BEFORE THE HEARINGS PANEL

IN THE MATTER	**of hearings on submissions concerning the Proposed One Plan notified by the Manawatu-Wanganui Regional Council**

SECTION 42A REPORT OF MRS KATHRYN JANE MCARTHUR

ON BEHALF OF HORIZONS REGIONAL COUNCIL

CONTENTS

1. INTRODUCTION

1.1 Qualifications and experience

1. My full name is Kathryn Jane McArthur. I hold a Bachelor of Science degree with Honours (2nd class) in Ecology from Massey University. My area of post-graduate research was the influence of land use on freshwater macroinvertebrate communities in the Manawatu-Wanganui Region. I am currently enrolled as a Masterate candidate in Applied Science, majoring in Natural Resource Management. I have more than 7 years post-graduate experience working in the field of freshwater sciences. I have been a member of the New Zealand Freshwater Sciences Society (formerly the NZ Limnological Society) since 2001 and I am currently a representative on the National Steering Committee for the long-term management of *Didymosphenia geminata* (Didymo). I have been an active participant in the Regional Council Surface Water Integrated Management interest group (SWIM) since joining Horizons in July 2006 and I am the champion and co-champion of two Envirolink Tools projects on updating aquatic plant and periphyton guidelines and developing methods to measure and guidelines to assess sedimentation in rivers.

2. Prior to my employment with Horizons I worked as a Resource Management and Compliance Officer for the Wellington and Taranaki Fish and Game Councils, as a Laboratory Supervisor at Massey, and as a contractor (through Massey University) for both Greater Wellington and Horizons Regional Councils in the fields of native freshwater fish management and aquatic biomonitoring. Before specialising in freshwater ecology I worked in the fields of captive management of native and exotic birds and fish and veterinary nursing. I hold a diploma in Animal Science from the New Zealand Veterinary Association.

3. I have worked for Horizons since July 2006 and my current role is Senior Environmental Scientist – Water Quality. In this role I lead the State of the Environment (SoE) Water Quality and Aquatic Biodiversity programmes, project managing and coordinating input from Council staff and external science providers. I have authored, with Maree Clark, a report on the contributions of nutrients to water from point and non-point sources for the Region in 2007 and reviewed and aligned the Council's SoE water and aquatic biodiversity monitoring programmes in 2008. I also led the investigation of water quality in the Mōwhānau Stream catchment in 2008 and 2009.

4. A core function of my role is to undertake technical assessments of environmental effects for resource consent and compliance enforcement activities. In this role I have

presented evidence at many resource consent hearings, participated in a number of Environment Court mediations and appeared as an expert witness before the District Court for enforcement proceedings relating to the effects of activities on water quality and aquatic biodiversity. I have also undertaken assessments of effects for water abstraction permits, river restoration projects, river engineering, structures in the bed of rivers and lakes, and permits for land use with the potential to affect water quality and/or aquatic biodiversity.

5. I have been involved in technical support for the Proposed One Plan (POP) since starting as an Environmental Scientist in July 2006. I coordinated and finalised the Water Management Zones framework and, with Dr Jon Roygard, Dr Olivier Ausseil and Maree Clark, I authored the technical report. I have also had input into the development of water body values and water quality standards and contributed to the development of the technical reports on these subjects, authored by Dr Olivier Ausseil and Maree Clark. I have had considerable input into the development of Schedule D of the POP and have assisted in compiling the Horizons Council submission and the further development of Schedule H as a result of hearings on the Coast Chapter of the Plan.

