BEFORE THE ENVIROMENT 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	**MERIDIAN ENERGY LTD ENV-2010-WLG-000149**
and	**MINISTER OF CONSERVATION ENV-2010-WLG-000150**
and	**PROPERTY RIGHTS IN NEW ZEALAND ENV-2010-WLG-000152**
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 SUSTAINABLE LAND USE AND ACCELERATED EROSION

ON BEHALF OF WELLINGTON FISH & GAME COUNCIL

Dated: 17 February 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 Marine and Freshwater Research.

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

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 Mr P Hindrup and the "will-say" statements of Dr J Quinn and Mr A Kirk dated January 2012 and provided to me prior to witness conferencing.

6. I attended expert witness conferencing on 7 February 2012. At the time of writing this evidence no agreed record of that conferencing has been produced.

7. 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.

8. 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

9. My evidence will deal with the following:

- The effect of land use activities on waterbody ecological health;
- The effect of deposited fine sediment from erosion and other land use activities on waterbody ecological health;
- The effect of nutrients from land use activities on waterbody ecological health;
- The usefulness of riparian buffers to prevent or lessen 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.

KEY FACTS AND OPINIONS

10. In my view, there is no doubt that 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.

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

12. 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 One Plan 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.

13. 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.

14. 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.

15. Riparian buffers setback 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).

16. Thus I would recommend a minimum setback of 10 m for rivers, lakes and wetlands and a minimum setback of 20 m for regionally significant waterbodies (i.e., Sites of Significance Aquatic). Furthermore, given the sensitivity of trout to sediment and nutrient inputs, trout spawning rivers should also have a minimum setback of 20 m to avoid potential adverse effects. I would recommend buffer widths equal to the

base buffer width (10 m) plus 0.62 times the LUC average slope (from (Barling & Moore, 1994; Wenger, 1999) i.e., buffer width = 10 + 0.62 x slope (m).

17. 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.

STREAM BIOLOGICAL COMMUNITIES

18. 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.

19. 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 that 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.

20. 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.

21. 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.

22. 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. It 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). 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.

WHY LAND USE ACTIVITIES NEED TO BE MANAGED/REGULATED TO MAINTAIN WATERBODY ECOLOGICAL HEALTH

23. 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).

24. 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. 1), 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 invertebrate communities from the preferred mayfly, stonefly and caddisfly dominated communities to worm, snail and midge dominated communities. 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.

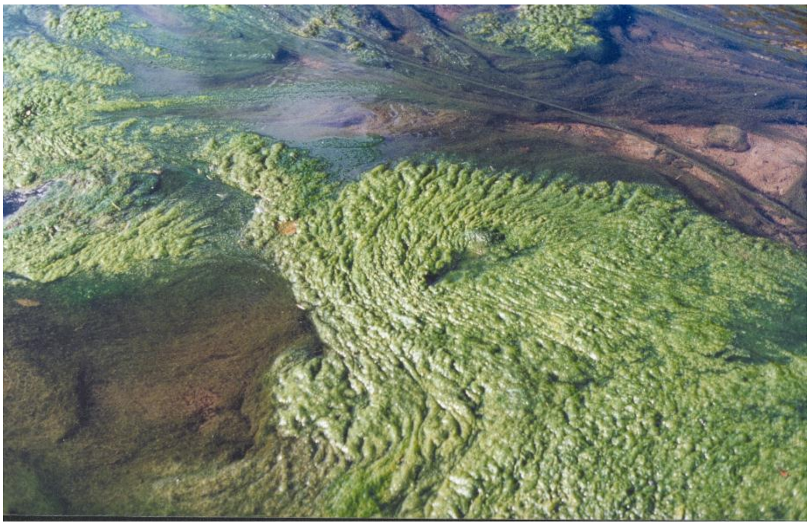

Figure 1.Excessive periphyton growth and smothered substrate.

25. 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).

26. 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. 2).

