIC OF WATER QUALITY AND NUTRIENT MANAGEMENT

ON BEHALF OF WELLINGTON FISH & GAME COUNCIL

Dated: 14 March 2012

QUALIFICATIONS AND EXPERIENCE

1. My full name is **Russell George Death.**

2. I have the following qualifications: BSc (Hons) and PhD in Zoology from the University of Canterbury. My general area of expertise is the community ecology of stream invertebrates and fish. I have particular expertise in the area of high and low flow effects on riverine invertebrate communities. In 2007 I was one of thirteen scientists funded to attend a special symposium of the Royal Entomological Society in Edinburgh to review the current state of research on aquatic invertebrates. I was asked to review the effects of floods on aquatic invertebrates. I am a member of the Ecological Society of America, the New Zealand Freshwater Sciences Society and the Society for Freshwater Science.

3. I am currently an Associate Professor in freshwater ecology in the Institute of Natural Resources – Ecology at Massey University where I have been employed since 1993. Prior to that I was a Foundation for Research, Science and Technology postdoctoral fellow at Massey University (1991-93). I have 75 peer-reviewed publications in international scientific journals and books. I have written 40 plus consultancy reports and given around 60 conference presentations. I have been the principal supervisor for 35 post-graduate research students. I have been a Quinney Visiting Fellow at Utah State University. I am on the editorial board of the Journal of Marine and Freshwater Research.

4. I have been researching the invertebrates, periphyton and fish of the streams and rivers of the Horizons Region for the past sixteen years and have conducted research and advised Horizons Regional Council (Horizons) between 1999 and 2007. I have conducted a range of research projects between 1999 and 2007 for Horizons related to the invertebrate, fish and periphyton communities of rivers and streams of the Horizons Region.

5. I am familiar with the evidence of those witnesses relevant to my area of expertise which is contained in the "Technical Evidence Bundle" lodged with the Court by the respondent, together with the additional evidence of Ms Barton, Dr Roygard, Ms McArthur, and Ms Clark dated 14 February 2012, and Dr Roygard and Ms Clark dated 24 February 2012.

6. I have read the Environment Court's Code of Conduct for Expert Witnesses, and I agree to comply with it. I confirm that the issues addressed in this brief of evidence are within my area of expertise.

7. I have not omitted to consider material facts known to me that might alter or detract from the opinions expressed. I have specified where my opinion is based on limited or partial information and identified any assumptions I have made in forming my opinions.

SCOPE OF EVIDENCE

8. My evidence will deal with the following:

- The state and trends in water quality particularly with respect to ecological health;
- The most likely causes of the low water quality and ecological health of the Region's waterbodies;
- The effect of deposited fine sediment from erosion and other land use activities on waterbody ecological health;
- The effect of nutrients from point and non-point sources on waterbody ecological health;
- The inappropriateness of a 20% change in QMCI as an effect trigger for point source discharges;
- The current ecological state of the Rangitikei River and the relative impact of nonpoint and point source discharges;
- The efficacy of livestock exclusion and riparian buffers in preventing or lessening the detrimental effects of land use activities on waterbody ecological health;
- The importance of small and ephemeral streams for biodiversity, proper ecosystems function and the ecological health of the entire river network;

- The implications for water quality and ecological health of outcomes for proposed approaches to managing intensive farming.

TERMS AND DEFINITIONS

9. Throughout my text I use the words ‘life supporting capacity’ and ‘ecological health’ interchangeably. Although there may be some distinction between these in a planning and/or legal arena they are the same in an ecological context. Furthermore, I also use the term ‘adverse’ and ‘significant adverse’ effect interchangeably. Again while there may be differences in these terms within the planning and/or legal arena they are identical in an ecological context.

KEY FACTS AND OPINIONS

10. There is a considerable body of evidence that land use activities if not managed appropriately can and do have significant adverse effects on the ecological health and life supporting capacity of waterbodies in the Horizons region.

11. In my view, discussion on the appropriate time frame to consider declining water quality trends in the Horizons Region is not constructive. The temporal linkages between land use activities and their effects on waterbodies are not clearly understood (e.g., we do not know if agricultural intensification today will affect water quality this month, this year, next year, in 10 years or all of these). It is clear water quality and ecological health in many of the Region’s waterbodies is poor and should be improved and that much of the poor water quality is a result of agricultural activities.

12. The principal driving factors for these adverse effects are increased nutrient levels, and suspended and deposited sediment.

13. Land use, primarily agriculture, results in increased levels of deposited fine sediment in surface waterbodies (up to 2000% more) that smothers plants and animals, buries habitats and changes the composition of fish and invertebrate communities, in turn reducing ecological health. The Proposed One Plan (POP) does not provide any guidance on acceptable levels of deposited sediment. The proposed addition to Schedule D (presented in Appendix 1) should go some way to correcting this.

14. Management of both nitrogen and phosphorus in all waterways is important to avoid the adverse effects of nutrient enrichment. If nutrients are not managed below certain thresholds this results in cascading affects through riverine food webs that result in degraded water quality and ecological health. The concentrations of nutrients presented in Schedule D are a good approximation of levels that are highly likely to lead to improved ecological health.

15. Healthy ecological systems require the appropriate chemical, physical and biological conditions. Both excess nutrients and sediment can detrimentally alter this environment. Improved ecological health will only result from managing both sediment and nutrients.

16. I can think of no reason why a 20% reduction in QMCI, as opposed to a statistically significant change, should be the trigger for an effect when assessing point source discharges. The 20% figure is arbitrary, unscientific, encourages lack of replication, does not increase the likelihood of finding ecologically significant changes and allows for greater degradation in cleaner water bodies.

17. There is convincing evidence that the ecological health of the Rangitikei River is moderate to poor and would be unlikely to assimilate increased detrimental effects that may result from unmanaged increases in agricultural intensification or less environmentally focused agricultural practises.

18. Stock access to waterways will increase stream bank erosion, sediment deposition, nutrient enrichment, pathogenic organism abundance in waterways, instream habitat destruction and, if riparian buffer zones are also open to stock access, the buffering ability of streamside vegetation will be undermined, greatly exacerbating the detrimental effects of land use activities.

19. As water runs downhill, management of small and ephemeral streams is critical to the management of larger downstream waterways and biodiversity. For that reason, protection and management also needs to be given to all ephemeral streams greater than 1 m, and all permanently flowing streams.

20. As aquatic ecological communities are complex ecosystems that are affected by multiple interacting stressors, the effects for ecological communities of specific

management practices that focus on controlling only one of these stressors (e.g., reductions in nitrogen loadings) is difficult to predict. Improvement in the ecological health of these waterbodies will require the management of all the interacting stressors, however, any reductions in nutrients, deposited sediment, faecal contamination, and restriction on stock access to waterbodies will result in an improvement from the current degraded state.

STREAM BIOLOGICAL COMMUNITIES

21. Periphyton is the algae (often only visible microscopically or as a coating of slime) that forms the basis of most stream and river food webs. Some periphyton is required as food for many aquatic invertebrates; however, too much algal growth can dramatically change the ecology and habitat conditions of a river.

22. Aquatic invertebrates consume this periphyton either directly (along with other organic sources) or by predating the smaller grazing invertebrates. The types of invertebrate present in a river will indicate the nature of the river habitat and to what extent it is affected by human activities. This is utilised by scientists to create indices (e.g., Macroinvertebrate Community Index, MCI) that measure the ecological health and/or water quality of a stream or river.

23. Native and sport fish eat these invertebrates. All of the biological components of a river food web require the correct habitat and water quality conditions in order to maintain healthy populations and functioning ecosystems.

24. The river ecosystem does not end at the water margin. Both as larvae within the river and as flying adults these invertebrates form an important dietary component for both aquatic (e.g., fish (McDowall, 1990) and terrestrial e.g., birds, spiders, bats (O`Donnell, 2004; Polis, Power & Huxel, 2004; Burdon & Harding, 2008)) food webs. Changes to the invertebrate and fish communities can potentially have significant widespread effects on ecosystem functioning both in the waterbody and within the wider catchment.

25. Apart from the effects of land use management practices on ecological health and water quality discussed below, the aquatic habitat is also intimately linked with the terrestrial riparian zone. The riparian zone provides suitable habitat for the adult stages

of many aquatic invertebrates (the in water life stage of many aquatic animals is the juvenile form with winged adults emerging from the water to mate and reproduce) (Collier & Scarsbrook, 2000; Collier & Winterbourn, 2000; Smith, Collier & Halliday, 2002; Smith & Collier, 2005). The riparian zone also provides instream habitat for fish (from overhanging vegetation), maintains and increases instream habitat diversity (natural character), and improves bank stability. Many fish species in New Zealand also use the riparian zone for egg laying (Charteris, Allibone & Death, 2003; McDowall & Charteris, 2006). Terrestrial insects and mammals from riparian zones often form a major component of the diet for many native and sport fish at certain times of the year (Main, 1988; McDowall, 1990). Thus riparian buffer zones also serve to maintain the proper ecological functioning of instream ecosystems.

STATE AND TRENDS IN REGIONAL WATER QUALITY

26. I support the evidence presented by Horizons scientists and expert witnesses on the current state of the water quality in waterbodies of the region (Roygard et al. Technical Expert Statement, 2012). As they highlight, the water quality of the region varies considerably from near pristine rivers and streams in much of the conservation estate (e.g., headwaters of the Pohangina River) to extremely polluted waterways in some agricultural (e.g., Kiwitea Stream and lower Mangatainoka River) and urban areas (e.g., Oroua River downstream of Feilding Sewage Treatment Plant). They provide evidence that many of the rivers and streams monitored in the Horizons Region do not meet the POP standards. This indicates the high level of degradation of these waterbodies NOT that the POP standards are particularly high. As discussed by Dr Ausseil, the POP standards were derived to represent ‘good’ or just ‘passable’ water quality, not ‘pristine’

27. Roygard et al. (Technical Expert Statement, 2012) in reviewing the frequency and occurrence of breaches of POP standards found that periphyton levels failed the POP standards at fewer sites than did MCI values. However, as periphyton levels fluctuate much more widely from day to day than the invertebrate communities in response to flow and temperature fluctuations, and given the time interval of monitoring is less for periphyton than MCI (13 years for MCI versus 4 years for periphyton), I would place

greater weight on the MCI findings in relation to exceedances. The periphyton exceedence results should not be considered in isolation.

28. Although the exact level of degradation at some individual sites could be an issue of debate amongst experts there seems to be universal agreement that the current state of many waterbodies in the Region could and should be improved.

29. There does appear to be some disagreement amongst experts on whether or not water quality in the Region is declining, improving or remaining constant depending on whether one considers the "short" term or "long" term view. I believe this debate is pointless. Although some believe the debate around water quality trends helps identify the cause of poor water quality, I believe this is a separate issue. Ecosystems respond at multiple spatial and temporal scales; there is no "correct" scale at which to consider their condition (O'Neill et al., 1986; Allen & Hoekstra, 1992) (Fig. 1). Irrespective, of how one looks at the trends in water quality it is clear that water quality could and should be improved in many streams and rivers of the Region. I concur with the view in the End of Hearing Report (Horizons staff) that "Aquatic ecosystems are influenced by state of water quality more than by trends" (p. 56 (Clapcott *et al.*, 2012).

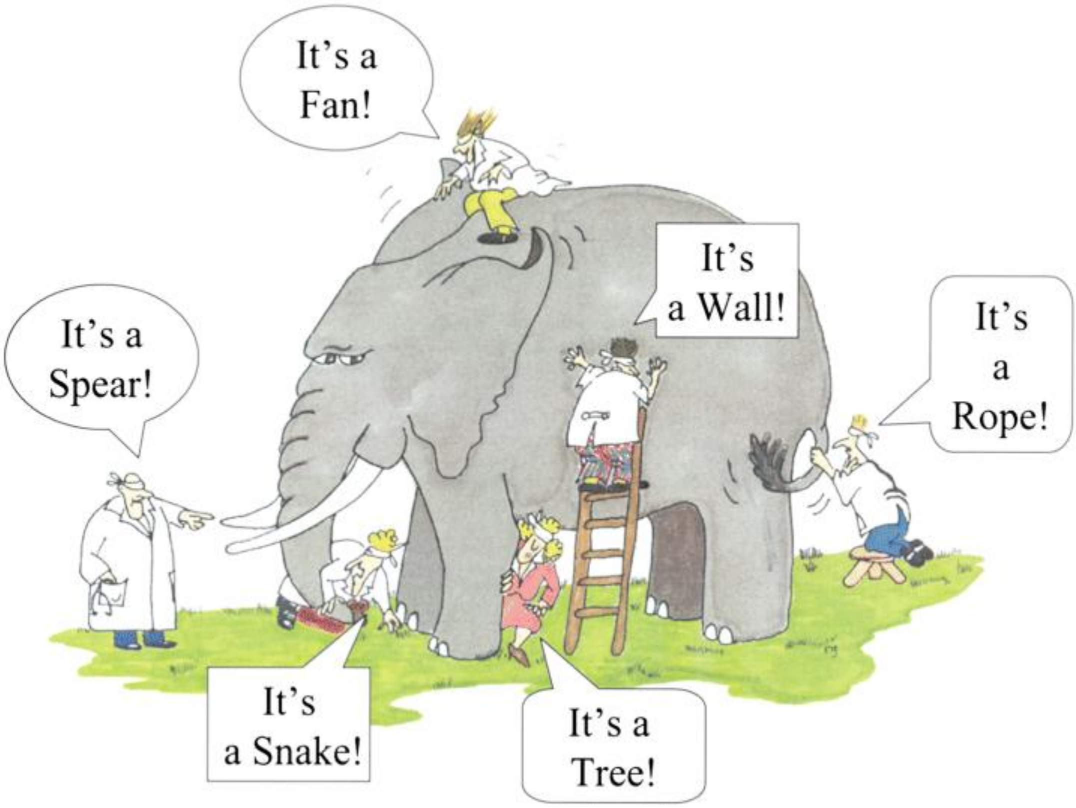

Figure 1 Illustration of how ecological scale can alter ones interpretation.

30. I agree with Dr Roygard's assessment of the four main issues for reduced water quality in waterbodies of the Region. These are 1. Sediment, water clarity; 2. Physicochemical characteristics (e.g., dissolved oxygen, pH, temperature); 3. Bacterial and/or faecal contamination and 4. Nutrient enrichment (e.g., nitrogen and phosphorus). Of these sedimentation and nutrient enrichment, are, I believe, the most important with respect to reduced ecological health of the Region's rivers and streams.

POTENTIAL CAUSES OF REDUCED WATER QUALITY/ ECOLOGICAL HEALTH

31. The principal candidates responsible for the decline in ecological condition of the Horizons Region waterbodies appear to be agriculture and urban sewage treatment discharge. Horticulture, forestry, and hydroelectricity generation have the potential to cause major degradation, but only affect a small proportion of waterbodies in the Horizons Region.

32. As an indication of how degraded many of the rivers in the region are, the Ministry for the Environment web site (http://www.mfe.govt.nz/environmental-reporting/freshwater/river/) presents data from NIWA monitoring of 77 rivers throughout New Zealand conducted in 2007. This data places the 3 monitoring sites on the Manawatu River amongst the lower decile of rivers in the country for a number of water quality / ecological health measures (Table 1).

Table 1. The ranking of water quality / ecological health measures for 3 NIWA monitoring sites on the Manawatu River in 2007 compared to other sites around New Zealand. 1= best site, 77 (or 66 for MCI) = worst site in New Zealand.

	Nitrate (mg/L)	**Total nitrogen (mg/L)**	**Dissolved reactive phosphorus (mg/L)**	**Total phosphorus (mg/L)**	***Escherichia coli* bacteria (n/100ml)**	**MCI (from 66 sites 2005 - 2007)**
Manawatu River at Weber Road	62/77	64/77	55/77	63/77	47/77	39/66
Manawatu River at Teachers College	66/77	60/77	51/77	49/77	40/77	62/66
Manawatu River at Opiki	68/77	71/77	69/77	73/77	37/77	65/66

33. There is a comprehensive body of scientific information dating from the 1970's (Hynes, 1975) that details how land use activities that occur in the catchment surrounding waterbodies have a major effect on the biological communities living in those waterbodies in New Zealand (e.g., Quinn *et al.*, 1997; Townsend *et al.*, 1997; Townsend & Riley, 1999; Quinn, 2000; Greenwood *et al.*, 2012) and mirror the findings elsewhere around the globe, reviewed by Allan, 2004.

34. Land use activities, often associated with agriculture, if not conducted appropriately can lead to a decline in ecological health of waterbodies that occur or flow through that land. This can include an excessive increase in periphyton (Fig. 2), a change in the chemical and physical characteristics of the habitat (e.g., pH, oxygen levels, substrate composition, deposited fine sediment), a change in the aquatic invertebrate communities from the preferred mayfly, stonefly and caddisfly dominated communities to worm, snail and midge dominated communities, and a loss of terrestrial inputs of invertebrates to aquatic food webs through riparian habitat destruction.

35. Changes in the aquatic invertebrate communities can cause significant impacts on the health of aquatic and terrestrial ecosystems. Both as larvae within the river, and as flying adults, these invertebrates form an important dietary component for both aquatic (e.g., fish (McDowall, 1990) and terrestrial (e.g., birds, spiders, bats (O`Donnell, 2004; Polis *et al.*, 2004; Burdon & Harding, 2008)) food webs. Changes to the invertebrate communities can potentially have significant widespread effects on ecosystem functioning both in the waterbody and within the wider catchment.