6. My key areas of technical input to the Proposed One Plan were in the areas of Water Management Zones, aquatic biodiversity, Ecosystem and Recreational and Cultural value groups, the water quality standards associated with these values and the relationship of nutrient inputs to water quality and the effects on water quality and water quality standards. With Dr Jon Roygard I co-authored a technical report entitled ‘A framework for managing non-point source and point source nutrient contributions to water quality’, which provided some of the technical basis for the proposed control of land use approach, in relation to water quality. This framework provided further technical advice on the management of point source discharges to water. I also undertook a review of the state of knowledge on aquatic biodiversity in the Region and completed the identification of Sites of Significance – Aquatic (SOS-A), authoring a report on this with Maree Clark and Joe McGehan. With James Lambie I authored a technical report on recreational fishery and spawning values and I also had technical input into the Rivers Works Environmental Code of Practice and Beds of Rivers and Lakes aspects of the Proposed One Plan.

7. The scope of my evidence includes the definition and identification of the Ecosystem and Recreational and Cultural value groups, the development of water quality standards and how they relate to the values, the state and trend of water quality in the Region, the effect of point and non-point source nutrient inputs on water quality standards and

values, limiting nutrients for periphyton growth, an assessment of the water quality and aquatic biodiversity in the target catchments, and an overview of the recommended changes to schedules D and H.

8. With regard to water body values, the scope of my expertise and evidence lies largely within the areas of Ecosystem and Recreational and Cultural value groups. I am unable to comment specifically on Mauri or Sites of Significance – Cultural (SOS-C), and my expertise on Contact Recreation, Amenity, Native Fishery, or Aesthetic values is limited to issues relating to water quality, aquatic biodiversity or trout fisheries. Additionally, I am unable to provide evidence on the Water Use, or Social and Economic value groups with the exception of relevant information on water quality, or where there is potential for these values to impact on the Ecosystem and Recreational and/or Cultural value groups.

9. In the area of nutrient management of surface water quality, my expertise is limited specifically to the measurement, state, trends and effect of nutrients and other contaminants on water quality and/or water body values and in particular point source contaminants. I am not an expert on nutrient transport through the land, attenuation between the landscape and surface water, or the sources of non-point source nutrient enrichment. Any questions on these matters should be directed to Dr Roygard and other experts providing evidence on these matters.

10. In combination with my colleagues Maree Clark and James Lambie, it is within the scope of my expertise to provide any further information the Panel might require on the definition of Water Management Zones, Schedule D and H recommended changes, development and use, Beds of Rivers and Lakes, River Works Environmental Code of Practice special standards and the relationship between Schedules H and D.

11. I have read and agree to comply with the Environment Court's practice note 'Expert Witnesses – Code of Conduct'. It is my intent that the duty to the Environment Court contained in that code of conduct will be treated as a duty to the Hearing Panel for the purposes of this hearing.

2. EXECUTIVE SUMMARY OF EVIDENCE

12. Water body values and water quality standards of the Proposed One Plan (POP) have been developed based on an extensive range of technical material, scientific analyses and policy input. This report presents the science underpinning the values and standards components of the Plan and provides linkages to associated s42A reports from Horizons Officers and external experts.

13. This report also draws together technical analyses and reports (both internally and externally authored) of related water quality and aquatic biodiversity research undertaken in the Region, where that research relates to water body values or water quality outcomes.

14. This report is divided into seven sections:
    i. Water body values
    ii. Freshwater quality and aquatic ecosystem health: state and trends of rivers and streams
    iii. Water quality standards: rivers and streams
    iv. Lake water quality
    v. Water Quality in the Coastal Marine Area (CMA)
    vi. Sources of contaminants and effects on values
    vii. Target catchments for FARM strategy management.

2.1 Water body values

15. Four value groups and twenty-two values are proposed for the Region's water bodies. Some values apply to all water bodies within a Water Management Zone or Sub-zone and others apply to identified river reaches or sites. The values, which are applied spatially over the Water Management Zones framework, underpin the objectives, policies, rules and non-regulatory methods for the sustainable management of water resources and land use activities that have the potential to affect water body values.