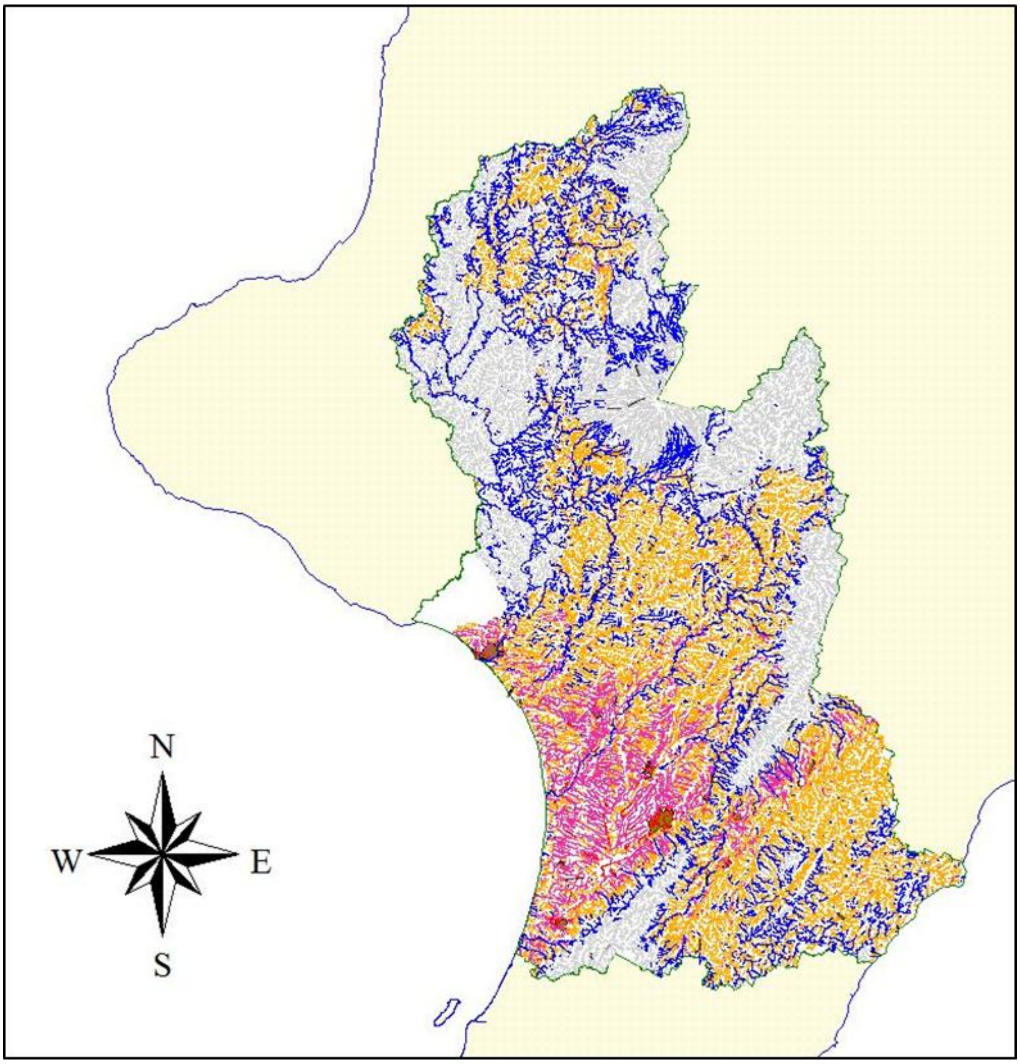

Figure 2.Percentage change in MCI with and without land use influences. Grey = -1 – 10% decrease, blue = 10 -20 % decrease, orange = 20-30 % decrease, pink = 30-40% decrease, red 40-50% decrease.

DEPOSITED SEDIMENT

27. 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.

28. The Proposed One Plan (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).

29. 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 much of the Horizons region includes steep, highly erodible, hill country that as a result of certain land use practices (e.g., native vegetation clearance, livestock access to waterways) often ends up deposited in the streams and rivers of the region, it is even more important in this region than in many others of 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.

30. 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. 3).