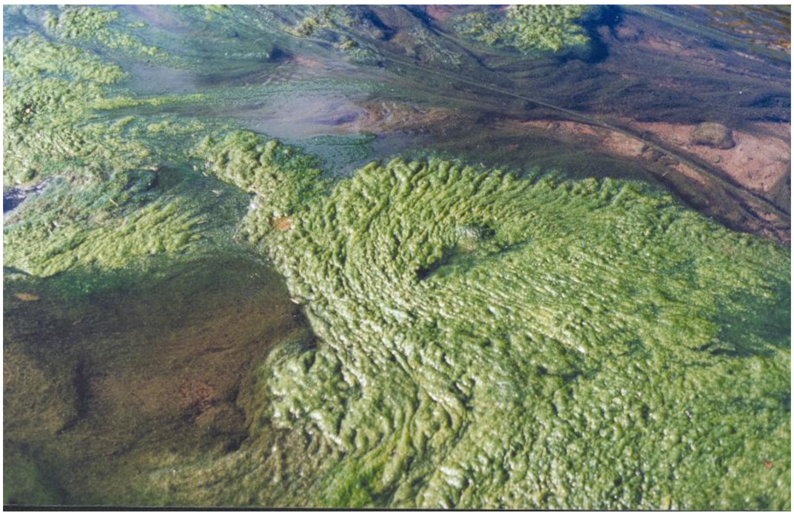

Figure 2. Excessive periphyton growth and smothered substrate.

36. These biological changes are a result of a few key driving factors that can occur with land use practices. These are: increased nutrient levels (nitrogen and phosphorous) from fertiliser use, direct and indirect inputs to surface water from livestock, and soil erosion; increased light and temperature levels from riparian forest removal, changes to hydrology, and instream habitat; and increased deposited sediment from land disturbance including cultivation, vegetation removal and livestock access to surface waterbodies and/or riparian margins which destabilise stream banks (Allan, 2004; Matthaei *et al.*, 2006; Townsend, Uhlmann & Matthaei, 2008).

37. To illustrate the effect of land use on waterbody ecological health, I have compared models of contemporary MCI (Macroinvertebrate Community Index) and MCI in the absence of land use (for details of the data and modelling approach see (Clapcott et al., 2011a; Clapcott et al., 2011b)). I have expressed the difference in MCI in the Horizons Region waterbodies as a percentage of what it would be in the absence of land use impacts and plotted it on a GIS (Geographic Information Systems) map (Fig. 4).

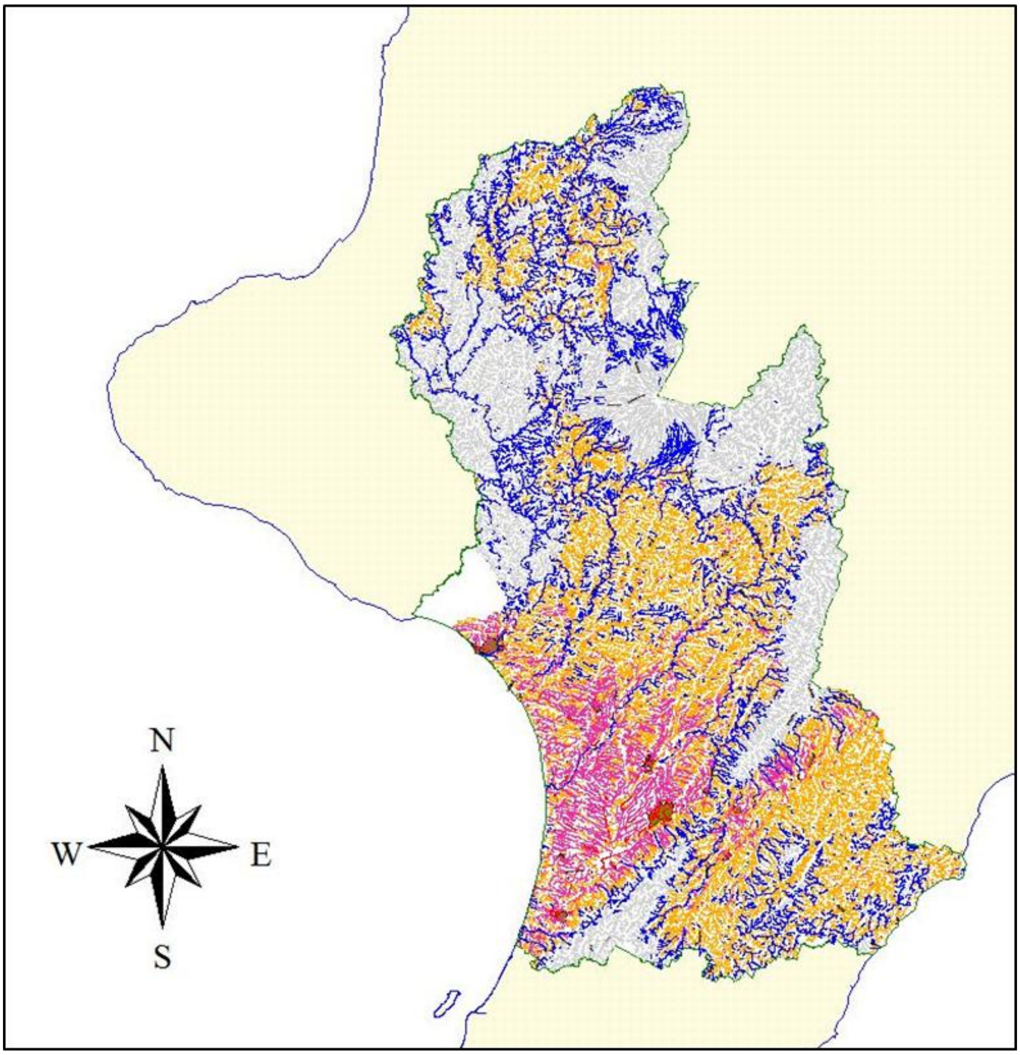

Figure 3.Percentage change in MCI with and without land use influences. Grey = -1 – 10% decrease, blue = 10 -20 % decrease, orange = 20-30 % decrease, pink = 30-40% decrease, red 40-50% decrease.

38. Given the large body of supporting studies demonstrating the detrimental effects of agriculture on waterbodies, my own observations and research in the Region's streams and rivers, and the evidence of Horizon's scientists and experts, it is, I believe, irrefutable that agriculture is having an adverse effect on many of the Region's waterbodies. Furthermore, I think there is strong evidence that many of the management options in the notified version of the POP, such as limiting or reducing nutrient and sediment inputs into waterways, will prevent any further degradation and lead to an improvement in ecological condition.

DEPOSITED SEDIMENT

39. From my studies and experience I would conclude that in general, nutrient enrichment and sedimentation are the two most pervasive and detrimental effects on water quality and ecological integrity on streams and rivers in the Horizons region.

40. The Proposed POP (POP) clearly identifies nutrients and *Escherichia coli* as issues of water quality. However, I believe they have overlooked an equally important detrimental influence on riverine ecological integrity in the form of sediment deposition. This appears to have been done because of a perception of a lack of scientific research on the link between sediment deposition and ecological integrity. However, I believe an equally rigorous approach could have been applied to sediment deposition standards as has been achieved for nutrients given the current status of our knowledge on the link between sediment and ecological integrity (Ryan, 1991; Waters, 1995; Matthaei *et al.*, 2006; Townsend *et al.*, 2008; Clapcott *et al.*, 2011b; Collins *et al.*, 2011).

41. Sedimentation is critically important for many of the values and objectives of the POP such as trout spawning and the protection of native fish communities. As a large proportion of the Horizons region (72.5%) is in agriculture, and much of this in highly erodible hill country, there is often a loss of productive soil to the streams and rivers of the region from activities like vegetation clearance and livestock access to waterways. It is therefore even more important in this region to manage land use practices than in many other regions in New Zealand. Avoiding the sediment issue runs a serious risk of not achieving many of the important goals of the POP. Along with specific regulatory and non-regulatory mechanisms to reduce sediment inputs from land use activities into waterways I believe this would be best dealt with by specific standards in schedule D for deposited sediment.

42. To illustrate the extent of the effect of land use in the Horizons Region on waterbody deposited sediment I have compared models of contemporary deposited sediment levels with those in the absence of land use (for details of the data and modelling approach see (Clapcott et al., 2011a; Clapcott et al., 2011b)). I have expressed the difference as a percentage of what it would be in the absence of land use impacts and plotted it on a GIS (Geographic Information Systems) map (Fig. 4).

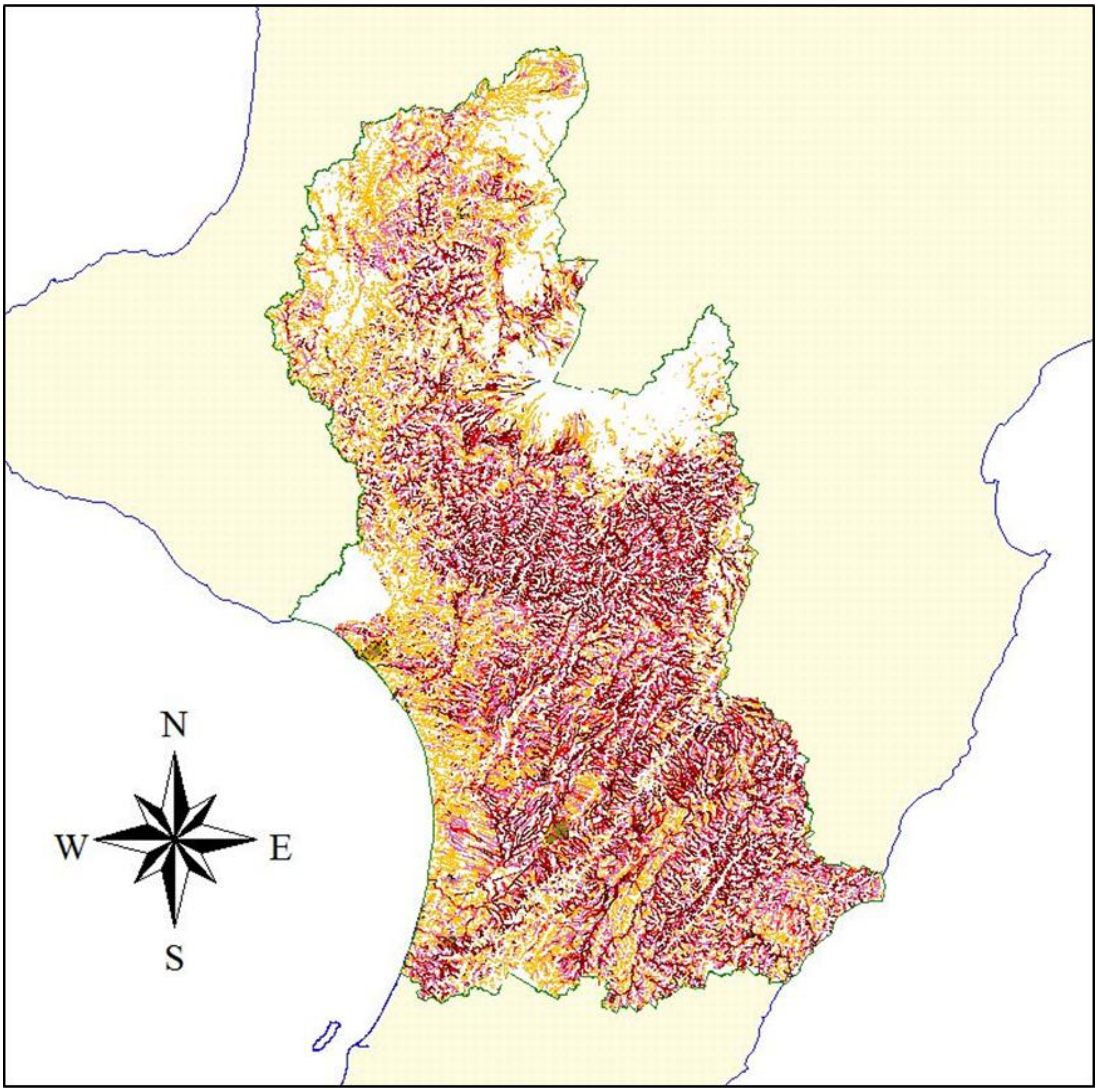

Figure 4. Percentage increase in stream deposited fine sediment with and without land use influences. Grey = -100 – 0% increase, orange = 100 - 500 % increase, pink = 500-1000 % increase, red = 1000-2000% increase, dark red greater than 2000% increase.

43. Figure 4 illustrates clearly the massive increases in deposited sediment (up to 2000% in some cases) in streams and rivers that have occurred as a result of land use change in the Region.

44. Deposited sediment can smother animals directly (Fig. 5A and 5B) and/or motivate them to leave. It can also smother and bind with the periphyton on rock surfaces that is the food for many aquatic invertebrates and lower the nutritional quality of this food. It fills in the interstitial spaces between rocks (Fig. 5C) where many of the fish and invertebrates live during the day (most are nocturnal) or during flood events. Stream invertebrates and many fish (e.g., eels) can live at least up to a metre under the stream bed if there are suitable interstitial spaces (Williams & Hynes, 1974; Stanford & Ward, 1988; Boulton *et al.*, 1997; McEwan, 2009).

Figure 5A. Koura struggling in deposited sediment.

Figure 4B.Banded kokopu struggling in deposited sediment.

Figure 5C. Stream substrate with interstitial spaces partly clogged with deposited sediment.

45. Sediment occurs as a natural component of many natural aquatic systems, which is transported as suspended sediment and bedload, mostly at times of high river flows and floods. Small particles, such as clay and silt, are generally transported in suspension, whereas larger particles, such as sand and gravel, usually roll or slide along the riverbed. However, erosion from land use activities greatly enhances sediment supply both during low and high flow events. Sediment levels during floods are considerably higher in agricultural catchments than similar catchments with native vegetation.

46. Increased levels of suspended and deposited sediment can have dramatic effects on stream ecosystems. Increased sediment loads can:

- smother natural benthos;
- reduce water clarity and increase turbidity;
- decrease primary production because of reduced light levels;
- decrease dissolved oxygen;
- cause changes to benthic fauna;
- kill fish;
- reduce resistance to disease;
- reduce growth rates; and
- impair spawning, and successful egg and alvein development.

(Ryan, 1991; Waters, 1995; Matthaei *et al.*, 2006; Townsend *et al.*, 2008; Clapcott *et al.*, 2011b; Collins *et al.*, 2011).

47. Trout can be especially sensitive to increased suspended and deposited sediment. They require cold, well oxygenated water with low sedimentation levels. This is especially important during the trout spawning period, where cold, well oxygenated water and gravels and minimal sedimentation are essential to spawning success and egg survival. Direct impacts include: mechanical abrasion to the body of the fish and more significantly its gill structures, death, reductions in growth rate, lowered resistance to disease, prevention of successful egg and larval development, and impediments to migration. Indirect impacts include: displacing macroinvertebrate communities that provide food, and reducing visual clarity so finding prey is more difficult (Peters, 1967; Acornley & Sear, 1999; Argent & Flebbe, 1999; Suttle *et al.*, 2004; Hartman & Hakala,

2006; Fudge *et al.*, 2008; Scheurer *et al.*, 2009; Sternecker & Geist, 2010; Collins *et al.*, 2011; Herbst *et al.*, 2012).

48. A number of fish species, particularly trout, are visual feeders, thus any increase in suspended sediment or corresponding reduction in water clarity reduces their ability to feed efficiently. The reduced water clarity results in visual feeding fish spending more time and energy foraging which in turn reduces growth rates, general heath, and causes potential reductions in reproductive fitness (Kragt, 2009).

49. Increases in suspended sediment have the potential to adversely affect macroinvertebrate communities. Reductions in water clarity can cause reductions in primary production, periphyton biomass and food quality. Invertebrate community composition may be altered as a result of sedimentation generally with a loss of stonefly and mayfly species, and an increase in chironomids and oligochaetes that can burry into silt. Sediment may also cause a reduction in dissolved oxygen by clogging substrate interstices leading to a reduction in gas exchange with more oxygenated surface water.

50. Data collected from streams and rivers in the Horizons Region indicates a clear decline in water quality as measured by the QMCI (Quantitative Macroinvertebrate Community Index) as the amount of deposited sediment increases (Fig. 6).