16. The definition of water body values is a regionally relevant translation of Schedule 3 of the Resource Management Act (1991) into management objectives. The group of management objectives governing a water body, determined by the values applicable to that water body, give a clear focus for Horizon's approach to activities that may affect that water body. The use of Water Management Zones provides a geographical framework for the application of values and water quality standards in a locally appropriate manner.

17. Values are divided into Ecosystem, Recreational and Cultural, Water Use and Social/Economic groups. This evidence focuses on the Ecosystem and Recreational and Cultural values. Recommended changes to water body values are provided.

2.2 Freshwater quality and aquatic ecosystem health: rivers and streams

18. Horizons undertakes several integrated monitoring programmes. Information from all programmes was used in the assessment of water quality state and trends throughout the Region. Notwithstanding headwaters of river catchments, water quality in a large number of the Region's rivers is poor, affected by faecal contamination, nutrient enrichment, low water clarity, and poor aquatic ecosystem health and biodiversity.

19. Long-term trend analysis shows significant increasing nutrient concentration at a number of sites, significant decreases in water clarity, and increases in turbidity. Shorter-term analysis identified some decreasing trends in nitrogen in recent years, particularly in the Manawatū catchment. Although decreasing trends are positive signs, the state of water quality and aquatic ecosystem health is still very poor in catchments with high proportions of pastoral land use or significant point source inputs. The state of Horizons' rivers is poor when compared to the state of water quality nationally and many sites do not comply with the POP water quality standards or nationally accepted guidelines.

20. Catchments worst affected by poor water quality are: the upper and lower Manawatū, Mangatainoka, Mākurī, the lower Oroua, Lake Horowhenua, the lower Hautapu, coastal Rangitīkei, Whangaehu and Waikawa. Water quality in the Whanganui and Rangitīkei Rivers is generally good in the upper and middle catchment with respect to nutrient loads, but has poor visual clarity. Native fish communities are declining nationally and fish diversity is regionally poor in catchments with pastoral or urban land cover.

2.3 Water quality standards: rivers and streams

21. Water quality standards are an integrated management tool, applied through the objectives of the POP, to provide for the values of each Water Management Sub-zone. Some water quality standards apply to all water bodies in the Region, others are more sub-zone specific, depending on the location of the values. Numerical water quality standards were defined parameter by parameter for each of the values where there was supporting science for a standard. Then the standards for each value were compared and the highest standard required to meet all of the values in that sub-zone was applied for each parameter. The key value for the development of water quality standards in the

Ecosystem Group was Life-Supporting Capacity. Standards providing for this value will also provide for the other Ecosystem values. Contact Recreation, Trout Fishery and Trout Spawning were used in the determination of standards for Recreational and Cultural values as these standards will also provide protection for other values (eg. Aesthetic or Amenity).

22. Nutrient standards for nitrogen (N) and phosphorus (P) were assigned to each sub-zone at levels designed to give effect to the periphyton biomass standards for the values of the sub-zone. Both nitrogen and phosphorus standards are required to control periphyton growth, year round and at all flows less than flood flows, as nutrient limitation of only phosphorus cannot be relied on as a management tool to control periphyton. Nutrient standards were determined on a sub-zone by sub-zone basis to provide for the desired periphyton biomass standards by a combination of: 1) the NZ Periphyton Guideline model; 2) expert opinion from Dr Barry Biggs; 3) consultation of the ANZECC nutrient guidelines; and 4) assessment of the current nutrient status. Standards were modified to ensure cumulative effects on downstream receiving environments were avoided.

23. The POP approach to numerical standards differs from the Manawatū Catchment Water Quality Regional Plan (MCWQRP) approach by: 1) having clear links between values, standards and effects; 2) applying standards in a locally relevant manner throughout the Region; 3) widening the range of contaminants and biological indicators (eg. nitrogen, Macroinvertebrate Community Index (MCI)); and 4) applying standards to all activities that affect water, rather than just point source discharges. Recommended changes to water quality standards for rivers and streams are included within this report.