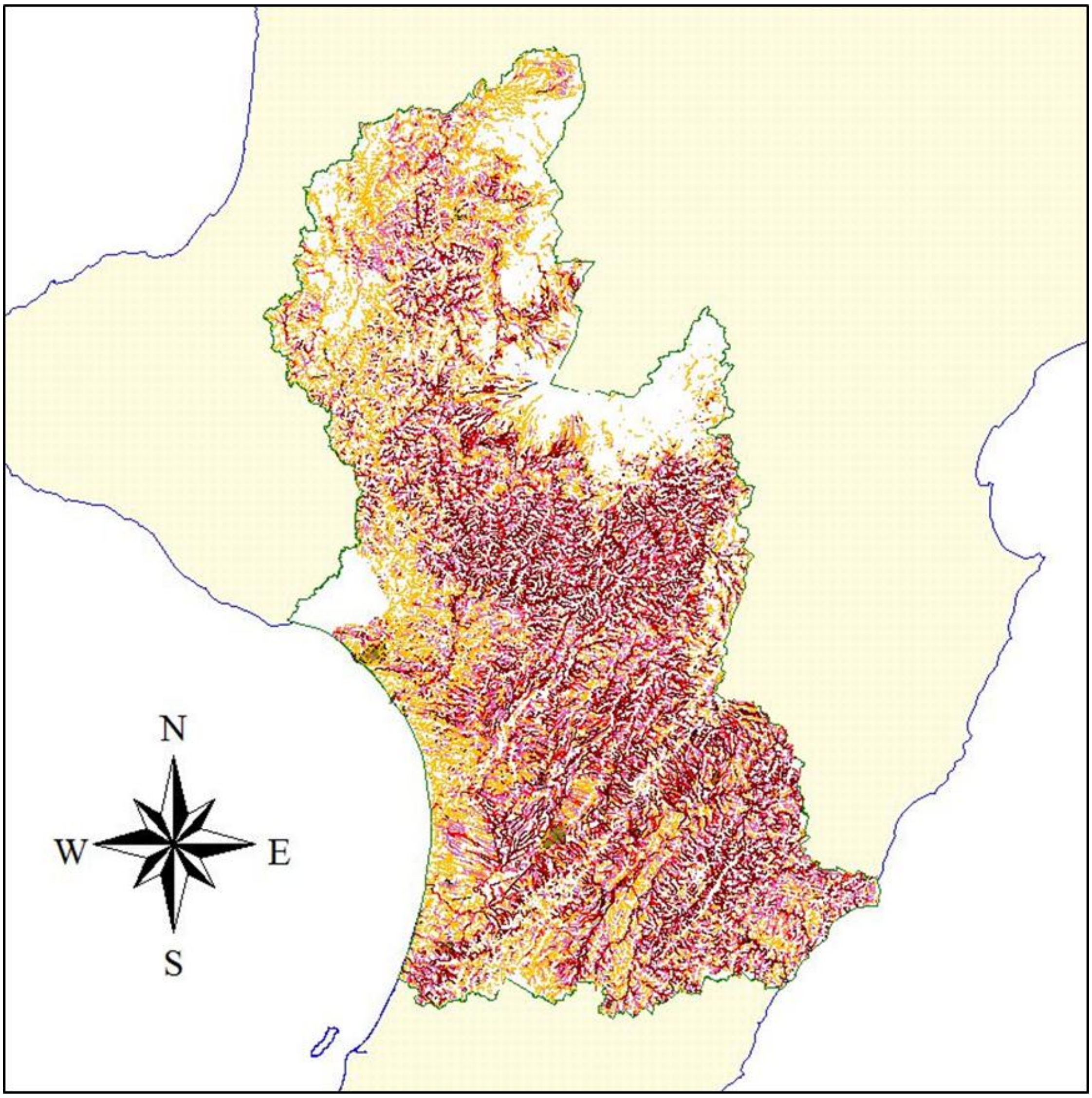

Figure 3. Percentage increase in stream deposited fine sediment with and without land use influences. Grey = -100 – 0% increase, orange = 100 - 500 % increase, pink = 500-1000 % increase, red = 1000-2000% increase, dark red greater than 2000% increase.

31. Deposited sediment can smother animals directly (Fig. 4A and 4B) 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. 4C) 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 4A. Koura struggling in deposited sediment.

Figure 4B.Banded kokopu struggling in deposited sediment.

Figure 4C. Stream substrate with interstitial spaces partly clogged with deposited sediment.

32. Sediment does occur 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 can greatly enhance 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.

33. 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; or
- Reduce resistance to disease;
- Reduce growth rates; and
- Impairs 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).

34. 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).

35. 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(Hay, Hayes & Young, 2006).

36. 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.

37. 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. 5).

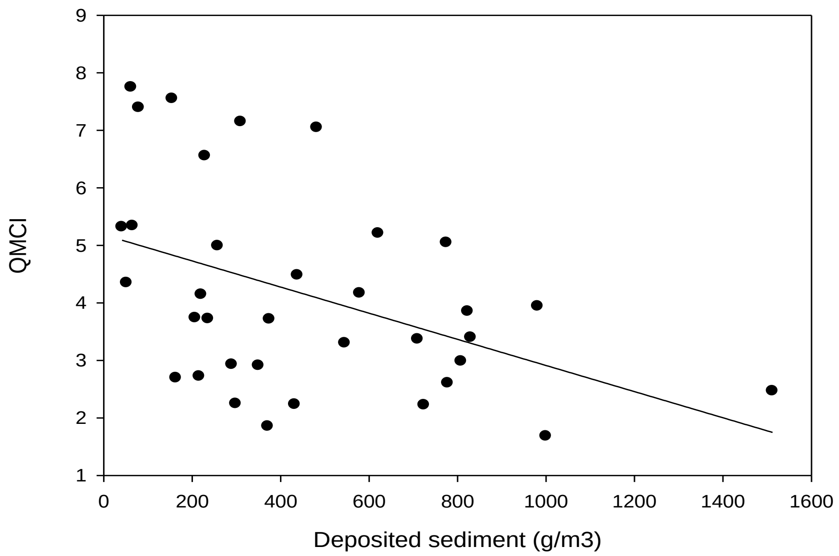

Figure 5. QMCI of invertebrate communities (higher the score more healthy the community) as a function of deposited sediment at 35 sites in the Horizons region.

38. These results (Fig. 5) 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)

39. 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).

40. 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 SOE purposes. 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. 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. I support those levels.