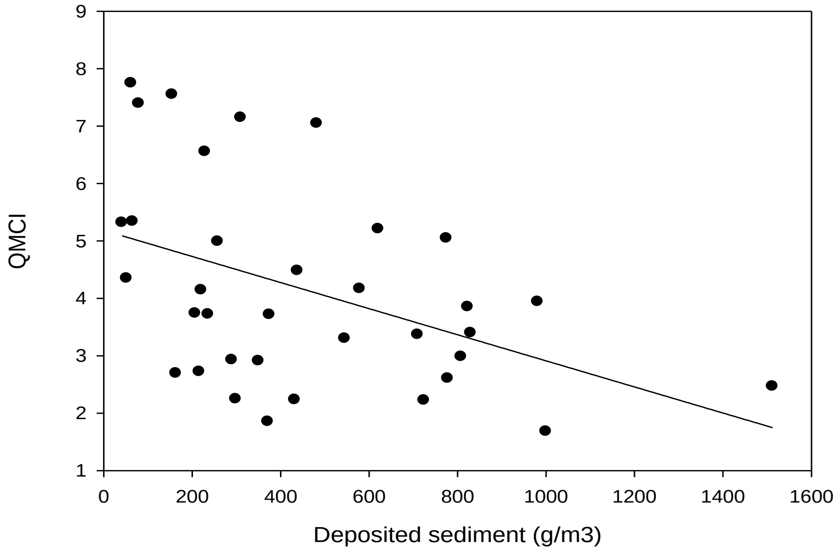

Figure 6. QMCI of invertebrate communities (higher the score more healthy the community) as a function of deposited sediment at 35 sites in the Horizons region.

51. These results (Fig. 6) are similar to those found in a national review commissioned by the Ministry for the Environment of the relationship between deposited sediment and stream ecological condition (Clapcott *et al.*, 2012).

52. Fish, such as salmonids, that lay their eggs in the substrate of the stream are also particularly sensitive to deposited sediment. The sediment can smother eggs directly or reduce oxygen levels in the area directly below the stream bed dramatically (Olsson & Persson, 1988; Crisp & Carling, 1989; Weaver & Fraley, 1993; Waters, 1995). Generally less than 10% sediment cover is considered good for trout spawning and none is optimal (Clapcott *et al.*, 2011b).

53. In light of these concerns and facts, Appendix 1 provides for a maximum deposited sediment level for streams and rivers in each water management zone (of, 15, 20 or 25%) in Schedule D for State of the Environment purposes. These limits would not apply to consented activities which could be dealt with on a case by case basis to ensure these activities do not lead to an increase in deposited sediment. Furthermore, under the Schedule, trout spawning sites would have a maximum allowable coverage of 10% deposited sediment and no measurable change in upstream/downstream deposited sediment levels. I support these levels.

Imposing a limit on the allowable water clarity reduction caused by a discharge is necessary to reduce the risk of increasing deposited sediment levels as suspended sediment eventually settles out. It is also important in its own right to protect the recreational, aesthetic, trout fishery, and native fish, values associated with surface waterbodies. I consider that a maximum water clarity change of 20 to 30% dependent on the geology of the river as defined in Schedule D is appropriate, and that this limit should apply year-round to protect the life supporting capacity of freshwater ecosystems. Also, the 20 – 30% change in visual clarity standard is the numerical equivalent to the narrative within s70 and s107 in the RMA (1991): "*no conspicuous change in colour or visual clarity*". I therefore consider reference to the change in visual clarity standard in Schedule D appropriate for permitted and controlled activities, as it addresses the issue of subjective assessments in regards to "*visual change*", and ensures that the effects of the activity in the freshwater environment are unlikely to be significant.

NUTRIENTS

54. Land use activities can also potentially contribute to the degradation of water quality and ecological condition in waterbodies through the run-off of nutrients. This can result in eutrophication (unnaturally high nutrient levels) that in turn can lead to excessive periphyton growth (Fig. 2). Nitrates and ammonia (NH_3) can also be directly toxic to many aquatic animals (Hickey & Martin, 2009). Nutrient toxicity is covered in more detail in the evidence of Dr Ausseil.

55. Agricultural land use practices contribute nutrients to waterways in a variety of ways. Application of fertiliser can inadvertently end up being applied directly into waterways or be washed into them during rain events. Livestock, if given access to waterways, have a preference for urinating and defecating directly into the waterway (Bagshaw, 2002; Davies-Colley *et al.*, 2004). Finally, land erosion from landslips, livestock trampling and wallowing, or cultivation too close to waterways, will deposit sediment into streams to which phosphorous is bound. This can subsequently dissolve into the water and become available for periphyton growth.

56. Excessive periphyton growths are not only aesthetically unappealing, but they can also result in dramatic changes to the biological communities in rivers and streams. They lead to a change from mayfly, stonefly and caddisfly dominated communities to ones with worms, snails and midges that do not support the same abundance, biomass or diversity of fish that the former communities do. The periphyton can also build up to such a biomass that the lower layers start to rot. This can dramatically reduce the oxygen levels and change the pH of the water making it unsuitable for many invertebrates and fish.

57. The change to habitat structure and quality (in particular pH and oxygen levels) as a result of excessive algal growth will result in fish emigrating, growing more slowly, being more susceptible to disease, or in the worst case dying. Large fish kills can be a result of reduced oxygen levels from excessive periphyton growth particularly on warm

summer days. Changes to the invertebrate fauna as a result of excessive periphyton growths have similar but slower effects on fish. The change often results in smaller prey items such that fish have to expend more energy to consume an individual prey item. This can result in slower grow rates, reduced condition, emigration or death (Hayes, Stark & Shearer, 2000).

58. Increased nutrient levels can also result in increased abundance and/or toxicity of cyanobacteria, such as *Phormidium,* which appears to be on the increase in the Horizons Region. Although the linkage between nutrient levels and *Phormidium* biomass and/or toxicity is not well understood (Wood & Young, 2011), a study by the Cawthron Institute found it was abundant in a number of rivers in the Horizons Region with high concentrations of toxins at two rivers (Mangatainoka and Mangawhero Rivers). They concluded it may pose a risk to drinking water supplies. They also concluded more research on the effects of the toxins for edible aquatic species (e.g., koura and trout) and potentially ecosystem health were warranted.

59. Dr Mike Joy and his research team at Massey University have also shown that juvenile native fish (*Galaxias* and *Gobiomorphus*) can detect the difference between water coming from high and low level nutrient waterbodies as they migrate upstream and actively avoid the high nutrient rivers altogether. Therefore elevated nutrient levels can act as a barrier to fish migration.

60. In general the two main nutrients that can result in excessive periphyton growth are nitrogen and phosphorous (Biggs, 1996; Dodds, Jones & Welch, 1998; Biggs, 2000; Death, Death & Ausseil, 2007).

61. The nutrient (N or P) that is limiting periphyton growth is the one that when added to a waterbody will result in an increase in periphyton biomass. To illustrate this you could consider a pot plant that needs light and water to grow; you can grow it in the best light possible, but if you do not water it then the plant will die. Water becomes the limiting resource because it is the scarcest resource; addition of any water (as long as the plant has not died) will result in the plant growing. Thus the resource (nutrient) that is at the lowest level in the waterbody is the one that can have the biggest impact. Management of that nutrient will therefore have the biggest effect on controlling periphyton growth in a waterbody.

62. The molar ratio of N to P in the water, termed the Redfield ratio (Redfield, 1958), has been suggested as a benchmark for assessing nutrient limitation. Ratios greater than 20:1 are considered P-limited, those less than 10:1 are N-limited and for values between 10 and 20 to 1 the distinction is not clear (Schanz & Juon, 1983; Borchardt, 1996). McArthur, Roygard & Clark (2010) used Redfield ratios to show there is considerable spatial and temporal variation in the indicated limiting nutrient.

63. There is experimental support for (Grimm & Fisher, 1986; Peterson *et al.*, 1993) and against (Francoeur *et al.*, 1999; Wold & Hershey, 1999; Francoeur, 2001) such ratios being indicative of actual nutrient limitation. A more effective alternative for assessing which nutrient is limiting is the deployment of nutrient diffusing substrates (Hauer & Lamberti, 1996; Biggs & Kilroy, 2000). Death *et al.* (2007) using nutrient diffusing substrates found nitrogen to be the limiting nutrient in summer at a number of sites in the Rangitikei River catchment.

64. Integrating this information on potential limiting nutrients and periphyton growth the conclusion is that without site and season specific studies both N and P can be potentially limiting nutrients throughout the waterbodies in the Region (Wilcock *et al.*, 2007; Kilroy, Biggs & Death, 2008). I support the evidence of Dr Biggs, and Dr Ausseil (paras 4.2 – 4.9) on this topic, and agree that appropriate management should be focussed on managing both nutrients, not just one or the other.

65. I have been studying nutrients, periphyton and invertebrate communities in 24 streams and rivers in the Manawatu over the last few years (Fig. 7).

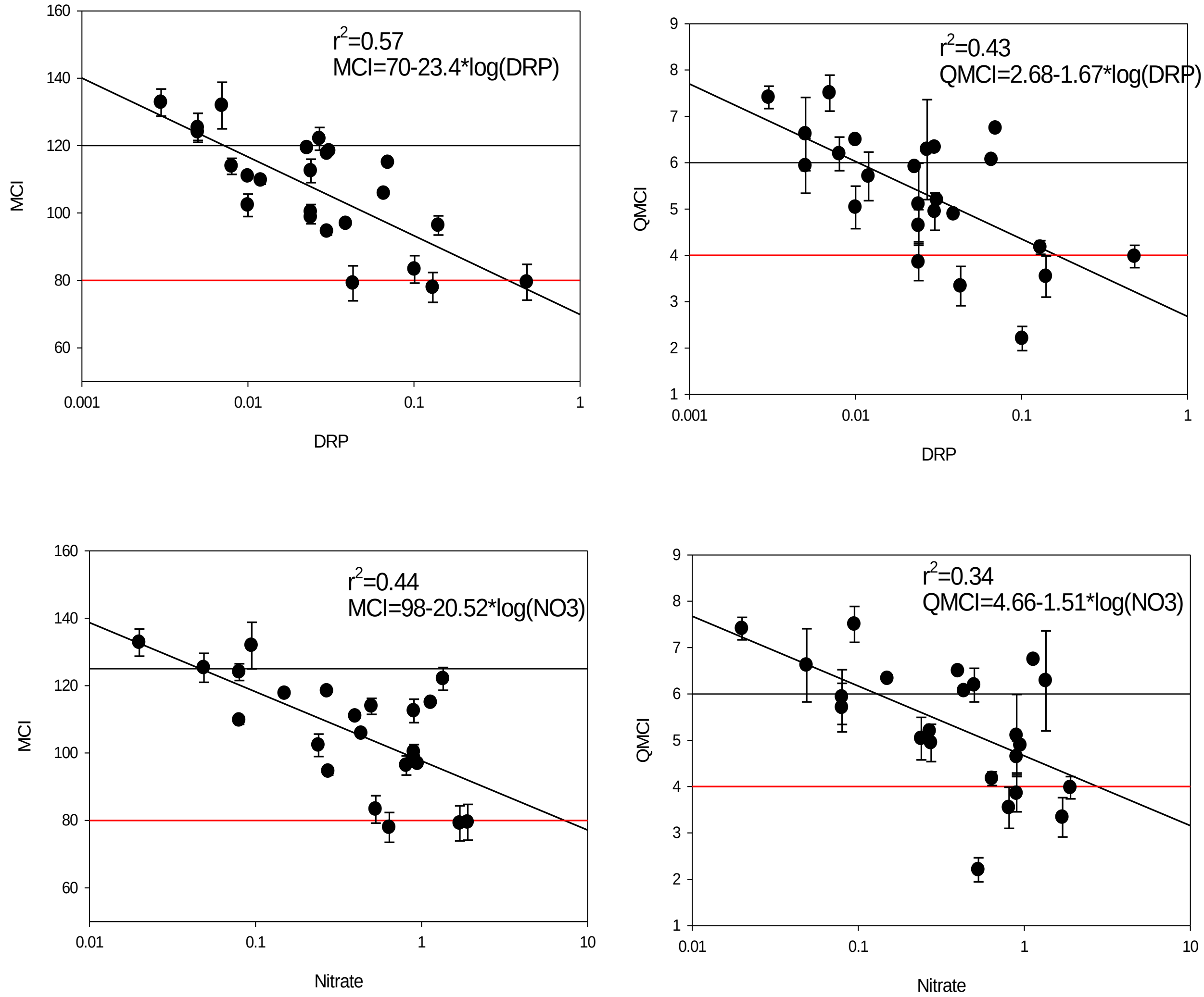

Figure 7. Water quality measured as MCI and QMCI from 24 streams plotted against mean nitrate and dissolved reactive phosphorous levels.

66. From the equations derived from these local streams (in contrast to most of the data used by Dr Biggs which was collected nationally) the data yields DRP thresholds of 0.007-0.01 g/m^3 and for Nitrate thresholds of 0.08 – 0.13 g/m^3 to maintain good water quality. These are broadly similar to the POP Schedule D standards for the upper Manawatu. Thus, while I have concerns about the application of nationally derived data to generate local water quality standards, I think Horizons and their experts have proposed appropriate levels for the standards in the plan that have been, to some degree, independently validated with my research in this region. I therefore consider that the management of activities that can impact water quality (including land use

activities) should be linked to the achievement of the standards in Schedule D in order to manage any potential effects on freshwater ecosystems.

NATIVE FRESHWATER FISH

67. Dr Mike Joy at Massey University (Joy, 2009) has reviewed data from 22,546 sites in the New Zealand Freshwater Fish Database between 2000 and 2007 to evaluate the state of freshwater fish in New Zealand. To allow for the strong elevational gradients in New Zealand Freshwater Fish he used an Index of Biotic Integrity (Joy & Death, 2004a) with higher scores indicative of healthier fish communities.

68. He found sites draining catchments of native vegetation had significantly higher scores and more species than those in pasture or urban sites (Fig. 8) He also found an overall significant decline in IBI scores over the 37 year period with greater declines in pasture, urban and tussock sites.

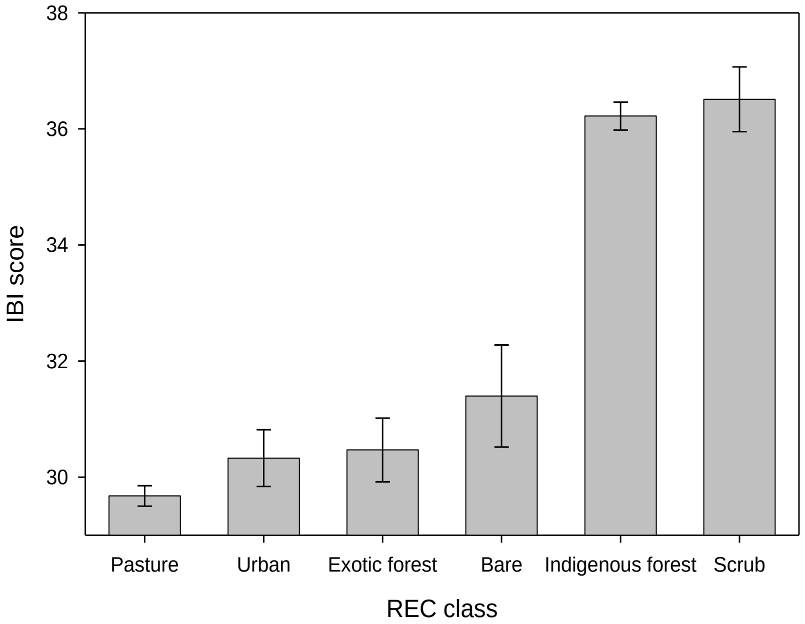

Figure 8. Mean IBI score (±1 SE) for all sites grouped by River Environment landcover class (Joy 2009).

69. He did not specifically investigate what factors associated with pastoral land use were directly responsible for the observed decline in native fish communities and

biodiversity, but numerous other research investigations has shown New Zealand native fish are affected by the same environmental changes highlighted in the above sections (McDowall, 1990; Joy, 2000; McDowall & Taylor, 2000; Joy & Death, 2002; Joy & Death, 2003a; Joy & Death, 2004a; McIntosh & McDowall, 2004; Eikaas, Kliskey & McIntosh, 2005; McEwan & Joy, 2009; Clapcott *et al.*, 2012). In particular increased deposited sediment, eutrophication (increased nutrient levels), reduction in instream habitat diversity, changes in invertebrate food communities, and severing of the linkage with the riparian zone has been shown to result in significant declines in native fish communities and biodiversity.

70. In the Horizons Region many fish surveys by ourselves at Massey University and other institutions have shown gaps in the spatial distribution of a number of sensitive native fish species in particular areas of Manawatu Catchment. Extensive searches of the Oroua River, Pohangina River and upper Manawatu River above the Gorge in the last 15 years have failed to reveal any migratory galaxiid species (adult whitebait - banded kokopu, short jaw kokopu and koaro) or redfin bullies (Joy, 1999; Joy, 2003; Joy & Death, 2003b; Joy & Death, 2004b; Joy & Death, 2004a). Although I believe Horizons and Department of Conservation staff have found one or two individuals of these species in these rivers in recent years. Redfin bullies are a migratory species known to be sensitive to anthropogenic disturbance from agricultural land use (Joy & Death, 2004a).

71. To examine these patterns Dr Mike Joy and myself have constructed a spatially and numerically predictive model of fish community distribution (Joy & Death, 2004b). This was constructed for the entire North Island of New Zealand with the Manawatu catchment data excluded. For model construction data from the Manawatu catchment was excluded so that it wouldn't effect prediction when subsequently applied to the Manawatu catchment. This predictive model was optimised and validated and then used to predict the distribution of fish in the Manawatu Catchment allowing comparison with the actual present distribution of fish. Effectively this comparison allows for an objective assessment of where fish would be distributed based on habitat suitability (Fig. 9).