2.4 Lake water quality

24. Lake water quality naturally varies as a result of seasonal influences, physical characteristics, trophic condition (related to nutrient concentration and algal biomass) and predominant water source (surface or groundwater). Regional water quality monitoring of lakes has been limited, with the exception of Lake Horowhenua. Available monitoring results suggest most coastal lakes are in an accelerated state of eutrophy (enrichment by nitrogen and/or phosphorus) and are unlikely to meet the POP standards for water quality due to their trophic condition. Deep and shallow lakes function differently and naturally have different trophic conditions; deep lakes are more mesotrophic and shallow lakes more eutrophic. Standards for water quality should be relevant to lake type.

25. Ammoniacal-N is elevated in Lake Papaitonga and occasionally in Lake Horowhenua to levels that have the potential to be toxic to aquatic life, with pH range occasionally above levels that will cause ammoniacal-N to become unionised ammonia. Lakes Pauri, Wiritoa, Dudding and Horowhenua are generally safe for contact recreation with regard to faecal contaminants, while Bason Reserve and Lakes Westmere, Virginia and Papaitonga are often not suitable. However, trophic condition and nutrient cycling cause algal blooms which can include potentially toxic cyanobacteria, significantly reducing the Contact Recreation and Amenity value of many of the Region's lakes every year. Further SoE monitoring of lakes is required to determine trophic status and to monitor for changes in trophic condition over time. Recommended changes to lake water quality standards are included in this report.

2.5 Water quality in the Coastal Marine Area (CMA)

26. Two key management units were created for the CMA: 1) the Seawater Management Zone; and 2) Estuary Water Management Sub-zones. Values and standards previously applied to these areas in Schedule D of the POP have been relocated to Schedule H.

27. Coastal water quality data collected from bathing beaches over the 2007/2008 summer showed coastal waters were highly enriched by both phosphorus and nitrogen, significantly exceeding POP water quality standards at all sites. It is likely that coastal waters are predominantly affected by the discharge of nutrients and sediment from the Region's large river catchments, which carry some of the highest nutrient loads in the country. The risk of eutrophication in the Region's estuaries is limited by the physical structure of the estuaries. This limitation may change due to high sediment loads carried to estuaries from rivers, potentially increasing the risk of eutrophication effects in future.

28. Most sites monitored in the CMA (with the exceptions of Hokio and Kai Iwi beaches) met the POP standards for Contact Recreation, but all sites exceeded the POP standards for Shellfish Gathering. Turbidity was often high. Regular monitoring is required, with concurrent conductivity and nutrient sampling, to better determine the sources of nutrient enrichment in coastal waters. Recommended changes to values and standards in Schedule H are included in this report.

2.6 Sources of contaminants and effects on values

29. Sources contributing to poor water quality vary between natural, point source and non-point source inputs depending on catchment geology, flow regime, land use and the scale

of point source discharges. A large number of Water Management Sub-zones do not meet the POP standards for nutrients or faecal indicator bacteria at different flows as the result of point and/or non-point source inputs. Point source discharges that contribute to sub-zone wide effects on nutrient and *Escherichia coli* concentrations include: Dannevirke sewage treatment plant (STP), Pahiatua STP, Palmerston North STP, Feilding STP, Taihape STP, Riverlands, Hunterville STP, Marton STP, Taumarunui STP, Winstone Pulp and the combined effects of Ohakune and Raetihi STPs. Discharges that have more localised effects include: Eketahuna STP, Woodville STP, Foxton STP and Waiouru STP.

30. There are a large number of sub-zones that are adversely affected by non-point source contamination, (eg. the Manawatū catchment including tributaries, Coastal Rangitīkei and some tributaries, Whanganui mainstem and some tributaries, Whangaehu mainstem and some tributaries and the Turakina, lower Ohau, coastal lakes, Waikawa, and East Coast rivers).