41. 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 s15, 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

42. The other major factor that land use activities can potentially contribute to the degradation of water quality and ecological condition in waterbodies is the run-off of nutrients. This can result in eutrophication (unnaturally high nutrient levels) that in turn can lead to excessive periphyton growth (Fig. 1). Nitrates and ammonia (NH_3) can also be directly toxic to many aquatic animals (Hickey & Martin, 2009) .

43. 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 being 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.

44. 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.

45. 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).

46. 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 actively avoiding the high nutrient rivers altogether.

47. 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).

48. 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.

49. 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).

50. I have been studying nutrients, periphyton and invertebrate communities in 24 streams and rivers in the Manawatu over the last few years (Fig. 6).

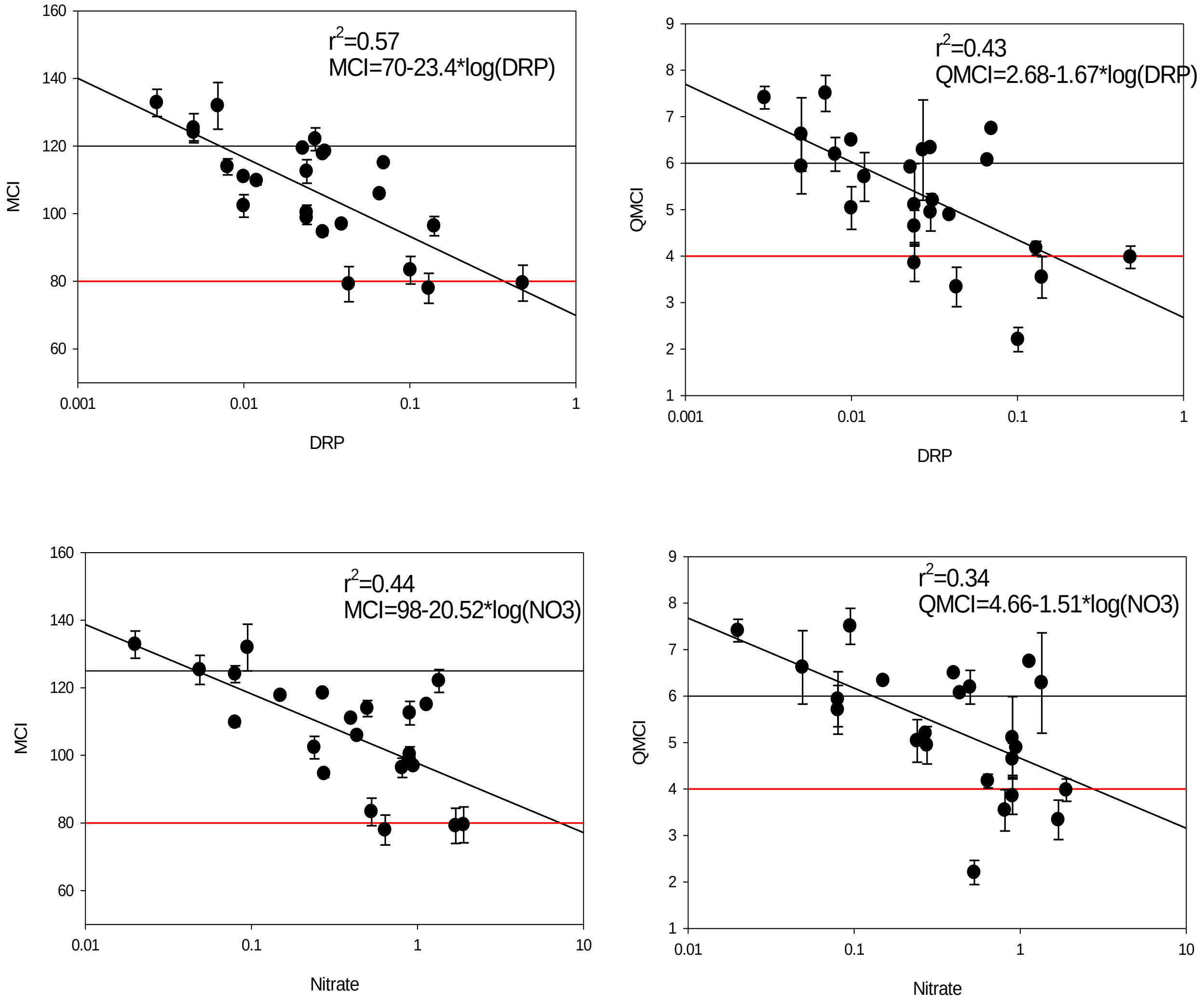

Figure 6. Water quality measured as MCI and QMCI from 24 streams plotted against mean nitrate and dissolved reactive phosphorous levels.

51. 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 proposed 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 land use activities should refer to the standards in Schedule D for assessing any potential effects of that land use.

RIPARIAN BUFFERS

52. One of the best ways to limit inputs of nutrients and/or sediment to waterways is the use of a riparian (alongside the waterbody) buffer strip (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). This 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.