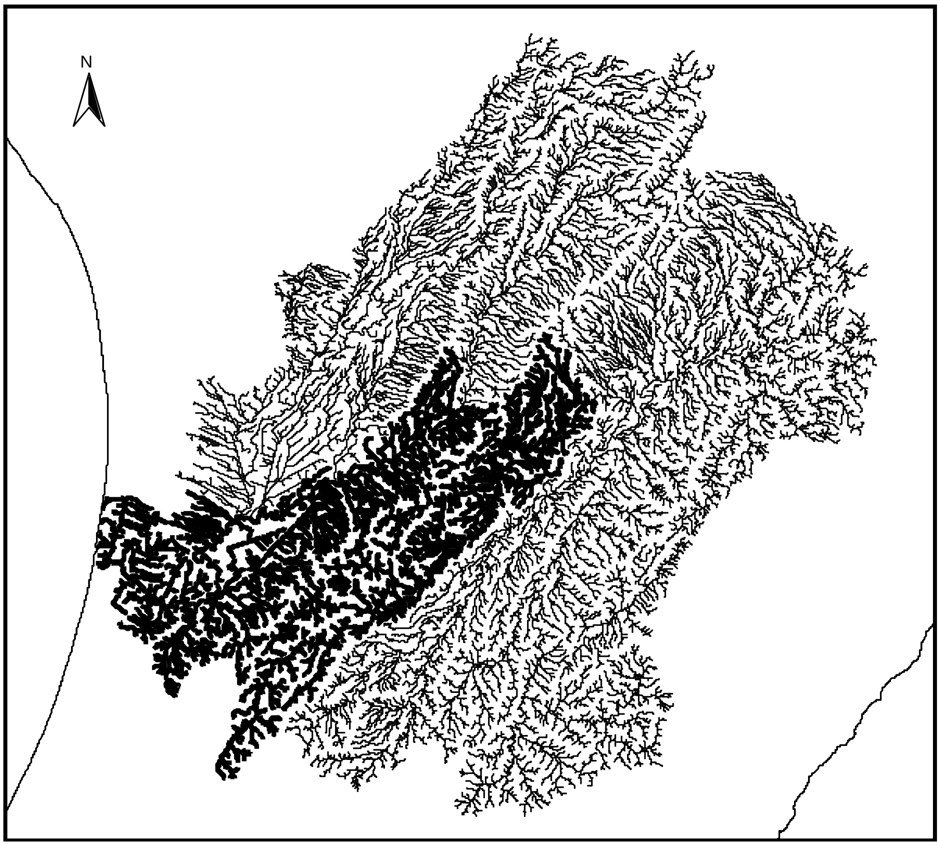

Figure 9. The Manawatu River Catchments, dark lines indicate waterways where sensitive fish species (koaro, banded kokopu, short jaw kokopu or redfin bullies) occur or would have to traverse to get to where they occur.

72. The Manawatu fish distribution model was then used to calculate the length of waterway the fish should occur at if the conditions were the same as the rest of the North Island by multiplying the probability of occurrence from the model by the length of waterway to give a currency for comparison. Next the actual lengths of waterway where fish species actually occur were calculated and the differences for each species between observed and expected distributions were calculated.

73. There was no difference in the predicted and actual distribution of short jaw kokopu as they were not predicted to be in any of the tributaries they are absent from (Table 2). However, the other three species showed a significant lack of congruence between observed and expected distribution. Banded kokopu and Redfin bullies were absent from half of their predicted habitat and the koaro is absent from 84% of the habitat it should occur at.

Table 2. The length of the Manawatu River each of four sensitive native fish species were predicted to occur at using a model using the rest of the North Island, and the actual length of river where they are now found.

Habitat loss	*Koaro*	*Banded kokopu*	*Short jaw kokopu*	*Redfin bully*
Length of ManawatuRiver fish should occur at	975km	537km	14km	690km
Length of ManawatuRiver fish actually occurs at	156km	279km	14km	327km
Proportion of habitat lost	84%	48%	0%	53%

74. This clearly shows how some native fish distributions have been severely constricted by land use activities. However, they still retain the potential to recolonize areas (via their larval whitebait stage), from which they previously inhabited if land use can be managed to ameliorate some of its adverse effects such as high nutrient and deposited sediment levels.

SUBMITTER TECHNICAL EVIDENCE PUT FORWARD AT COUNCIL LEVEL HEARINGS

75. My principal area of concern here is the assertion in the evidence of Dr Scarsbrook that short-term improvements in water quality at some assessment sites indicate agricultural impacts on water quality are not as severe as thought. Dr Roygard, Ms McArthur (End of Hearing Report), Mr McBride (Hearing Evidence), and my own Hearing Evidence all provide extensive counter arguments to this assertion.

There is extensive data and research from this region, elsewhere in New Zealand and internationally that agriculture, if not managed appropriately, results in significant declines in water quality and waterbody ecological health.

STANDARDS FOR THE REDUCTION IN QMCI AS A RESULT OF POINT SOURCE DISCHARGES

76. I do not believe there is any scientific justification for adopting a 20% change in QMCI as the trigger for an effect over a statistically significant change.

77. There are a number of reasons for this:

- The 20 % threshold is arbitrary.
- No scientific study would be accepted if the scientists use an arbitrary effect size rather than statistical significance from an appropriate statistical test. Is environmental assessment not science?
- The requirement for statistical significance ensures, by default, consultants use replicates.
- Opponents to the use of statistical significance claim that situations may occur where statistical significance occurs but ecologically significant change does not. While I agree in theory this can occur, in twenty years of practical ecology and reviewing an extensive number of scientific articles submitted to a wide range of international journals I have never encountered this situation. Furthermore, in my actual evaluation of point source discharges for resource consent compliance requirements in this Region I have never encountered this situation.
- Apart from the arbitrariness of this standard, my primary concern with the 20% change threshold is that as the QMCI increases in size with water quality the 20% change threshold allows for more degradation in water quality at more pristine sites. For example high water quality such as a 20% change in the QMCI=7.0 would be a 1.4 unit change as opposed to a low water quality site where a 20% of QMCI=4.00 would be only 0.8 units change. Thus by default you are allowing more degradation in more pristine streams (in the example nearly twice as much degradation) which is counter to what I would think best management would be aiming for. Another example using the land use QMCI relationship from Death & Collier (2010) indicates a 20% reduction in QMCI from 7 to 5.6 would be equivalent to a 52% reduction in native vegetation in a catchment.

78. I have read the evidence of Ms McArthur and supplementary evidence of Dr Stark but still do not see any justification for a percentile effect size (as opposed to statistical significance) that will allow greater degradation of more pristine waterbodies.

79. Thus I recommend the following words replace the 20% Quantitative Macroinvertebrate Community Index (QMCI).“There must be no statistically significant decrease (P<0.05) in mean Quantitative Macroinvertebrate Community Index (QMCI) score between appropriately matched habitats upstream and downstream of discharges to water”.

IMPACTS OF NON POINT SOURCE VERSUS POINT SOURCE POLLUTION IN THE RANGITIKEI RIVER

Macroinvertebrate Community Health

80. The ecological health (MCI) of the Rangitikei River declines as you move further down the catchment (Fig. 8) potentially as a result of the cumulative effects of increasing agricultural landuse. Inputs of sewage from Taihape (via the Hautapu River) and Bulls do not indicate any dramatic effects on water quality of the main stem or tributaries (Fig. 12). However, the sewage from Hunterville (via the Porewa Stream) and Marton (via the Tutaenui Stream) do seem to result in a decline in water quality.

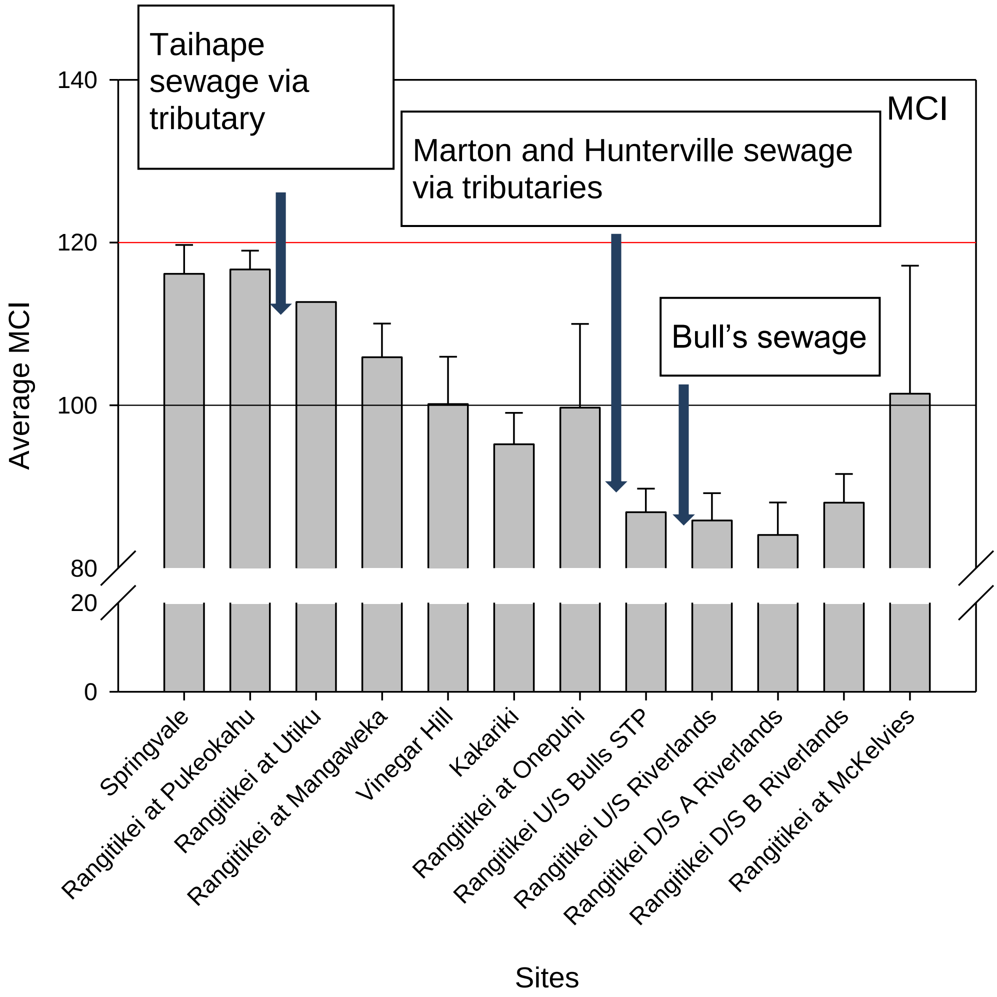

Figure 8. Average MCI (± 1 SE) at sites along the Rangitikei River. Red line is POP standard above Onepuhi; black line POP standard for lower Rangitikei. Data is from Horizons State of the Environment and Resource Consents monitoring.

81. Note that although Springvale is the highest monitoring site on the Rangitikei there is still around 15% of the catchment in agriculture at this point along the river. The more pristine headwaters, where MCI values will exceed 120, are not monitored because of access difficulties.

82. Roygard et al in their joint technical expert statement (page 5045 – 5047) also highlight that none of Horizons monitoring sites in the Rangitikei catchment meet the POP standards for MCI.

83. Not meeting the MCI POP standards indicates water quality and ecological health is compromised below the minimum acceptable limit for this kind of water body under best land use practice. This in turn is indicative that habitat and food resources for

introduced and native fish are also compromised below acceptable levels i.e., that there are significant adverse effects on ecological functioning of these ecosystems.

Periphyton

84. Periphyton biomass remains low until Bulls (Fig. 9), when levels increase upstream from the town and sewage discharge. Below Bulls, periphyton levels are elevated in comparison with levels above Bulls, and on occasion breach the POP standards as discussed in the technical evidence of Roygard et al (2012, pages 5048 – 5052). However, these breaches occurred on only a small proportion of the monitoring occasions (4-5 out of 35). On average, periphyton biomass levels continue to meet the POP standards.

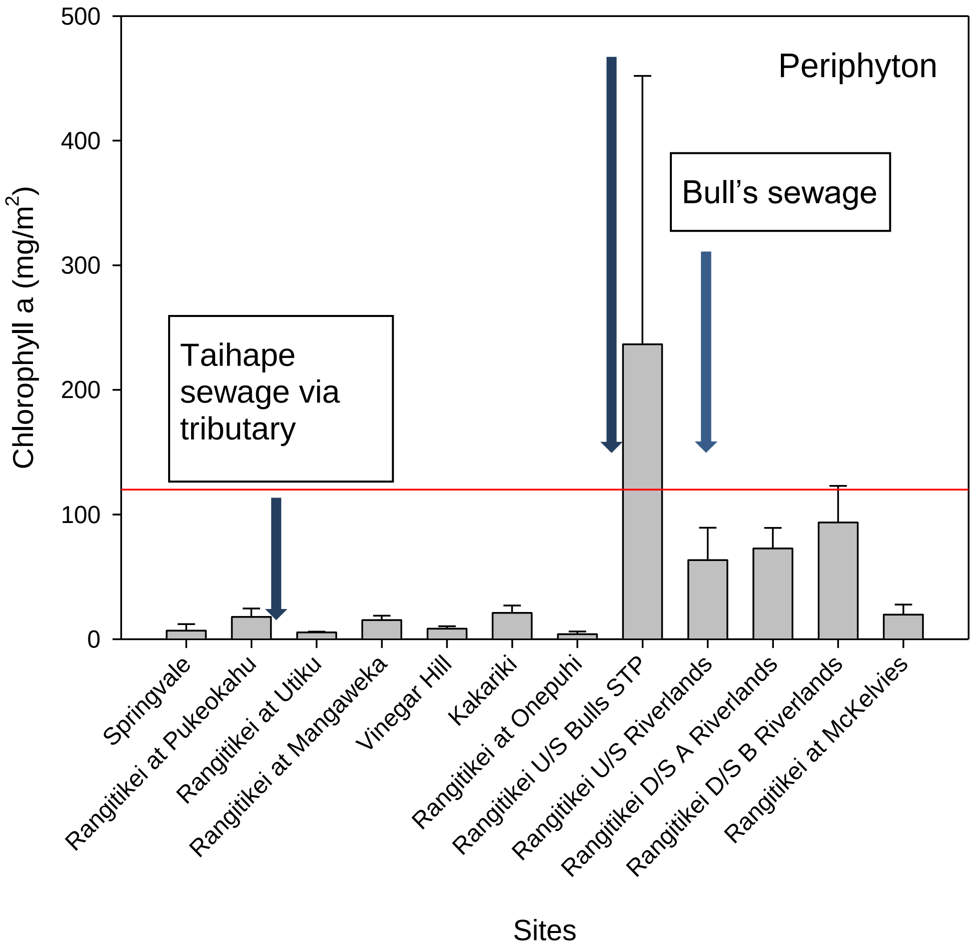

Figure 9.Average periphyton biomass (± 1 SE) (measured as chlorophyll a) at sites along the Rangitikei River. Red line is the POP standard. Data is from Horizons State of the Environment and Resource Consents monitoring.

85. Monitoring of some of the tributaries of the Rangitikei River (Hautapu River, Porewa Stream, and Tutaenui Stream) indicate that their life-supporting capacity is significantly adversely impacted, with ecological health being well below their respective Schedule D standards. These tributaries are in a far worse ecological condition than equivalent streams in the Manawatu catchment. Ecological health in these tributaries is affected more by non-point source influences than the sewage discharges that are monitored (Fig. 10).