31. Some sub-zones affected by non-point source contamination are included in the POP as target catchments for the management of intensive land use operations. Sub-zones affected by non-point source pollution that are not included as target catchments are generally affected by more extensive pastoral land use (eg. sheep and beef farming) rather than intensive land use.

32. The effects of reductions in nutrient load to meet water quality standards were examined in two case study catchments, the upper Manawatū and Mangatainoka Rivers. In these catchments, significant improvements in periphyton biomass were predicted with the implementation of nutrient load restrictions. This reduction would also improve water bodies for Life-Supporting Capacity, Contact Recreation and Trout Fishery values.

33. Non-point source faecal inputs are classed as direct (from stock access to water) or indirect (from run-off from the landscape). Direct faecal inputs negatively impact on contact recreation because they often occur at low flows when swimming is common. Indirect faecal inputs can affect Contact Recreation and Shellfish Gathering values for longer periods while flows recede and rivers clear.

2.7 Target catchments for FARM strategy management

34. Resource consent will be required for intensive land uses such as dairy farming, irrigated sheep and beef farming, cropping or commercial vegetable growing within target

catchments. The POP defines nitrogen output limits for intensive land uses in these catchments to achieve water quality outcomes via Rule 13-1. The output limits are to be phased in over time depending on Water Management Zone. Key issues for each target catchment are summarised below. Output limits for each target catchment, based on the Land Use Capability (LUC) class are included in this report.

35. The **Mangapapa** Stream is a small tributary of the Mangaatua and Manawatū Rivers. Soluble inorganic nitrogen (SIN), dissolved reactive phosphorus (DRP) and *E. coli* regularly exceed POP standards and degrade water quality, contributing loads to the Manawatū River above the Gorge. Periphyton biomass can be high, and aquatic macroinvertebrate health is low in some areas. Predominant catchment land uses are Sheep & Beef (50%), Native Cover (Ruahine Forest Park 26%) and Dairy (16%). There are seven dairy effluent consents. Contact Recreation, Stockwater, Life-Supporting Capacity and Trout Spawning values are potentially compromised by poor water quality.

36. The **Mōwhānau** is a small, slow-flowing coastal stream north of Whanganui. Soluble inorganic nitrogen, DRP and *E. coli* regularly exceed standards, degrading water quality and contributing to loads in the Mōwhānau Estuary and CMA. The stream is affected by prolific aquatic weed growth and is heavily sedimented. Predominant land use is Sheep & Beef (73%) and there is little woody vegetative cover. Dairy farming is estimated to be less than 20% of the land use and there is only one dairy effluent discharge consent. Contact Recreation, Stockwater, Amenity, Life-Supporting Capacity, Shellfish Gathering and potentially the Site of Significance – Aquatic values are compromised by poor water quality.

37. The **Mangatainoka** River is a major tributary of the upper Manawatū River. Soluble inorganic nitrogen is extremely high from non-point sources (>99%), DRP is elevated at high flows and is largely non-point sourced (84%) and *E. coli* is generally within the standards but increases downstream. Periphyton occasionally exceeds the standards, aquatic macroinvertebrate health declines downstream and cyanobacterial blooms can be pervasive at a number of sites in the catchment when flows are low. Sheep & Beef is the predominant catchment land use (51%), followed by Dairy (28%) and Native Cover (18%). There are 97 dairy discharge consents. Contact Recreation, Life-Supporting Capacity, Regionally Significant Trout Fishery, Stockwater, Amenity, Aesthetic and potentially Site of Significance – Aquatic values are compromised by poor water quality. The year 20 output loss limits predicted from the LUC classes are approximately 13% greater than the Standard load limit.