53. 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. 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).

54. 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.

55. 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 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 ecosystems.

56. In recognition of the value of native fish and the importance of maintaining their habitats, the One Plan identifies Sites of Significance Aquatic under Schedule AB Surface Water Management Values. The SOS-aquatic sites were identified by examining the distribution records from the New Zealand National Freshwater Fish Database between 1991 and 2006 to identify sites where one or more of the nationally and/or regionally rare/threatened species (Table 2) were known to occur (McArthur et al, 2007).

Table Two: List of nationally and regionally rare/threatened species used for identification of SOS-A.

Giant kōkopu	Dwarf galaxiid
Kōaro	Banded kōkopu
Brown mudfish	Shortjaw kōkopu
Lamprey	Redfin bully
Bluegill bully	Whio

57. In the Biodiversity provisions of the One Plan woody vegetation within the 20m riparian zone adjacent to Sites of Significance Aquatic are identified under Schedule E as ‘at risk habitats’. Vegetation clearance, land disturbance, or cultivation, activities within these riparian zones are regulated under Rule 12-6 which will be addressed in the Biodiversity hearing. However, as discussion around the appropriateness of riparian margins is occurring in this hearing I felt it was important to discuss the importance of retaining the 20 m riparian setback for SoSA, and ensuring that activities are assessed within a consenting framework within this zone so that they do not adversely impact on this value.

58. I support the recognition of the importance of this habitat type because of the strong relationship between riparian vegetation and instream aquatic values, and I strongly support the retention of the 20m woody vegetation zone within which land use activities would need to be assessed under Rule 12-6. I understand that the 20m set-back from SOS-aquatic applies to a restricted area of the Region, and applies only to woody vegetation where it currently exists. Including the riparian margin

habitat in schedule E recognises the importance of that vegetation not just the habitat type itself, but also the linkages and processes crucial to the protection of sites of significant aquatic which maintain rare and threatened species of native fish.

59. One benefit of a 20m buffer for vegetation clearance around waterways is to provide an environment around the waterway that is more similar to its original context. Woody vegetation communities, such as forests, have a different microclimate to open country. Forest environments are shadier than open cultivated land. They are also usually more humid, less windy, have different precipitation regimes, and are buffered from large shifts in temperature.

60. Although there has been considerable research over the nature and width of riparian buffer strips necessary to maintain ecological health and/or limit the effects of land use activities in the surrounding land the actual width depends on a variety of factors such as adjoining land use practises, soil type slope and the values that require protection (Osborne & Kovacic, 1993; Quinn et al., 1993; Davies & Nelson, 1994; Weigel et al., 2000; Kiffney et al., 2003; Parkyn et al., 2003; Yuan et al., 2009; Weller et al., 2011).

61. Several international reviews of buffer width requirements to protect a cross section of instream values found widths ranged between 5 and more than 100 m (Barling & Moore, 1994; Wenger, 1999; Hickey & Doran, 2004; Lee, Smyth & Boutin, 2004; Yuan et al., 2009). There do not appear to be any equivalent reviews from New Zealand research. Parkyn (2004) has reviewed buffer zone effectiveness in agriculture but provides no specific recommendations, Parkyn et al. (2000) recommended buffer widths of 10 – 20 m to manage vegetation in Auckland streams and Collier et al. (1995) presented a table to relate land slope, drainage and proportion of soil as clay to the efficiency of buffer strip widths expressed as percentage hill slope length. A draft National Environmental Standard for forestry (Environment, 2010) also lists buffer set back widths to protect differing types of waterbody.

62. Integrating the information from the above reviews, an approach to setting a riparian buffer zone width that involves consideration of at least land use, soil type and catchment slope, and the goals of the set back (e.g., ecological health versus limiting contaminant runoff) would seem the most sensible.

63. Although there has been considerable research on buffer widths there is still a large level of uncertainty (because of the interacting effects of factors such as those listed above in 14.7) around the widths necessary to achieve particular outcomes. Yuan et al. (2009) fitted a log-linear model to compiled data from a multitude of sediment retention buffer width studies and concluded sediment trapping efficiency increases with buffer width. Dr Quinn in his evidence has highlighted one prediction of their model: around 80% sediment retention occurs with buffer widths greater than 5 m. However, the authors themselves conclude ".. attempts made to use the buffer width as a predictor for sediment trapping efficiency was not very successful." (model r2=0.29). The authors go on to state "Although sediment trapping efficiency is significantly affected by buffer width, there is still a lack of comprehensive understanding of the relationships between buffer width and trapping efficiency despite this ample research." I would therefore be reluctant to put as much weight on this model as Dr Quinn. The Natural Resources Conservation Service (NRCS) an agency of the United States Department of Agriculture that provides technical assistance to US farmers recommend minimum grass buffer widths of 8-10 m to protect water quality (Yuan et al 2009). Phosphorus removal rates increase from 53 to 98% as buffers increase from 4.6 to 27 m (Parkyn, 2004). Nitrogen removal of 70% is possible with 10 m wide strips but may need to be 20-30 m wide for 100% retention. Ecological health may require at least 10 -20 m buffers often much greater (Parkyn et al., 2000).