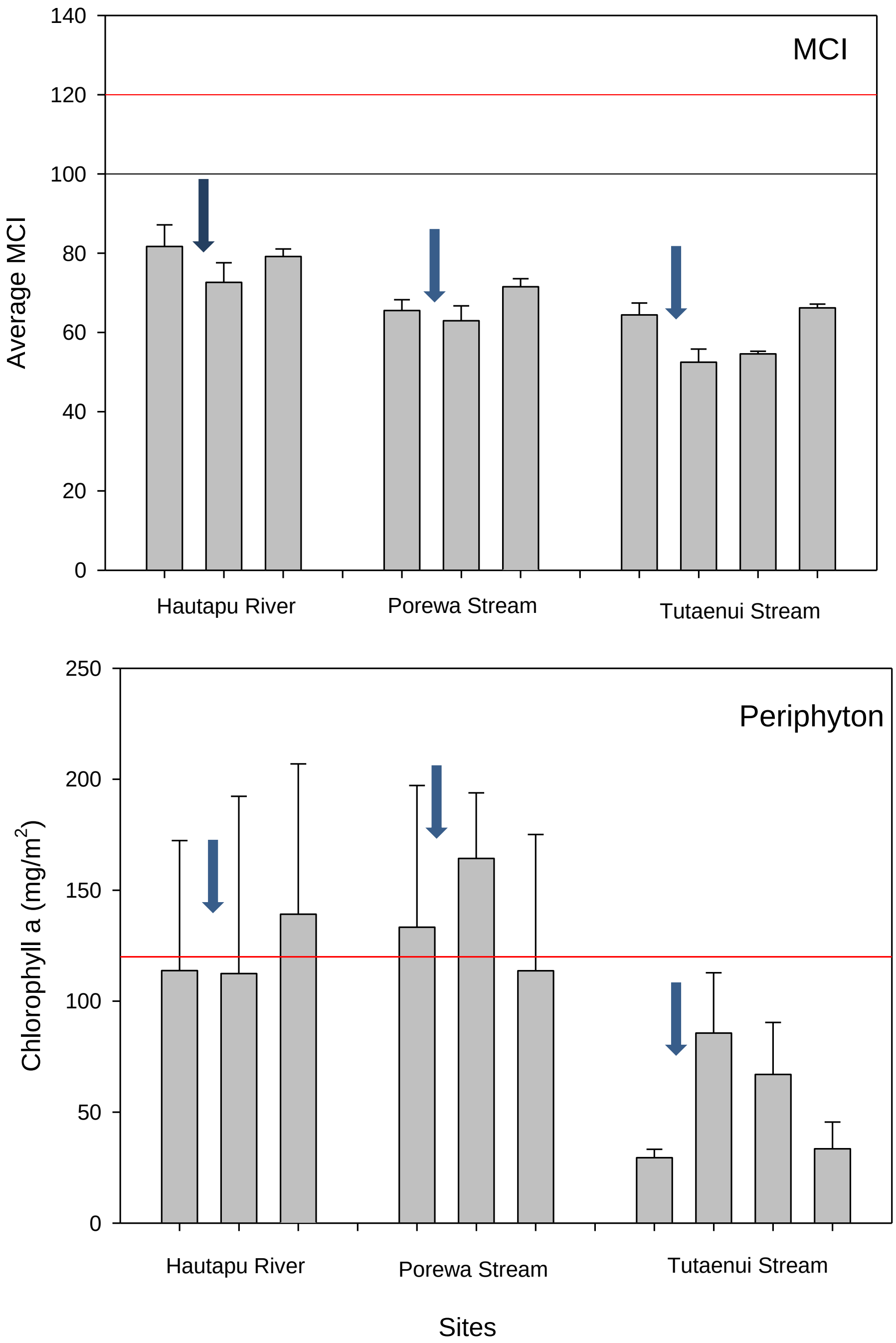

Figure 10. Average MCI and periphyton biomass (± 1 SE) (measured as chlorophyll a) in tributaries of the Rangitikei River. Samples have been collected upstream (indicated by arrow) and at two (or in the case of Tutaenui Stream three) sites downstream of town sewage discharges. In MCI graph red line is POP standard above Onepuhi; black line POP standard for lower Rangitikei. In periphyton graph red line is the POP standard. Data is from Horizons Resource Consents monitoring.

86. Both the MCI, and to a lesser extent periphyton biomass, indicate water quality and ecological health in the Rangitikei River is moderate even as far upstream as Springvale. Both water quality and ecological health decline as one moves downstream, predominantly as a result of the cumulative effects of land use activities but also to a lesser extent due to town sewage treatment plant (STP) discharges. Together these agricultural and STP cumulative effects result in a more dramatic decline in water quality around and downstream from the township of Bulls. Many of the tributary streams and rivers, are significantly degraded, so that their life-supporting capacity is compromised, predominantly as a result of agricultural land use in the upstream catchment.

87. Much of the Rangitikei River could be considered of only moderate ecological health. Failure to meet the POP standards for macroinvertebrate health indicates impaired life-supporting capacity, which will impact on the values identified for the river e.g., trout fishery value. While the mainstem may meet on average periphyton biomass standards, and water quality standards as discussed by Dr Ausseil (2012), the river clearly could not assimilate any increased detrimental effects that may result from unmanaged increases in agricultural intensification or less environmentally focused agricultural practises. Many of the tributaries are well below the POP Schedule D standards. Further degradation of the waterways in the catchment is likely to result from any intensification or on-going poor agriculture practice.

The Coastal Rangitikei catchment should therefore be included as a Target catchment in the POP as notified. Furthermore, I would strongly recommend that the middle and lower Rangitikei water management zones (Rang_2 and Rang_3 as described in the POP) be included as target catchments and that not only intensive but extensive agriculture land use be managed to control cumulative impacts on the ecological health of the Rangitikei river.

IMPACTS OF STOCK ON ECOSYSTEM HEALTH

88. Riparian buffer zones can range from a simple strip of vegetation from which livestock or other agricultural activities are excluded to a completely vegetated native forest riparian strip. The principal effect of the riparian buffer is to act as a barrier to nutrients,

sediment, pathogens and other potential contaminants running off the land and to prevent it entering the waterway and consequently flowing downstream to lakes and estuaries. It will also stabilise stream banks and limit erosion and undercutting. The vegetation can also take up some of the nutrients. If a forested riparian zone exists this can also serve to limit light reaching the stream bed (which can also exacerbate periphyton growth) and water temperature (most aquatic animals have an upper threshold for survival which can be comparatively low, e.g., 19°C for stoneflies).

89. The riparian buffer zone can also provide suitable habitat for the adult stages of many aquatic invertebrates (the in water life stage of many aquatic animals is the juvenile form with winged adults emerging from the water to mate and reproduce) (Collier & Scarsbrook, 2000; Collier & Winterbourn, 2000; Smith *et al.*, 2002; Smith & Collier, 2005). Terrestrial insects and mammals from riparian zones often form a major component of the diet for many native and sport fish at certain times of the year (Main, 1988; McDowall, 1990). Thus riparian buffer zones also serve to maintain the proper ecological functioning of instream ecosystems.

90. Riparian buffer zones, particularly those with forested vegetation, are also important for providing instream habitat for native fish and trout by enhancing habitat diversity (e.g., overhanging branches, bank under cutting), creating pools and areas of day time and flood refuge. Grassy or forested river banks and lake shores also provide spawning habitat for Inanga and other Galaxias species, respectively. Thus riparian buffer zones also serve to maintain the proper ecological functioning of instream and lake ecosystems.

91. Livestock access to waterways results in the loss or destruction of the riparian buffer zone, significantly compromising its ecological function (Osborne & Kovacic, 1993; Quinn, Cooper & Williamson, 1993; Davies & Nelson, 1994; Weigel *et al.*, 2000; Kiffney, Richardson & Bull, 2003; Parkyn *et al.*, 2003; Yuan, Bingner & Locke, 2009; Weller, Baker & Jordan, 2011). Cattle and dairy cows, if given access to waterways, have a preference (in one study up to 50 times greater) for urinating and defecating directly into the waterway that will contribute to elevated levels of nitrogen and microbial contaminates (Bagshaw, 2002; Davies-Colley *et al.*, 2004). Livestock (principally cattle, dairy cows and deer) trampling (Fig. 11 A and 11 B) and wallowing can result in sediment deposition into streams, rivers and lakes. This can result in

increased levels of deposited fine sediment with the direct detrimental ecological effects highlighted above. Phosphorous is also bound to the sediment and this can subsequently dissolve into the water and become available for periphyton growth. Finally livestock grazing will remove or degrade any riparian vegetation that might provide stream cover (to reduce light and temperature), stablise banks, and provide habitat for aquatic and terrestrial invertebrates which are part of the aquatic food web, along with instream and lake habitat for fish.

Figure 11 A Stock damage to stream (Photos courtesy Kate McArthur, Horizons Regional Council)

Figure 11 B Stock damage to streams (Photos courtesy Kate McArthur, Horizons Regional Council)

92. In the only published study of pathogenic organisms in New Zealand waterways I am aware of (McBride *et al.*, 2002), catchments classed as dairy were the second most contaminated (after bird catchments) with pathogenic microorganisms. Contamination of water bodies by pathogenic organisms such as bacteria (e.g.,*Escherichia coli*), viruses (e.g., norovirus) and protozoa (e.g.,Giardia and Cryptosporidium) from stock and other sources can be reduced by riparian buffer strips and denying stock direct access to streams (Winkworth, Matthaei & Townsend, 2008b; Winkworth, Matthaei & Townsend, 2008a; Winkworth, Matthaei & Townsend, 2010). For example Winkworth *et al.*, 2008b found a 26% reduction in Giardia flowing into waterways when planted riparian buffers are present, and this reduction was greater with native versus exotic vegetation (Winkworth *et al.*, 2010).

93. Riparian buffer setbacks from land use activities will assist with managing both sediment and nutrients and promote ecological health. In establishing the appropriate width of riparian buffer zones consideration must be given to surrounding land use activity, soil type and catchment slope, and the goals of the set back (e.g., ecological health versus limiting contaminant runoff). Even in situations where it may not be

possible to have riparian setbacks then exclusion of stock from those waterways would be the best alternative for attempting to manage waterway ecological health.

SMALL AND EPHEMERAL STREAMS

94. Considerable focus in water quality management in agricultural land focuses on larger waterbodies. For example the Clean Stream's Accord refers to streams that are "larger than a stride and deeper than a red-band". Assuming this description only applies to third order or greater streams this would exclude at least 6,000 km of stream length in the Manawatu catchment alone (I measured only that on 1:50,000 topographic maps) from any management (Fig. 12).

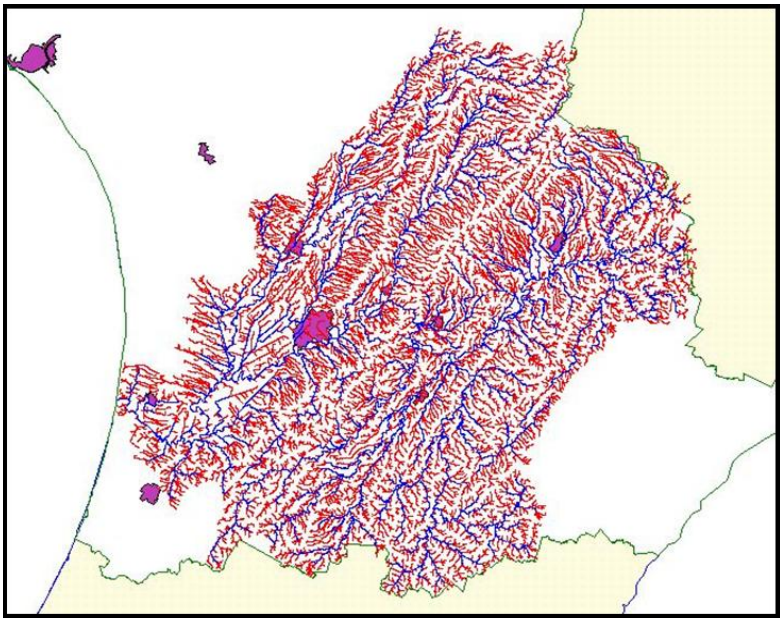

Figure 12.Small streams (in red) and other streams (~ greater than a stride and deeper than a red band) in blue for the Manawatu catchment.

95. As water runs downhill if these streams are not managed/protected then the sediment and nutrients entering them will flow down into the larger streams. A variety of studies have shown that riparian management of water bodies is strongly affected by the condition of the upstream environment (Storey & Cowley, 1997; Scarsbrook & Halliday, 1999; Parkyn *et al.*, 2003; Death & Collier, 2010).

96. Furthermore recent research has found that both small (Heino *et al.*, 2003; Clarke *et al.*, 2008; Clarke *et al.*, 2010) and ephemeral (Storey & Quinn, 2008) streams can have very high biodiversity, often greater than in larger streams. Figure 12 below show that, for 960 streams and rivers sampled in the lower North Island, that the highest diversity occurs in the smaller streams.

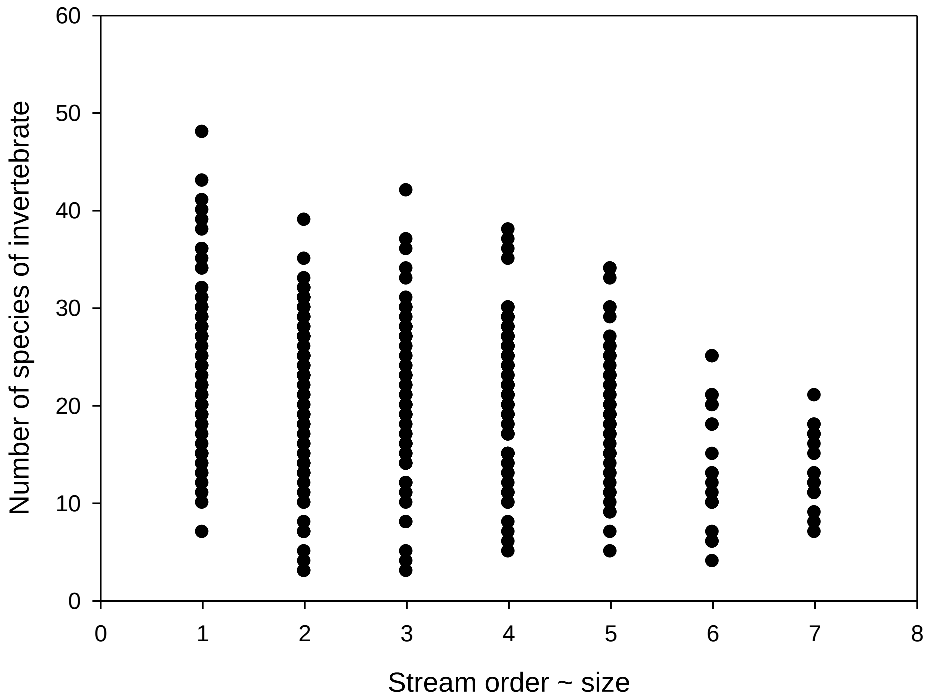

Figure 12.Number of taxa collected in 5 Surber samples in 960 streams and rivers in the lower North Island as a function of stream order (this provides a good approximation to stream size as higher order streams are larger).

97. Equivalent protection and management needs to be given to all ephemeral streams greater than 1 m and all permanently flowing streams.

OUTCOMES OF INTENSIVE FARMING MANAGEMENT SCENARIOS

98. Alternative farming management scenarios are presented in the expert evidence of Dr Roygard et al. (2012) and Dr Aussiel (2012), identifying resulting changes in Nitrogen loads from these scenarios. The scenarios show that imposing either the year 1 LUC

nitrogen leaching limits (dependent on the assumptions), or year 20 LUC nitrogen leaching limits, will halt the decline in water quality in regards to instream nitrogen loads, and result in an improvement of water quality.

99. Translating the alternative farming management scenarios discussed by Dr Roygard and Dr Ausseil in their evidence into outcomes with respect to improvements or declines in ecological health of the receiving waterbodies is extremely difficult. These management scenarios evaluate the outcomes for nitrogen loads only. As I have discussed above, instream ecological health is a result of a combination of nutrient levels (both nitrogen and phosphorous), deposited sediment, water quantity and flow pattern (particularly flushing flows, i.e., those that remove periphyton) and habitat quality (Death, Dewson & James, 2009; Death & Collier, 2010; Clapcott *et al.*, 2012).

100. There is a considerable body of evidence that declines in the quality of these environmental drivers result in reduced ecological health. Yet, there is considerably less study on how these factors interact and what effect the reduction in one variable (e.g., nitrogen) may have if none of the other parameters change (Townsend *et al.*, 2008). It is therefore impossible to say if nitrogen loads reduce by 4% there will be a certain percent increase in ecological health as a result.

101. However, in the absence of these multistressor studies what is clear is that any reductions in the factors stressing these systems (e.g., nitrogen, phosphorous, sediment) is more likely to result in ecological improvement then the status quo. As I detailed above, the current state of many of these waterways is poor as a result of agricultural land use management. Maintaining current farming practise will not create any improvement, and increasing intensification will result in further significant declines in ecological condition and life-supporting capacity.

102. Many of the rivers and streams do not currently meet the POP standards in terms of their water quality, ecological health and/or life-supporting capacity (Roygard et al. 2012). Native freshwater fish numbers, diversity and range are declining (Joy 2009). Trout numbers are declining in many rivers (Ms Jordan evidence).A number of river sites in the region monitored by NIWA as part of a national monitoring programme rank the regions rivers as amongst the most polluted rivers in New Zealand. Some measures of ecosystem function (i.e., Gross primary productivity) (Roger Young s42a

report, Technical Evidence Bundle) even rank it amongst the worst in the world. Clearly managing land use impacts on the waterways in the current way will not safeguard current life-supporting capacity and is more likely to result in significant declines in that capacity.

103. Dr Biggs in his End of Hearing Technical report reaches a similar conclusion with respect to Rule 13.1 by assessing the effects of nutrient levels, under differing farming scenarios, on periphyton biomass. Dr Biggs showed that by reducing the current in river load of Nitrogen that the occurrence and frequency of periphyton blooms was reduced. Current land use activities, along with any level of increased intensification which exceeds current nutrient instream loads, will result in increasingly deleterious periphyton blooms (more so than at present) with consequent adverse effects on the other aspects of life-supporting capacity such as fish and invertebrates.

104. The current land and water management practises are therefore compromising life-supporting capacity of these waterways, and further degradation will result in further significant adverse effects on ecological health. Any improvements (such as reducing nitrogen leaching, and excluding stock from waterways) that move conditions towards the Schedule D standards (the closer the better) are necessary to maintain or improve the aquatic ecosystem health and life-supporting capacity of the Regions waterways.

CONCLUSION

105. There is a considerable body of evidence that land use activities if not managed appropriately can and do have significant adverse effects on the ecological health of waterbodies in the Horizons Region.

106. In my view, discussion on the appropriate time frame to consider declining water quality trends in the Horizons Region is not constructive. The temporal linkages between land use activities and their effects on waterbodies are not clearly understood (e.g., we do not know if agricultural intensification today will affect water quality this month, this year, next year, in 10 years or in 100 years or all of these). It is clear water quality and ecological health in many of the Region’s waterbodies is poor and should be improved. Furthermore, land use activities, particularly agriculture and land disturbance, if not

managed appropriately can and do have significant adverse effects on the ecological health of waterbodies in the Horizons Region.