38. The **upper Manawatū** target area is part of a large catchment draining the Ruahine and Puketoi Ranges to the Hopelands SoE site. Soluble inorganic nitrogen and DRP significantly exceed the standards and are generally non-point sourced (98% and 80% respectively). *Escherichia coli* exceeds safe swimming standards in some tributaries at low flows and in all water bodies in the catchment when flows are elevated. Periphyton proliferation and cyanobacterial blooms are common, the aquatic macroinvertebrate health is low (declining downstream) and migratory native fish are almost absent from the catchment. Land use is predominantly Sheep & Beef (69%) with some Dairy (16%) and Native Cover (10%). There are 148 dairy discharge consents within the target area. Contact Recreation, Life-Supporting Capacity, Stockwater, Regionally Significant Trout Fishery, Amenity, and potentially Sites of Significance – Aquatic values are compromised by poor water quality and sediment loads. The year 20 output loss limits predicted from the application of Table 13.2 of the POP will be approximately 110% greater than the Standard load limit and may exceed the current Measured load if land use intensifies to maximum LUC potential.

39. **Lake Horowhenua** is the Region's largest coastal dune lake and has considerable biodiversity and cultural values. Total and soluble nitrogen and phosphorus regularly exceed POP standards, ammoniacal-N is also high. Nutrient contamination is non-point sourced, although point sources have contributed significantly in the past. *Escherichia coli* are generally within safe swimming levels, indicating nutrient contamination may not be sourced from animal-based intensive land uses and may result from other intensive land uses in the catchment such as commercial vegetable production. The lake is hypertrophic (extremely nutrient enriched); algal and cyanobacterial blooms occur regularly and are frequently toxic. Land use in the catchment is dominated by Sheep & Beef (51%), Dairy (18%), urban land cover (Levin 10%) and Cropping/Horticulture (7%). There are ten dairy discharge consents in the target area. Contact Recreation, Life-Supporting Capacity, Amenity, potentially Site of Significance – Aquatic and coastal Shellfish Gathering values are compromised by poor water quality and the hypertrophic state of the lake.

40. The **Waikawa** is a small catchment at the southern border of the Region. Soluble inorganic nitrogen, DRP and *E. coli* all increase significantly between the upper and lower catchment monitoring sites, exceeding the standards; contamination is from non-point sources. The Waikawa has high aquatic biodiversity values because of the forested headwater habitat in close proximity to the sea; however periphyton proliferation and cyanobacterial blooms are common. Land use is dominated by Native Cover (35%), Sheep & Beef (26%) and Dairy (24%), with seven dairy effluent discharge consents in the

catchment. Contact Recreation, Stockwater, Amenity, Life-Supporting Capacity, coastal Shellfish Gathering and potentially Sites of Significance – Aquatic values are compromised by poor water quality.

41. The **Manawatū above upper Gorge** target catchment exceeds SIN and DRP POP standards most of the time, although concentrations are lower than the Manawatū at Hopelands site upstream. Median *E. coli* is similar to the Manawatū at Hopelands, and is elevated at high flows. The vast majority of the contaminants are non-point sourced, with a minor contribution from Woodville STP. The upper Gorge site has been subject to severe cyanobacterial blooms over the 2008/2009 summer and MCI is often below the recommended standard, indicating impacted aquatic ecosystem health. Catchment land use is predominantly Sheep & Beef (48%) and Dairy (41%), and there are 24 dairy effluent discharge consents in the catchment. Contact Recreation, Amenity, Aesthetic, Stockwater, Regionally Significant Trout Fishery, Life-Supporting Capacity and potentially Sites of Significance – Aquatic values are compromised by poor water quality and cyanobacterial blooms.

42. The **Waitarere** target catchment is comprised of coastal sand country to the south of the Manawatū Estuary, and includes wetlands, lagoons and drainage systems. No monitoring data exists for the water bodies; water quality can only be assumed to be similar to other coastal dune lakes and coastal areas. The large number of wetlands means there are significant biodiversity values associated with this target catchment. Water body values potentially compromised by land use influences on water quality include Contact Recreation, coastal Shellfish Gathering, Amenity, Stockwater and Life-Supporting Capacity. Catchment land use is predominantly Exotic Cover (48%) and Dairy (34%), and there are three dairy effluent discharges.