64. To limit sediment and nutrient runoff and to factor in slope (Wenger, 1999) in the USA and (Barling & Moore, 1994) in Australia based on their reviews recommended a base width and an addition factor based on slope.

Buffer width = 15.2 + 0.61 per 1% of slope (m) (Wenger, 1999)

Buffer width = 8 + 0.65 x slope (m) (Barling & Moore, 1994).

Collier et al. (1995) present a table to relate land slope, drainage and proportion of soil as clay to the efficiency of buffer strip widths expressed as percentage hill slope length (Appendix 2). However this may be difficult to implement in a planning framework.

65. All of the reviews, recommendations and guidelines all opt for a base or minimum buffer width, excluding any effect of slope at 8 – 10 m. Given the high level of uncertainty, a precautionary base width of 10 m would be the most sensible pragmatic option to achieve good water quality outcomes from land management. Therefore I support the Proposed One Plan Rule 12-5 as notified which established riparian buffer zones of “10m from the bed of a river, lake, or wetland, and 5m from artificial waterbodies”.

66. All of the research (as illustrated above, and in Dr Quinn’s evidence) highlight that as slope increases the ability of a buffer zone of a given width to offer protection to water quality declines. Identifying a particular slope threshold at which to increase buffer width or even assessing the highly variable slope of a hill has some practical limitations. However, given the large area of steep, highly erodible land in the Horizons Region it is clearly important to give a signal in the Plan that buffer widths on steeper country need to be wider to achieve the same water quality outcomes as on flat land. Dr Quinn in his evidence presents the riparian guidelines produced by NIWA (Collier et al. 1995) as a mechanism for accounting for slope in establishing buffer widths. I would support this approach but think it may be difficult to follow in translating percentage of hillslope into a buffer width for individual landowners. They do provide a practical solution to the issue of landowners having to measure actual slope by relating the slope class back to the LRI (Land Resource Inventory) class of the land. This could be amalgamated with the Erosion Management Area map (that utilises LUC Land Use Capability classes) that is proposed for identifying erosion prone areas. Thus for land in the EMA area, I would recommend buffer widths equal to the base buffer width (10 m) plus 0.62 times the LUC average slope (from (Barling & Moore, 1994; Wenger, 1999) i.e., buffer width = 10 + 0.62 x slope (m).

67. Dr Quinn, expert for Horizons, reviews and presents similar data on the benefits of buffer zones to reducing land use impacts on the ecological condition of streams. He also highlights the difficulty of coming up with a single width to meet all possible

situations, identifying, as I do above, that land use, soil type, slope and the role of the buffer zone are all important in determining the appropriate width.

68. Although considering a wide range of information sources Dr Quinn does rely quite heavily on the comprehensive review of Yuan et al. (2009), to the extent that he concludes 5 m is an appropriate buffer width for permanent waterways greater than 1 m and 10 m is appropriate for trout spawning and Sites of Significance Aquatic. I do not believe a decision based strongly on the Yuan et al. (2009) study alone is warranted, as I have discussed above under section 63. Their review is comprehensive, but the model they fit is weak (r^2=0.29), only deals with the sediment trapping role of buffer zones and do not identify 5 m as a critical buffer width. Dr Quinn has chosen the narrowest buffer width (5 m) from this range. The limitations of the study are clearly discussed in their paper and they do not have the confidence in their own work to make any specific recommendations.

69. I believe given the large level of uncertainty around the Yuan et al. (2009) study, the multiple goals of the buffer zone,(reduction in sediment, nutrients, pathogens, temperature and light), the potential influence of slope and soil type (requiring wider buffer widths) that the setback distances I have proposed above have a higher probability of achieving the desired outcomes, while still being pragmatic.

70. The other issue that Dr Quinn and I agree on is the need to offer greater protection, with respect to wider buffer widths, in receiving waterbodies that may have more sensitive organisms such as trout spawning rivers, and regionally significant waterbodies (i.e., Sites of Significance Aquatic). However, in this respect Dr Quinn is proposing 10m while I am proposing 20m. As discussed above in the section on deposited and suspended sediment native fish and trout are strongly affected by decreases in water clarity, food resources, loss of habitat and the smothering of eggs. Given the sensitivity of trout and native fish to sediment and other contaminants as well as the need to retain an intact vegetated buffer zone, I feel that a more precautionary approach of 20 m in regards to the appropriate width of buffer zones is appropriate while still being pragmatic.

71. I understand that there may be an issue of scope around a buffer width of 20 m I would therefore strongly recommend as wide a buffer zone, up to 20 m, under the constraints of scope as is possible.