107. The principal driving factors for these adverse effects are predominately increased nutrient levels, and suspended and deposited sediment.

108. Agriculture, particularly on highly erodible land results in increased levels of deposited fine sediment (up to 2000% more) that smother plants and animals, buries habitats and changes the composition of fish and invertebrate communities, in turn reducing ecological health. The Proposed POP does not provide any guidance on acceptable levels of deposited sediment. The proposed addition to Schedule D (presented in Appendix 1) should go some way to correcting this.

109. Management of both nitrogen and phosphorus in all waterways is important to avoid the adverse effects of nutrient enrichment. If nutrients are not managed below certain thresholds this results in cascading affects through riverine food webs that result in degraded water quality and ecological health. The concentrations of nutrients presented in Schedule D are a good approximation of levels that are highly likely to lead to improved ecological health if concentration is restricted to those levels.

110. Healthy ecological systems require the appropriate chemical, physical and biological conditions. Both excess nutrients and sediment can detrimentally alter this environment. Improved ecological health will only result from managing both sediment and nutrients.

111. I can think of no reason why a 20% reduction in QMCI, as opposed to a statistically significant change, should be the trigger for an effect when assessing point source discharges. The 20% figure is arbitrary, unscientific, encourages lack of replication, does not increase the likelihood of finding ecologically significant changes and allows for greater degradation in cleaner water bodies.

112. There is convincing evidence that the ecological health of the Rangitikei River is moderate to poor and would be unlikely to assimilate increased detrimental effects that may result from unmanaged increases in agricultural intensification or less environmentally focused agricultural practises. It is possible that any increased

agricultural intensification in the catchment would result in dramatic declines in ecological health.

113. Stock access to waterways will increase stream bank erosion, sediment deposition, nutrient enrichment, pathogenic organism abundance in waterways, instream habitat destruction, and if riparian buffer zones are also open to stock access, greatly exacerbate the detrimental effects of land use activities that can potentially be ameliorated by the buffering ability of streamside vegetation. In my opinion the single best management practise that could be implemented to improve ecological condition of waterways is to exclude all stock.

114. As water runs downhill, management of small and ephemeral streams is critical to the management of larger downstream waterways and biodiversity. For that reason, this protection and management also needs to be given to all ephemeral streams greater than 1 m, and all permanently flowing streams.

115. As aquatic ecological communities are complex ecosystems that are affected by multiple interacting stressors, the effects for ecological communities of specific management practices that focus on controlling only one of these stressors is difficult to predict. Improvement in the ecological health of these waterbodies will require the management of all the interacting stressors, as proposed by the notified version of Rule 13.1. However, any reductions in nutrients, deposited sediment, and restriction of stock access to waterbodies, will improve the current poor state.

Associate Professor Russell George Death

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Appendix 1

SCHEDULE D: SURFACE *WATER*^ QUALITY TARGETS

Schedule D is a component of Part II - the Regional Plan.

SCHEDULE D INDEX:

USER GUIDE: How to use the contents of Schedule D
Step 1: Identify the *WMSZ**for your proposed activity (go to Schedule AA)
Step 2: Check if Trout Spawning is a Value for your *WMSZ** (go to Schedule AB)
Step 3: Identify which targets apply to your activity using steps a to c:

a. A *river*^:
   i. Turn first to Table D.1Ato see the targets that apply to all *rivers*^ in the Region
   ii. Then turn to Table D.2A to see the targets that apply to *rivers*^ in your *WMSZ**
   iii. If the *river*^ at the *site** of your proposed activity has the Schedule AB Value of Trout Spawning, turn to Table D.3A to see additional targets that apply 1 May to 30 September (inclusive).

b. A *lake*^:
   i. Turn to Schedule E Table E.2(b) to determine if your type of*lake*^ is referred to in v to vii
   ii. If your type of*lake*^ is not referred to inSchedule E Table E.2(b) v to vii then turn to Table D.4A
   iii. Determineifthe*lake*^ meetsthedescriptionofa “deep”or“shallow”*lake*^ from Table D.4A andseethetargetsthatapplytothe*lake*^*water*^inTable D.4A.

c. *Water*^in the *coastal marine area*^:
   i. Turn to Tables H.4 to H.7 in Schedule H to see the targets that apply in the *coastal marine area*^.

USER NOTE: For table abbreviations – please refer to the fold-out**TARGETSKEY**at the back of this schedule.

Table D.1A:Region-wide *Water*^ Quality Targets that apply to all *Rivers*^

Water Management Zone*	***Sub-zone****	***E.coli*/ 100 ml**		**Periphyton Filamentous Cover**	**Diatom or Cyanobacterial Cover**	**QMCI %Δ[1]**
		< 50th %ile	**< 20th%ile**			
All *Water Management Zones**	All *Water Management Sub- zones**	260	550	30%	60%	20

[Formerly POP at D-88]

1 This target is only relevant for measuring the percentage of change in Quantitative Macroinvertebrate Community Index (QMCI) between appropriately matched habitats upstream and downstream of activities, such as *discharges*^ to *water*^, for the purposes of measuring the effect of *discharges*^ on aquatic macroinvertebrate communities. It is not an appropriate target for the measurement of the general state of macroinvertebrate communities in each *Water Management Sub-zone**.

Table D.2A: *Water^* Quality Targets for *Rivers^* in each *Water Management Sub-zone (Note: refer to Table D.4A for the *water^* quality targets that apply to *lakes^*)**																		
Water Management Zone*	***Sub-zone****	**pH**		**Temp (°C)**		**DO (%SAT)**	**scBOD$_5$ (g/m^3)**	**POM (g/m^3)**	**Periphyton**	**DRP (g/m^3)**	**SIN (g/m^3)**	**Deposited sediment (%)**	**MCI**	**Ammoniacal Nitrogen g/m^3)**		**Tox.**	**Visual Clarity (m)**	
		Range	**Δ**	**<**	**Δ**	**>**	**<**	**<**	**Chla (mg/m^2)**	**<**	**<**	**≤**	**>**	**<**	**Max**	**%**	**< 50th %ile**	**% Δ**
Upper Manawatu (Mana_1)	Upper Manawatu (Mana_1a)	7 to 8.5	0.5	19	3	80	1.5	5	120	0.010	0.167	20	120	0.400	2.1	99	3	20
	Mangatewainui (Mana_1b)	7 to 8.5	0.5	19	3	80	1.5	5	120	0.010	0.167	20	120	0.400	2.1	99	3	20
	Mangatoro (Mana_1c)	7 to 8.5	0.5	19	3	80	1.5	5	120	0.010	0.110	20	120	0.400	2.1	99	3	20
Weber-Tamaki (Mana_2)	Weber-Tamaki (Mana_2a)	7 to 8.5	0.5	19	2	80	1.5	5	120	0.010	0.444	20	120	0.400	2.1	99	3	20
	Mangatera (Mana_2b)	7 to 8.5	0.5	22	3	70	2	5	120	0.010	0.444	20	100	0.400	2.1	99	2.5	30
Upper Tamaki (Mana_3)	Upper Tamaki (Mana_3)	7 to 8.2	0.5	19	2	80	1.5	5	50	0.006	0.070	15	120	0.320	1.7	99	3	20
Upper Kumeti (Mana_4)	Upper Kumeti (Mana_4)	7 to 8.2	0.5	19	2	80	1.5	5	50	0.006	0.070	15	120	0.320	1.7	99	3	20

Table D.2A: *Water^* Quality Targets for *Rivers^* in each *Water Management Sub-zone (Note: refer to Table D.4A for the *water^* quality targets that apply to *lakes^*)**

Water Management Zone*	***Sub-zone****	**pH**		**Temp (°C)**		**DO (%SAT)**	**scBOD$_5$ (g/m^3)**	**POM (g/m^3)**	**Periphyton**	**DRP (g/m^3)**	**SIN (g/m^3)**	**<u>Deposited sediment (%)</u>**	**MCI**	**Ammoniacal Nitrogen g/m^3)**		**Tox.**	**Visual Clarity (m)**	
		Range	**Δ**	**<**	**Δ**	**>**	**<**	**<**	**Chla (mg/m^2)**	**<**	**<**	**<u>≤</u>**	**>**	**<**	**Max**	**%**	**< 50th %ile**	**% Δ**
Tamaki-Hopelands (Mana_5)	Tamaki-Hopelands (Mana_5a)	7 to 8.5	0.5	19	3	80	1.5	5	120	0.010	0.444	<u>20</u>	120	0.400	2.1	99	3	20
	Lower Tamaki (Mana_5b)	7 to 8.5	0.5	22	3	70	2	5	120	0.010	0.444	<u>20</u>	100	0.400	2.1	99	2.5	30
	Lower Kumeti (Mana_5c)	7 to 8.5	0.5	22	3	70	2	5	120	0.010	0.444	<u>20</u>	100	0.400	2.1	99	2.5	30
	Oruakeretaki (Mana_5d)	7 to 8.5	0.5	22	3	70	2	5	120	0.010	0.444	<u>20</u>	100	0.400	2.1	99	2.5	30
	Raparapawai (Mana_5e)	7 to 8.5	0.5	22	3	70	2	5	120	0.010	0.444	<u>20</u>	100	0.400	2.1	99	2.5	30
Hopelands-Tiraumea (Mana_6)	Hopelands-Tiraumea (Mana_6)	7 to 8.5	0.5	19	3	80	1.5	5	120	0.010	0.444	<u>20</u>	120	0.400	2.1	99	3	20

Table D.2A: *Water*^ Quality Targets for *Rivers*^ in each *Water Management Sub-zone** (Note: refer to Table D.4A for the *water*^ quality targets that apply to *lakes*^)																		
Water Management Zone*	***Sub-zone****	**pH**		**Temp (°C)**		**DO (%SAT)**	**scBOD$_5$ (g/m^3)**	**POM (g/m^3)**	**Periphyton**	**DRP (g/m^3)**	**SIN (g/m^3)**	**Deposited sediment (%)**	**MCI**	**Ammoniacal Nitrogen g/m^3)**		**Tox.**	**Visual Clarity (m)**	
		Range	**Δ**	**<**	**Δ**	**>**	**<**	**<**	**Chla (mg/m^2)**	**<**	**<**	**≤**	**>**	**<**	**Max**	**%**	**< 50th %ile**	**% Δ**
Tiraumea (Mana_7)	Upper Tiraumea (Mana_7a)	7 to 8.5	0.5	23	3	70	2	5	120	0.010	0.444	25	100	0.400	2.1	95	2	30
	Lower Tiraumea (Mana_7b)	7 to 8.5	0.5	23	3	70	2	5	120	0.010	0.444	25	100	0.400	2.1	95	2	30
	Mangaone River (Mana_7c)	7 to 8.5	0.5	23	3	70	2	5	200	0.010	0.444	25	100	0.400	2.1	95	1.6	30
	Makuri (Mana_7d)	7 to 8.5	0.5	19	2	80	1.5	5	120	0.010	0.110	20	120	0.400	2.1	99	3	20
	Mangaramarama (Mana_8e)	7 to 8.5	0.5	22	3	70	2	5	200	0.010	0.444	25	100	0.400	2.1	95	1.6	30
Mangatainoka (Mana_8)	Upper Mangatainoka (Mana_8a)	7 to 8.2	0.5	19	2	80	1.5	5	50	0.006	0.070	15	120	0.320	1.7	99	3	20

Table D.2A: *Water*^ Quality Targets for *Rivers*^ in each *Water Management Sub-zone** (Note: refer to Table D.4A for the *water*^ quality targets that apply to *lakes*^)																		
Water Management Zone*	***Sub-zone****	**pH**		**Temp (°C)**		**DO (%SAT)**	**scBOD$_5$ (g/m^3)**	**POM (g/m^3)**	**Periphyton**	**DRP (g/m^3)**	**SIN (g/m^3)**	**Deposited sediment (%)**	**MCI**	**Ammoniacal Nitrogen g/m^3)**		**Tox.**	**Visual Clarity (m)**	
		Range	**Δ**	**<**	**Δ**	**>**	**<**	**<**	**Chla (mg/m^2)**	**<**	**<**	**≤**	**>**	**<**	**Max**	**%**	**< 50th %ile**	**% Δ**
	Middle Mangatainoka (Mana_8b)	7 to 8.5	0.5	19	3	80	1.5	5	120	0.010	0.444	20	120	0.400	2.1	99	3	20
	Lower Mangatainoka (Mana_8c)	7 to 8.5	0.5	19	3	80	1.5	5	120	0.010	0.444	20	120	0.400	2.1	99	3	20
	Makakahi (Mana_8d)	7 to 8.5	0.5	19	3	80	1.5	5	120	0.010	0.444	20	120	0.400	2.1	99	3	20
Upper Gorge (Mana_9)	Upper Gorge (Mana_9a)	7 to 8.5	0.5	22	3	70	2	5	120	0.010	0.444	20	100	0.400	2.1	95	2.5	30
	Mangapapa (Mana_9b)	7 to 8.5	0.5	22	3	70	2	5	120	0.010	0.444	20	100	0.400	2.1	95	2.5	30
	Mangaatua (Mana_9c)	7 to 8.5	0.5	22	3	70	2	5	120	0.010	0.444	20	100	0.400	2.1	95	2.5	30
	Upper Mangahao (Mana_9d)	7 to 8.2	0.5	19	2	80	1.5	5	50	0.006	0.167	15	120	0.320	1.7	99	3	20

Table D.2A: *Water*^ Quality Targets for *Rivers*^ in each *Water Management Sub-zone (Note: refer to Table D.4A for the *water*^ quality targets that apply to *lakes*^)**																		
Water Management Zone*	***Sub-zone****	**pH**		**Temp (°C)**		**DO (%SAT)**	**scBOD$_5$ (g/m^3)**	**POM (g/m^3)**	**Periphyton**	**DRP (g/m^3)**	**SIN (g/m^3)**	**Deposited sediment (%)**	**MCI**	**Ammoniacal Nitrogen g/m^3)**		**Tox.**	**Visual Clarity (m)**	
		Range	**Δ**	**<**	**Δ**	**>**	**<**	**<**	**Chla (mg/m^2)**	**<**	**<**	**≤**	**>**	**<**	**Max**	**%**	**< 50th %ile**	**% Δ**
	Lower Mangahao (Mana_9e)	7 to 8.5	0.5	22	3	70	2	5	120	0.010	0.444	20	100	0.400	2.1	95	2.5	30
Middle Manawatu (Mana_10)	Middle Manawatu (Mana_10a)	7 to 8.5	0.5	22	3	70	2	5	120	0.010	0.444	20	100	0.400	2.1	95	2.5	30
	Upper Pohangina (Mana_10b)	7 to 8.2	0.5	19	2	80	1.5	5	120	0.006	0.070	15	120	0.320	1.7	99	3	20
	Middle Pohangina (Mana_10c)	7 to 8.5	0.5	22	3	70	2	5	120	0.010	0.110	20	100	0.400	2.1	95	2.5	30
	Lower Pohangina (Mana_10d)	7 to 8.5	0.5	22	3	70	2	5	120	0.010	0.110	20	100	0.400	2.1	95	2.5	30
	Aokautere (Mana_10e)	7 to 8.5	0.5	22	3	70	2	5	120	0.010	0.110	20	100	0.400	2.1	95	2.5	30
Lower Manawatu (Mana_11)	Lower Manawatu (Mana_11a)	7 to 8.5	0.5	22	3	70	2	5	120	0.010	0.444	20	100	0.400	2.1	95	2.5	30

Table D.2A: *Water*^ Quality Targets for *Rivers*^ in each *Water Management Sub-zone (Note: refer to Table D.4A for the *water*^ quality targets that apply to *lakes*^)**

Water Management Zone*	***Sub-zone****	**pH**		**Temp (°C)**		**DO (%SAT)**	**scBOD$_5$ (g/m^3)**	**POM (g/m^3)**	**Periphyton**	**DRP (g/m^3)**	**SIN (g/m^3)**	**Deposited sediment (%)**	**MCI**	**Ammoniacal Nitrogen g/m^3)**		**Tox.**	**Visual Clarity (m)**	
		Range	**Δ**	**<**	**Δ**	**>**	**<**	**<**	**Chla (mg/m^2)**	**<**	**<**	**≤**	**>**	**<**	**Max**	**%**	**< 50th %ile**	**% Δ**
	Turitea (Mana_11b)	7 to 8.2	0.5	19	2	80	1.5	5	50	0.006	0.070	15	120	0.320	1.7	99	3	20
	Kahuterawa (Mana_11c)	7 to 8.2	0.5	19	2	80	1.5	5	50	0.006	0.070	15	120	0.320	1.7	99	3	20
	Upper Mangaone Stream (Mana_11d)	7 to 8.5	0.5	24	3	60	2	5	200	0.010	0.444	25	100	0.400	2.1	95	2.5	30
	Lower Mangaone Stream (Mana_11e)	7 to 8.5	0.5	24	3	60	2	5	200	0.010	0.444	25	100	0.400	2.1	95	2.5	30
	Main Drain (Mana_11f)	7 to 8.5	0.5	24	3	60	2	5	200	0.015	0.444	25	100	0.400	2.1	95	2.5	30
Oroua (Mana_12)	Upper Oroua (Mana_12a)	7 to 8.5	0.5	22	3	70	2	5	120	0.010	0.167	20	100	0.400	2.1	95	2.5	30
	Middle Oroua (Mana_12b)	7 to 8.5	0.5	22	3	70	2	5	120	0.010	0.444	20	100	0.400	2.1	95	2.5	30

Table D.2A: *Water*^ Quality Targets for *Rivers*^ in each *Water Management Sub-zone (Note: refer to Table D.4A for the *water*^ quality targets that apply to *lakes*^)**

*Water Management Zone**	*Sub-zone**	pH		Temp (°C)		DO (%SAT)	scBOD$_5$ (g/m^3)	POM (g/m^3)	Periphyton	DRP (g/m^3)	SIN (g/m^3)	Deposited sediment (%)	MCI	Ammoniacal Nitrogen g/m^3)		Tox.	Visual Clarity (m)	
		Range	Δ	<	Δ	>	<	<	Chla (mg/m^2)	<	<	≤	>	<	Max	%	< 50th %ile	% Δ
	Lower Oroua (Mana_12c)	7 to 8.5	0.5	24	3	70	2	5	200	0.015	0.444	25	100	0.400	2.1	95	2.5	30
	Kiwitea (Mana_12d)	7 to 8.5	0.5	22	3	70	2	5	120	0.010	0.167	20	100	0.400	2.1	95	2.5	30
	Makino (Mana_12e)	7 to 8.5	0.5	24	3	70	2	5	120	0.015	0.444	25	100	0.400	2.1	95	2.5	30
Coastal Manawatu (Mana_13)	Coastal Manawatu (Mana_13a)	7 to 8.5	0.5	24	3	70	2	5	200	0.015	0.444	25	100	0.400	2.1	95	2.5	30
	Upper Tokomaru (Mana_13b)	7 to 8.2	0.5	19	2	80	1.5	5	50	0.006	0.070	15	120	0.320	1.7	99	3	20
	Lower Tokomaru (Mana_13c)	7 to 8.5	0.5	24	3	70	2	5	120	0.010	0.444	25	100	0.400	2.1	95	2.5	30
	Mangaore (Mana_13d)	7 to 8.5	0.5	22	3	70	2	5	120	0.010	0.167	20	100	0.400	2.1	95	2.5	30
	Koputaroa (Mana_13e)	7 to 8.5	0.5	24	3	60	2	5	200	0.015	0.444	25	100	0.400	2.1	95	2.5	30

Table D.2A: *Water*^ Quality Targets for *Rivers*^ in each *Water Management Sub-zone (Note: refer to Table D.4A for the *water*^ quality targets that apply to *lakes*^)**																		
Water Management Zone*	***Sub-zone****	**pH**		**Temp (°C)**		**DO (%SAT)**	**scBOD$_5$ (g/m^3)**	**POM (g/m^3)**	**Periphyton**	**DRP (g/m^3)**	**SIN (g/m^3)**	**Deposited sediment (%)**	**MCI**	**Ammoniacal Nitrogen g/m^3)**		**Tox.**	**Visual Clarity (m)**	
		Range	**Δ**	**<**	**Δ**	**>**	**<**	**<**	**Chla (mg/m^2)**	**<**	**<**	**≤**	**>**	**<**	**Max**	**%**	**< 50th %ile**	**% Δ**
	Foxton Loop (Mana_13f)	7 to 8.5	0.5	24	3	60	2	5	200	0.015	0.444	25	100	0.400	2.1	95	2.5	30
Upper Rangitikei (Rang_1)	Upper Rangitikei (Rang_1)	7 to 8.2	0.5	19	2	80	1.5	5	50	0.006	0.070	15	120	0.320	1.7	99	3.4	20
Middle Rangitikei (Rang_2)	Middle Rangitikei (Rang_2a)	7 to 8.2	0.5	19	2	80	1.5	5	50	0.006	0.070	15	120	0.320	1.7	99	3.4	20
	Pukeokahu – Mangaweka (Rang_2b)	7 to 8.5	0.5	19	3	80	1.5	5	120	0.010	0.110	15	120	0.320	1.7	99	3.4	20
	Upper Moawhango (Rang_2c)	7 to 8.2	0.5	19	2	80	1.5	5	50	0.006	0.070	15	120	0.320	1.7	99	3	20
	Middle Moawhango (Rang_2d)	7 to 8.5	0.5	19	2	80	1.5	5	120	0.010	0.110	20	100	0.400	2.1	95	2.5	30

Table D.2A: *Water^* Quality Targets for *Rivers^* in each *Water Management Sub-zone (Note: refer to Table D.4A for the *water^* quality targets that apply to *lakes^*)**

*Water Management Zone**	*Sub-zone**	pH		Temp (°C)		DO (%SAT)	scBOD$_5$ (g/m^3)	POM (g/m^3)	Periphyton	DRP (g/m^3)	SIN (g/m^3)	Deposited sediment (%)	MCI	Ammoniacal Nitrogen g/m^3)		Tox.	Visual Clarity (m)	
		Range	Δ	<	Δ	>	<	<	Chla (mg/m^2)	<	<	≤	>	<	Max	%	< 50th %ile	% Δ
	Lower Moawhango (Rang_2e)	7 to 8.5	0.5	22	3	70	2	5	120	0.010	0.110	25	100	0.400	2.1	95	2	30
	Upper Hautapu (Rang_2f)	7 to 8.5	0.5	19	2	80	1.5	5	120	0.010	0.110	20	120	0.400	2.1	99	3	20
	Lower Hautapu (Rang_2g)	7 to 8.5	0.5	22	3	70	2	5	120	0.010	0.110	25	100	0.400	2.1	95	2	30
Lower Rangitikei (Rang_3)	Lower Rangitikei (Rang_3a)	7 to 8.5	0.5	19	3	80	1.5	5	120	0.010	0.110	15	120	0.400	2.1	99	3	20
	Makohine (Rang_3b)	7 to 8.5	0.5	22	3	70	2	5	200	0.010	0.110	25	100	0.400	2.1	95	1.6	30
Coastal Rangitikei (Rang_4)	Coastal Rangitikei (Rang_4a)	7 to 8.5	0.5	22	3	70	2	5	120	0.010	0.110	20	100	0.400	2.1	95	2.5	30
	Tidal Rangitikei (Rang_4b)	7 to 8.5	0.5	24	3	70	2	5	200	0.015	0.167	25	100	0.400	2.1	95	2.5	30

Table D.2A: *Water*^ Quality Targets for *Rivers*^ in each *Water Management Sub-zone (Note: refer to Table D.4A for the *water*^ quality targets that apply to *lakes*^)**

*Water Management Zone**	*Sub-zone**	pH		Temp (°C)		DO (%SAT)	scBOD$_5$ (g/m^3)	POM (g/m^3)	Periphyton	DRP (g/m^3)	SIN (g/m^3)	Deposited sediment (%)	MCI	Ammoniacal Nitrogen g/m^3)		Tox.	Visual Clarity (m)	
		Range	Δ	<	Δ	>	<	<	Chla (mg/m^2)	<	<	≤	>	<	Max	%	< 50th %ile	% Δ
	Porewa (Rang_4c)	7 to 8.5	0.5	22	3	70	2	5	120	0.010	0.110	25	100	0.400	2.1	95	1.6	30
	Tutaenui (Rang_4d)	7 to 8.5	0.5	24	3	60	2	5	200	0.010	0.110	25	100	0.400	2.1	95	2.5	30
Upper Whanganui (Whai_1)	Upper Whanganui (Whai_1)	7 to 8.2	0.5	19	2	80	1.5	5	50	0.006	0.070	15	120	0.320	1.7	99	3	20
Cherry Grove (Whai_2)	Cherry Grove (Whai_2a)	7 to 8.5	0.5	19	2	80	1.5	5	120	0.010	0.110	20	100	0.400	2.1	95	2.5	30
	Upper Whakapapa (Whai_2b)	7 to 8.2	0.5	19	2	80	1.5	5	50	0.006	0.070	15	120	0.320	1.7	99	3	20
	Lower Whakapapa (Whai_2c)	7 to 8.2	0.5	19	2	80	1.5	5	50	0.006	0.070	15	120	0.320	1.7	99	3	20
	Piopiotea (Whai_2d)	7 to 8.2	0.5	19	2	80	1.5	5	50	0.006	0.070	15	120	0.320	1.7	99	3	20

Table D.2A: *Water*^ Quality Targets for *Rivers*^ in each *Water Management Sub-zone** (Note: refer to Table D.4A for the *water*^ quality targets that apply to *lakes*^)																		
Water Management Zone*	***Sub-zone****	**pH**		**Temp (°C)**		**DO (%SAT)**	**scBOD$_5$ (g/m^3)**	**POM (g/m^3)**	**Periphyton**	**DRP (g/m^3)**	**SIN (g/m^3)**	**Deposited sediment (%)**	**MCI**	**Ammoniacal Nitrogen g/m^3)**		**Tox.**	**Visual Clarity (m)**	
		Range	**Δ**	**<**	**Δ**	**>**	**<**	**<**	**Chla (mg/m^2)**	**<**	**<**	**≤**	**>**	**<**	**Max**	**%**	**< 50th %ile**	**% Δ**
	Pungapunga (Whai_2e)	7 to 8.5	0.5	19	2	80	1.5	5	120	0.010	0.110	20	100	0.400	2.1	95	2.5	30
	Upper Ongarue (Whai_2f)	7 to 8.2	0.5	19	2	80	1.5	5	50	0.006	0.070	15	120	0.320	1.7	99	3	20
	Lower Ongarue (Whai_2g)	7 to 8.5	0.5	19	2	80	1.5	5	120	0.010	0.110	20	100	0.400	2.1	95	2.5	30
TeMaire (Whai_3)	TeMaire (Whai_3)	7 to 8.5	0.5	19	2	80	1.5	5	120	0.010	0.110	20	100	0.400	2.1	95	2.5	30
Middle Whanganui (Whai_4)	Middle Whanganui (Whai_4a)	7 to 8.5	0.5	19	2	80	1.5	5	120	0.010	0.110	20	100	0.400	2.1	95	2.5	30
	Upper Ohura (Whai_4b)	7 to 8.5	0.5	22	3	70	2	5	200	0.015	0.167	25	100	0.400	2.1	95	1.6	30
	Lower Ohura (Whai_4c)	7 to 8.5	0.5	22	3	70	2	5	200	0.015	0.167	25	100	0.400	2.1	95	1.6	30
	Retaruke (Whai_4d)	7 to 8.5	0.5	19	2	80	1.5	5	120	0.010	0.110	20	100	0.400	2.1	95	2.5	30

Table D.2A: *Water*^ Quality Targets for *Rivers*^ in each *Water Management Sub-zone (Note: refer to Table D.4A for the *water*^ quality targets that apply to *lakes*^)**

*Water Management Zone**	*Sub-zone**	pH		Temp (°C)		DO (%SAT)	scBOD5 (g/m^3)	POM (g/m^3)	Periphyton	DRP (g/m^3)	SIN (g/m^3)	Deposited sediment (%)	MCI	Ammoniacal Nitrogen g/m^3)		Tox.	Visual Clarity (m)	
		Range	Δ	<	Δ	>	<	<	Chla (mg/m^2)	<	<	≤	>	<	Max	%	< 50th %ile	% Δ
Pipiriki (Whai_5)	Pipiriki (Whai_5a)	7 to 8.5	0.5	22	3	70	2	5	120	0.010	0.110	25	100	0.400	2.1	95	2	30
	Tangarakau (Whai_5b)	7 to 8.5	0.5	22	3	70	2	5	200	0.015	0.167	25	100	0.400	2.1	95	1.6	30
	Whangamomona (Whai_5c)	7 to 8.5	0.5	22	3	70	2	5	200	0.015	0.167	25	100	0.400	2.1	95	1.6	30
	Upper Manganui o te Ao (Whai_5d)	7 to 8.2	0.5	19	2	80	1.5	5	50	0.006	0.070	15	120	0.320	1.7	99	3.4	20
	Makatote (Whai_5e)	7 to 8.2	0.5	19	2	80	1.5	5	50	0.006	0.070	15	120	0.320	1.7	99	3.4	20
	Waimarino (Whai_5f)	7 to 8.2	0.5	19	2	80	1.5	5	50	0.006	0.070	15	120	0.320	1.7	99	3.4	20
	Middle Manganui o teAo (Whai_5g)	7 to 8.2	0.5	19	2	80	1.5	5	50	0.006	0.070	15	120	0.320	1.7	99	3.4	20

Table D.2A: *Water^* Quality Targets for *Rivers^* in each *Water Management Sub-zone** (Note: refer to Table D.4A for the *water^* quality targets that apply to *lakes^*)																		
Water Management Zone*	***Sub-zone****	**pH**		**Temp (°C)**		**DO (%SAT)**	**scBOD$_5$ (g/m^3)**	**POM (g/m^3)**	**Periphyton**	**DRP (g/m^3)**	**SIN (g/m^3)**	**Deposited sediment (%)**	**MCI**	**Ammoniacal Nitrogen g/m^3)**		**Tox.**	**Visual Clarity (m)**	
		Range	**Δ**	**<**	**Δ**	**>**	**<**	**<**	**Chla (mg/m^2)**	**<**	**<**	**≤**	**>**	**<**	**Max**	**%**	**< 50th %ile**	**% Δ**
	Mangaturuturu (Whai_5h)	7 to 8.2	0.5	19	2	80	1.5	5	50	0.006	0.070	15	120	0.320	1.7	99	3.4	20
	Lower Manganui o teAo (Whai_5i)	7 to 8.5	0.5	19	2	80	1.5	5	120	0.010	0.110	15	120	0.320	1.7	99	3.4	20
	Orautoha (Whai_5j)	7 to 8.5	0.5	19	2	80	1.5	5	120	0.010	0.110	15	120	0.320	1.7	99	3.4	20
Paetawa (Whai_6)	Paetawa (Whai_6)	7 to 8.5	0.5	22	3	70	2	5	120	0.010	0.110	25	100	0.400	2.1	95	2	30
Lower Whanganui (Whai_7)	Lower Whanganui (Whai_7a)	7 to 8.5	0.5	22	3	70	2	5	200	0.015	0.167	25	100	0.400	2.1	95	1.6	30
	Coastal Whanganui (Whai_7b)	7 to 8.5	0.5	24	3	60	2	5	200	0.015	0.167	25	100	0.400	2.1	95	1.6	30
	Upokongaro (Whai_7c)	7 to 8.5	0.5	22	3	70	2	5	200	0.015	0.167	25	100	0.400	2.1	95	1.6	30

Table D.2A: *Water*^ Quality Targets for *Rivers*^ in each *Water Management Sub-zone** (Note: refer to Table D.4A for the *water*^ quality targets that apply to *lakes*^)																		
Water Management Zone*	***Sub-zone****	**pH**		**Temp (°C)**		**DO (%SAT)**	**scBOD$_5$ (g/m^3)**	**POM (g/m^3)**	**Periphyton**	**DRP (g/m^3)**	**SIN (g/m^3)**	**Deposited sediment (%)**	**MCI**	**Ammoniacal Nitrogen g/m^3)**		**Tox.**	**Visual Clarity (m)**	
		Range	**Δ**	**<**	**Δ**	**>**	**<**	**<**	**Chla (mg/m^2)**	**<**	**<**	**≤**	**>**	**<**	**Max**	**%**	**< 50th %ile**	**% Δ**
	Matarawa (Whai_7d)	7 to 8.5	0.5	22	3	70	2	5	200	0.015	0.167	25	100	0.400	2.1	95	1.6	30
Upper Whangaehu (Whau_1)	Upper Whangaehu (Whau_1a)	7 to 8.2	0.5	19	2	80	1.5	5	50	0.006	0.070	15	120	-0.320	1.7	99	3	20
	Waitangi (Whau_1b)	7 to 8.5	0.5	19	2	80	1.5	5	120	0.010	0.110	20	100	0.400	2.1	95	2.5	30
	Tokiahuru (Whau_1c)	7 to 8.2	0.5	19	2	80	1.5	5	50	0.006	0.070	15	120	0.320	1.7	99	3	20
Middle Whangaehu (Whau_2)	Middle Whangaehu (Whau_2)	7 to 8.5	0.5	22	3	70	2	5	200	0.015	0.167	25	100	0.400	2.1	95	1.6	30
Lower Whangaehu (Whau_3)	Lower Whangaehu (Whau_3a)	7 to 8.5	0.5	22	3	70	2	5	200	0.015	0.167	25	100	0.400	2.1	95	2	30
	Upper Makotuku (Whau_3b)	7 to 8.2	0.5	19	2	80	1.5	5	50	0.006	0.070	15	120	0.320	1.7	99	3	20

Table D.2A: *Water*^ Quality Targets for *Rivers*^ in each *Water Management Sub-zone (Note: refer to Table D.4A for the *water*^ quality targets that apply to *lakes*^)**