72. To summarise there is considerable research on buffer widths to minimise the effects of land management on water quality. Clearly buffers are effective in minimising the effects of land use activities on waterways. However, despite all the research there is still considerable uncertainty around the exact width necessary to account for land use, soil type, catchment slope, and the goals of the set back in providing that protection. I believe a precautionary, but pragmatic view, similar to that adopted by a number of other land use management agencies around the world is sensible with a minimum setback distance of 10 m from all lakes, wetlands and waterbodies. This distance should be increased in areas of erosion management to10 + 0.62 x slope (m). The distance should also be increased to 20 m in trout spawning or Sites of Significance (Aquatic).

SMALL AND EPHEMERAL STREAMS

73. Considerable focus in water quality management in agricultural land focuses on larger waterbodies. For example the clean stream 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. 7).

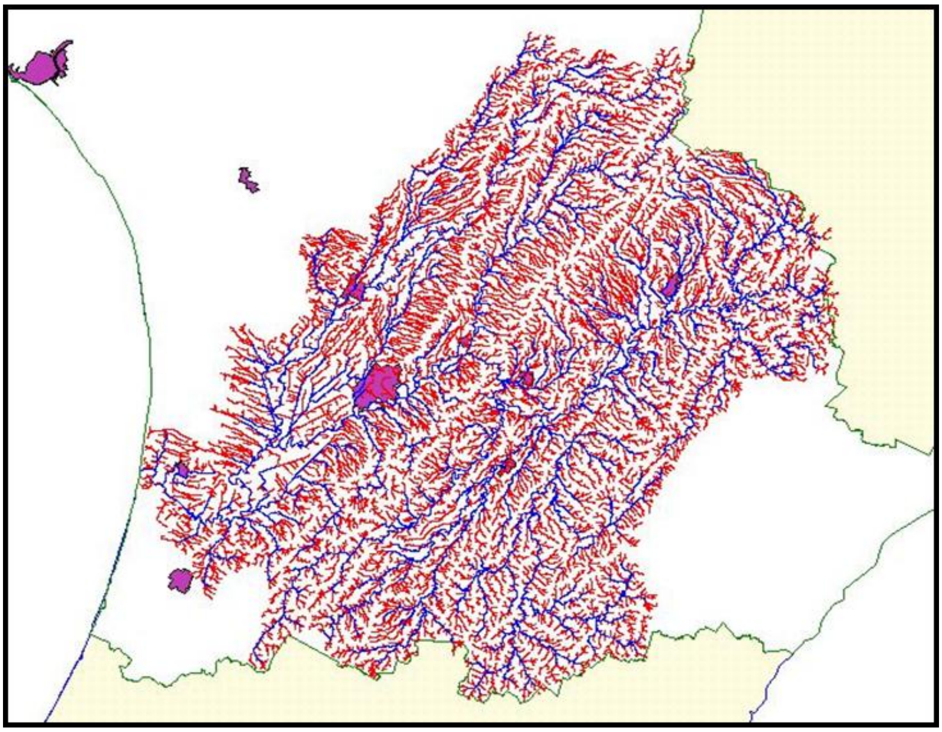

Figure 7.Small streams (in red) and other streams (~ greater than a stride and deeper than a red band) in blue for the Manawatu catchment.

74. 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).

75. 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 8 below show that, for 960 streams and rivers sampled in the lower North Island that the highest diversity occurs in the smaller streams.