*Water Management Zone**	*Sub-zone**	pH		Temp (°C)		DO (%SAT)	scBOD$_5$ (g/m^3)	POM (g/m^3)	Periphyton	DRP (g/m^3)	SIN (g/m^3)	Deposited sediment (%)	MCI	Ammoniacal Nitrogen g/m^3)		Tox.	Visual Clarity (m)	
		Range	Δ	<	Δ	>	<	<	Chla (mg/m^2)	<	<	≤	>	<	Max	%	< 50th %ile	% Δ
	Lower Makotuku (Whau_3c)	7 to 8.2	0.5	19	2	80	1.5	5	50	0.006	0.070	15	120	0.320	1.7	99	3	20
	Upper Mangawhero (Whau_3d)	7 to 8.2	0.5	19	2	80	1.5	5	50	0.006	0.070	15	120	0.320	1.7	99	3	20
	Lower Mangawhero (Whau_3e)	7 to 8.5	0.5	22	3	70	2	5	120	0.010	0.110	25	100	0.400	2.1	95	2	30
	Makara (Whau_3f)	7 to 8.2	0.5	19	2	80	1.5	5	50	0.006	0.070	15	120	0.320	1.7	99	3	20
Coastal Whangaehu (Whau_4)	Coastal Whangaehu (Whau_4)	7 to 8.5	0.5	22	3	70	2	5	200	0.015	0.167	25	100	0.400	2.1	95	1.6	30
Turakina (Tura_1)	Upper Turakina (Tura_1a)	7 to 8.5	0.5	22	3	70	2	5	200	0.015	0.167	25	100	0.400	2.1	95	1.6	30

Table D.2A: *Water*^ Quality Targets for *Rivers*^ in each *Water Management Sub-zone (Note: refer to Table D.4A for the *water*^ quality targets that apply to *lakes*^)**

Water Management Zone*	***Sub-zone****	**pH**		**Temp (°C)**		**DO (%SAT)**	**scBOD$_5$ (g/m^3)**	**POM (g/m^3)**	**Periphyton**	**DRP (g/m^3)**	**SIN (g/m^3)**	**Deposited sediment (%)**	**MCI**	**Ammoniacal Nitrogen g/m^3)**		**Tox.**	**Visual Clarity (m)**	
		Range	**Δ**	**<**	**Δ**	**>**	**<**	**<**	**Chla (mg/m^2)**	**<**	**<**	**≤**	**>**	**<**	**Max**	**%**	**< 50th %ile**	**% Δ**
	Lower Turakina (Tura_1b)	7 to 8.5	0.5	22	3	70	2	5	200	0.015	0.167	25	100	0.400	2.1	95	1.6	30
	Ratana (Tura_1c)	7 to 8.5	0.5	24	3	60	2	5	200	0.015	0.167	25	100	0.400	2.1	95	2.5	30
Ohau (Ohau_1)	Upper Ohau (Ohau_1a)	7 to 8.2	0.5	19	2	80	1.5	5	50	0.006	0.070	15	120	0.320	1.7	99	3	20
	Lower Ohau (Ohau_1b)	7 to 8.5	0.5	22	3	70	2	5	120	0.010	0.110	20	100	0.400	2.1	95	2.5	30
Owahanga (Owha_1)	Owahanga (Owha_1)	7 to 8.5	0.5	22	3	70	2	5	200	0.015	0.167	25	100	0.400	2.1	95	1.6	30
East Coast (East_1)	East Coast (East_1)	7 to 8.5	0.5	22	3	70	2	5	200	0.015	0.167	25	100	0.400	2.1	95	1.6	30
Akitio (Akit_1)	Upper Akitio (Akit_1a)	7 to 8.5	0.5	22	3	70	2	5	200	0.015	0.167	25	100	0.400	2.1	95	1.6	30
	Lower Akitio (Akit_1b)	7 to 8.5	0.5	22	3	70	2	5	200	0.015	0.167	25	100	0.400	2.1	95	1.6	30
	Waihi (Akit_1c)	7 to 8.5	0.5	22	3	70	2	5	200	0.015	0.167	25	100	0.400	2.1	95	1.6	30

Table D.2A: *Water*^ Quality Targets for *Rivers*^ in each *Water Management Sub-zone (Note: refer to Table D.4A for the *water*^ quality targets that apply to *lakes*^)**																		
Water Management Zone*	***Sub-zone****	**pH**		**Temp (°C)**		**DO (%SAT)**	**scBOD$_5$ (g/m^3)**	**POM (g/m^3)**	**Periphyton**	**DRP (g/m^3)**	**SIN (g/m^3)**	**Deposited sediment (%)**	**MCI**	**Ammoniacal Nitrogen g/m^3)**		**Tox.**	**Visual Clarity (m)**	
		Range	**Δ**	**<**	**Δ**	**>**	**<**	**<**	**Chla (mg/m^2)**	**<**	**<**	**≤**	**>**	**<**	**Max**	**%**	**< 50th %ile**	**% Δ**
Northern Coastal (West_1)	Northern Coastal (West_1)	7 to 8.5	0.5	24	3	60	2	5	200	0.015	0.167	25	100	0.400	2.1	95	2.5	30
Kai Iwi (West_2)	Kai Iwi (West_2)	7 to 8.5	0.5	22	3	70	2	5	200	0.015	0.167	25	100	0.400	2.1	95	1.6	30
Mowhanau (West_3)	Mowhanau (West_3)	7 to 8.5	0.5	24	3	60	2	5	200	0.015	0.167	25	100	0.400	2.1	95	2.5	30
Kaitoke Lakes (West_4)	Kaitoke Lakes (West_4)	7 to 8.5	0.5	24	3	60	2	5	200	0.015	0.167	25	100	0.400	2.1	95	2.5	30
Southern Whanganui Lakes (West_5)	Southern Whanganui Lakes (West_5)	7 to 8.5	0.5	24	3	60	2	5	200	0.015	0.167	25	100	0.400	2.1	95	2.5	30
Northern Manawatu Lakes (West_6)	Northern Manawatu Lakes (West_6)	7 to 8.5	0.5	24	3	60	2	5	200	0.015	0.167	25	100	0.400	2.1	95	2.5	30

Table D.2A: *Water*^ Quality Targets for *Rivers*^ in each *Water Management Sub-zone** (Note: refer to Table D.4A for the *water*^ quality targets that apply to *lakes*^)																		
*Water Management Zone**	*Sub-zone**	pH		Temp (°C)		DO (%SAT)	scBOD$_5$ (g/m^3)	POM (g/m^3)	Periphyton	DRP (g/m^3)	SIN (g/m^3)	Deposited sediment (%)	MCI	Ammoniacal Nitrogen g/m^3)		Tox.	Visual Clarity (m)	
		Range	Δ	<	Δ	>	<	<	Chla (mg/m^2)	<	<	≤	>	<	Max	%	< 50th %ile	% Δ
Waitarere (West_7)	Waitarere (West_7)	7 to 8.5	0.5	24	3	60	2	5	200	0.015	0.167	25	100	0.400	2.1	95	2.5	30
Lake Papaitonga (West_8)	Lake Papaitonga (West_8)	7 to 8.5	0.5	24	3	60	2	5	200	0.015	0.167	25	100	0.400	2.1	95	2.5	30
Waikawa (West_9)	Waikawa (West_9a)	7 to 8.5	0.5	22	3	70	2	5	120	0.010	0.167	20	100	0.400	2.1	95	2.5	30
	Manakau (West_9b)	7 to 8.5	0.5	22	3	70	2	5	120	0.010	0.167	20	100	0.400	2.1	95	2.5	30
Lake Horowhenua (Hoki_1)	Lake Horowhenua (Hoki_1a)	7 to 8.5	0.5	24	3	60	2	5	200	0.015	0.167	25	100	0.400	2.1	95	2.5	30
	Hokio (Hoki_1b)	7 to 8.5	0.5	24	3	60	2	5	200	0.015	0.167	25	100	0.400	2.1	95	2.5	30

[Formerly POP at D-81 to D-87]

Table D.3A: Additional *Water*^ Quality Targets that apply 1 May to 30 September (inclusive) to all Specified Sites/Reaches of *Rivers*^ with a Trout Spawning (TS) Value					
Temp (°C)		**DO (%SAT)**	**Deposited Sediment or POM**	**Deposited Sediment Cover (%)**	**Toxicants (%)**
<	**Δ**	**>**	**Δ[2]**	**≤**	
11	2	80	No measurable increase of deposited sediment or particulate organic matter (POM) on the *bed*^ of the *river*^	10	99

[Formerly POP at D-92]

[2]This numeric is only relevant for measuring the change in deposited sediment in relation to a resource consent application for rivers valued for Trout Spawning. Measurements should be undertaken using the deposited sediment protocols of Clapcott et al. (2010).
[3]The Deposited Sediment numeric only applies for State of the Environment monitoring purposes to determine if the percentage cover of deposited sediment on the bed of the river will provide for and maintain the values in each WMSZ.

Table D.4A: *Lake*^ *Water*^ Quality Targets(Note: targets apply year-round to the *waters*^ of types of *lakes*^ not excluded by Schedule E Table E.2(b) v to vii)

Lake Type	Algal Biomass Chla(mg/m^3)		TP (g/m^3)	TN (g/m^3)	Ammoniacal Nitrogen (g/m^3)	Tox.	Visual Clarity (m)		Euphotic Depth	*E. coli* / 100 ml	
	<	Max.	<	<	<[4]	%	>	%Δ	%Δ	Summer (1 Nov – 30 Apr)	Winter (1 May – 31 Oct)
Deep lakes (≥ 5 m deep)	5	15	0.020	0.337	0.400	95	2.8	20	10	260	550
Shallow lakes (< 5 m deep)	12	30	0.043	0.735	0.400	95	0.8	20	10	260	550

[Formerly POP at D-88 to D-89]

4 Target only applieswhen lake pH exceeds 8.5 within the epilimnion (shallow lakes) or within 2 m of the water surface (deep lakes)

Table D.5A:*Water*^ Quality Targets Key: Definition of abbreviations and full wording of the targets (placement of the numerical values for a specified target are indicated by [...])		
Abbreviations used in Tables D.1A to D.4A		**Full Wording of theTarget**
Header	Sub-header	
pH	Range	The pH of the *water*^must be within the range […] to […]unless natural levels are already outside this range.
	Δ	The pH of the *water*^must not be changed by more than […].
Temp(^{o}C)	<	The temperature of the *water*^must not exceed […] degrees Celsius.
	Δ	The temperature of the *water*^must not be changed by more than […]degrees Celsius.
DO (%SAT)	>	The concentration of dissolved oxygen (DO) must exceed […] % of saturation.
$sCBOD_5$ (g/m^3)	<	The monthly average five-days filtered / soluble carbonaceous biochemical oxygen demand ($sCBOD_5$) when the *river*^ flow is at or below the 20th *flow exceedance percentile**must not exceed […] grams per cubic metre.
POM (g/m^3)	<	The average concentration of particulate organic matter when the *river*^ flow is at or below the 50th *flow exceedance percentile**must not exceed […] grams per cubic metre.
Periphyton (r*ivers*^)	Chl*a*(mg/m^2)	The algal biomass on the *river*^*bed*^must not exceed […] milligrams of chlorophyll *a* per square metre.
	% cover	The maximum cover of visible *river*^ *bed*^byperiphyton as filamentous algae more than 2 centimetres long must not exceed […]%.
		The maximum cover of visible river bed by periphyton as diatoms or cyanobacteria more than 0.3 centimetres thick must not exceed […]%.
Algal biomass Chl*a*(mg/m^3) (*lakes*^)	<	The annual average algal biomass must not exceed […] milligrams chlorophyll *a*per cubic metre.
	Maximum	Samplesmust not exceed […] milligrams chlorophyll *a*per cubic metre.
DRP(g/m^3)	<	The annual average concentration of dissolved reactive phosphorus (DRP) when the *river*^ flow is at or below the 20th *flow exceedance percentile**must not exceed […]grams per cubic metre, unless natural

		levels already exceed this target.
TP (g/m³) (*lakes*^)	<	The annual average concentration of total phosphorus (TP) must not exceed […]grams per cubic metre.
SIN (g/m³)	<	The annual average concentration of soluble inorganic nitrogen (SIN)[5] when the *river*^ flow is at or below the 20th *flow exceedance percentile**must not exceed […]grams per cubic metre, unless natural levels already exceed this target.
TN (g/m³) (*lakes*^)	<	The annual average concentration of total nitrogen must not exceed […]grams per cubic metre.
Deposited Sediment[6]	% cover	The maximum cover of visible river bed by deposited sediment less than 2 millimetres in diameter must be less than […] %, unless natural physical conditions are beyond the scope of the application of the deposited sediment protocol of Clapcott et al. (2010).
MCI[7]	>	The MacroinvertebrateCommunityIndex (MCI) must exceed […], unless natural physical conditions are beyond the scope of application of the MCI. In cases where the *river*^ habitat is suitable for the application of the soft-bottomed variant of the MCI (sb-MCI) the targets also apply.
QMCI	%Δ	There must be no more than a 20% reduction in Quantitative MacroinvertebrateCommunityIndex (QMCI) score betweenappropriately matched habitats upstream and downstream of discharges to *water*^.
Ammoniacal nitrogen[8] (g/m³) (*rivers*^)	<	The average concentration of ammoniacal nitrogen must not exceed […]grams per cubic metre.
	Max	The maximum concentration of ammoniacal nitrogen must not exceed […] grams per cubic metre.
Ammoniacalnitrogen (g/m³) (*lakes*^)	<	The concentration of ammoniacalnitrogenmust not exceed […] grams per cubic metre when *lake*^ pH exceeds 8.5 within the epilimnion (shallow *lakes*^) or within 2m of the *water*^ surface (deep *lakes*^).

5 Soluble inorganic nitrogen (SIN) concentration is measured as the sum of nitrate nitrogen, nitrite nitrogen, and ammoniacal nitrogen or the sum of total oxidised nitrogen and ammoniacal nitrogen.

6 The Deposited Sediment numeric only applies for State of the Environment monitoring purposes to determine if the percentage cover of deposited sediment on the bed of the river will provide for and maintain the values in each WMSZ. The effects of deposited sediment on the bed of rivers in relation to resource consent applications should be determined using the deposited sediment protocols of Clapcott et al. (2010).

7 The Macroinvertebrate Community Index (MCI) target applies only for State of the Environment monitoring purposes to determine if the aquatic macroinvertebrate communities are adequate to provide for and maintain the values in each WMSZ. This target is not appropriate for monitoring the effect of activities such as discharges to water on macroinvertebrate communities upstream and downstream of the activity.

8 Ammoniacal nitrogen is a component of SIN. SIN target should also be considered when assessing ammoniacal nitrogen concentrations against the targets.

Tox. or Toxicants	%	For toxicants not otherwise defined in these targets, the concentration of toxicants in the *water*^must not exceed the trigger values for freshwater defined in the 2000 ANZECC guidelines Table 3.4.1 for the level of protection of […] % of species.For metals the trigger value must be adjusted for hardness and apply to the dissolved fraction as directed in the table.
Visual Clarity (m) (*rivers*^) Visual Clarity (m) (*lakes*^)	% Δ	The visual clarity of the *water*^ measured as the horizontal sighting range of a black disc must not be reduced by more than […] %.
	>	The visual clarity of the *water*^ measured as the horizontal sighting range of a black disc must equal or exceed […] metres when the *river*^ is at or below the 50^{th} *flow exceedance percentile**.
	% Δ	The visual clarity of the *water*^ measured as the horizontal sighting range of a black disc must not be reduced by more than […] %.
	>	The visual clarity of the *water*^ measured as the horizontal sighting range of a black disc must equal or exceed […] metres.
E. coli / 100 ml (*rivers*^)	< m	The concentration of *Escherichia coli* must not exceed […] per 100 millilitres 1 November - 30 April (inclusive) when the *river*^ flow is at or below the 50^{th} *flow exceedance percentile**.
	<20^{th} %ile	The concentration of *Escherichia coli* must not exceed […] per 100 millilitres year round when the *river*^ flow is at or below the 20^{th} *flow exceedance percentile**.
E. coli / 100 ml (*lakes*^)	Summer	The concentration of *Escherichia coli* must not exceed […] per 100 millilitres 1 November - 30 April (inclusive).
	Winter	The concentration of *Escherichia coli* must not exceed […] per 100 millilitres 1 May - 31 October (inclusive).
Euphotic Depth (*lakes*^)	% Δ	Euphotic depth must not be reduced by more than […] %.

Appendix 2

Table 3 from (Collier et al., 1995) relating land slope, drainage and proportion of soil as clay to the efficiency of buffer strip widths expressed as percent hill slope length.

Table 3 Estimates of optimal width and performance for riparian filter strips. For definitions of slope categories see Tables 1 and 2 and the text.

SITE CHARACTERISTICS			FILTER WIDTH (% hillslope length)	FILTER PERFORMANCE (% reduction)
SLOPE CATEGORY	DRAINAGE CATEGORY	CLAY CATEGORY		
L	L	L	1	95
		M	5	90
		H	9	80
	M	L	1	95
		M	2	90
		H	4	80
	H	L	1	95
		M	1	95
		H	3	85
M	L	L	2	90
		M	7	70
		H	15	50
	M	L	1	95
		M	4	80
		H	11	55
	H	L	1	95
		M	2	85
		H	4	60
H	L	L	5	45
		M	15	30
		H	30	20
	M	L	3	60
		M	7	50
		H	13	35
	H	L	3	75
		M	4	70
		H	11	50