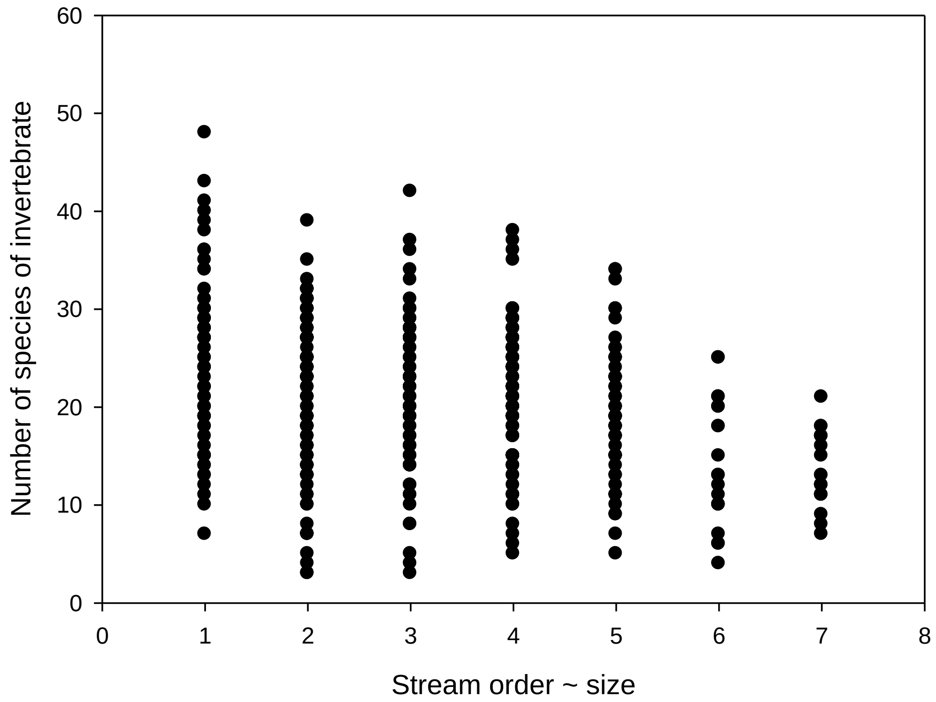

Figure 6.Number of taxa collected in 5 Surber samples in 960 streams and rivers in the lower North Island as a function of stream order (this provides a good approximation to stream size as higher order streams are larger).

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

CONCLUSION

77. 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. Therefore I recommend that the land and water chapters are linked with respect to the objectives and standards of the plan.

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

79. The Proposed One Plan does not provide enough guidance on acceptable levels of deposited sediment. The proposed addition to Schedule D (presented in Appendix 1) should go some way to correcting this.

80. Management of both nitrogen and phosphorus in all waterways is important to avoid the adverse effects of nutrient enrichment. Concentrations of nutrients presented in Schedule D are a good approximation to levels that are highly likely to lead to maintenance and where degraded improved ecological health if concentrations are restricted to those levels.

81. Improved ecological health will only result from managing both sediment and nutrients.

82. Riparian buffers will assist with managing both sediment and nutrients. Establishing the appropriate width of these must consider surrounding land use, soil type and catchment slope, and the goals of the set back (e.g., ecological health versus limiting contaminant runoff).

83. Thus I would recommend a minimum setback of 10 m for rivers, lakes and wetlands and a minimum setback of 20 m for regionally significant waterbodies (i.e., Sites of Significance Aquatic). Furthermore, given the sensitivity of trout to sediment and nutrient inputs, trout spawning rivers should also have a minimum setback of 20 m to avoid potential adverse effects. I would recommend buffer widths equal to the base buffer width (10 m) plus 0.62 times the LUC average slope (from (Barling & Moore, 1994; Wenger, 1999) i.e., buffer width = 10 + 0.62 x slope (m).

84. As management of small and ephemeral streams is critical for management of downstream larger waterways and biodiversity, this .protection and management needs to be given to all ephemeral streams greater than 1 m and all permanently flowing streams.

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**.

*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^*)

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
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	20	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	20	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	20	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	20	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	20	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	20	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)**	**<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**
	Lower Mangahao (Mana_9e)	7 to 8.5	0.5	22	3	70	2	5	120	0.010	0.444	<u>20</u>	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	<u>20</u>	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	<u>15</u>	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	<u>20</u>	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	<u>20</u>	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	<u>20</u>	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	<u>20</u>	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)**	**<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**
	Turitea (Mana_11b)	7 to 8.2	0.5	19	2	80	1.5	5	50	0.006	0.070	<u>15</u>	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	<u>15</u>	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	<u>25</u>	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	<u>25</u>	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	<u>25</u>	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	<u>20</u>	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	<u>20</u>	100	0.400	2.1	95	2.5	30

*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
	Lower Oroua (Mana_12c)	7 to 8.5	0.5	24	3	70	2	5	200	0.015	0.444	<u>25</u>	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	<u>20</u>	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	<u>25</u>	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	<u>25</u>	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	<u>15</u>	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	<u>25</u>	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	<u>20</u>	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	<u>25</u>	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*^)

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)	<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
	Pungapunga (Whai_2e)	7 to 8.5	0.5	19	2	80	1.5	5	120	0.010	0.110	<u>20</u>	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	<u>15</u>	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	<u>20</u>	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	<u>20</u>	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	<u>20</u>	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	<u>25</u>	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	<u>25</u>	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	<u>20</u>	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**
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**	**>**	**<**	**<**	**Chl*a* (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/m³)**		**TP (g/m³)**	**TN (g/m³)**	**Ammoniacal Nitrogen (g/m³)**	**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 Header	Sub-header	**Full Wording of theTarget**
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(°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 (*rivers*^)	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/m^3) (*lakes*^)	<	The annual average concentration of total phosphorus (TP) must not exceed […]grams per cubic metre.
SIN (g/m^3)	<	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/m^3) (*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/m^3) (*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/m^3) (*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*^).
Tox. or Toxicants	%	For toxicants not otherwise defined in these targets,

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.

		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 50th *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 50th *flow exceedance percentile**.
	<20th %ile	The concentration of *Escherichia coli* must not exceed […] per 100 millilitres year round when the *river*^ flow is at or below the 20th *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