43. The **Lake Papaitonga** target catchment encompasses the surface water catchment surrounding the Lake, outflowing Waiwiri Stream and coastal sand country and wetlands to the west of the Lake. Total and soluble nitrogen are extremely elevated, as is ammoniacal-N. Total and soluble phosphorus and *E. coli* are also high. Aquatic and terrestrial biodiversity values are significant for the lake, wetlands and outflow stream, and for the forested remnant on the margin of the lake. Land use is predominantly Sheep & Beef (54%) and Dairy (19%). There is one dairy effluent consent in the zone. Contact Recreation, Amenity, Stockwater, coastal Shellfish Gathering and potentially Sites of Significance – Aquatic values are compromised by poor water quality.

44. **Other coastal lakes** have limited monitoring data and the interactions between ground and surface water are complex; hydrologic regimes are not well described. Contact Recreation, Amenity, Stockwater and coastal Shellfish Gathering values are affected by poor water quality and cyanobacterial blooms throughout these catchments. The **Kaitoke Lakes** target catchment comprises the lakes, wetlands and drainage systems south of the Whanganui River. Nutrient concentrations are elevated above standards but higher in Lake Pauri than in Lake Wiritoa. *Escherichia coli* is generally within standards, although cyanobacterial blooms often occur and are frequently toxic. Land use is predominantly Sheep & Beef (65%) and Exotic Cover (25%), with only 4% of the catchment land use in Dairy and one dairy effluent discharge consent. The **Southern Whanganui Lakes** target catchment comprises the lakes, wetlands and drainage systems between the Kaitoke Lakes and the Rangitīkei River. Nitrogen concentrations in Lake Dudding are elevated, but *E. coli* is generally within POP standards. Cyanobacterial blooms occur and are toxic at times. Land use is predominantly Sheep & Beef (54%) and Exotic Cover (36%), with 9% of the zone in Dairy. There are ten dairy effluent discharge consents. **Northern Manawatū Lakes** is comprised of lakes, wetlands and drainage systems in the Himatangi sand country north of the Manawatū River. Limited water quality monitoring suggests the Kaikōkopu Stream has elevated nutrient concentrations flowing from Lake Kaikōkopu, which is subject to algal blooms. Land use is predominantly Dairy (50%) with Sheep & Beef (28%) and Exotic Cover (19%) making up the remainder; there are 29 dairy effluent consents.

45. The **Coastal Rangitīkei zone** is a large zone covering the Rangitīkei mainstem and tributaries between Onepuhi and the coast. Nutrient concentrations are elevated in the lower river catchments, increasing downstream. *Escherichia coli* are generally within standards but increase at downstream sites. Some of the contaminants are point-sourced in the mainstem and tributaries, in particular the Riverlands meatworks discharge below the Bulls Bridge. Macroinvertebrate Community Index score decreases downstream and is often below the recommended standard at downstream sites. Periphyton proliferation has been considerable over recent summers. Land use in the catchment is predominantly Sheep & Beef (66%) with Dairy the second most common (20%). There are 95 dairy discharge consents in the catchment, three of which are to water. Poor water quality and high periphyton growth adversely affect Contact Recreation, Amenity, Life-Supporting Capacity, Stockwater, Trout Fishery and potentially Sites of Significance – Aquatic values.

46. The **Mangawhero and Mākōtuku** are two main tributaries of the Whangaehu catchment flowing from the western slopes of Mount Ruapehu. Soluble inorganic nitrogen and DRP

concentrations exceed standards due to a combination of point and non-point sources. *Escherichia coli* is generally within the POP standard but is elevated downstream of point sources and at elevated flows. Macroinvertebrate Community Index ranking declines rapidly downstream from ‘excellent’ at upper catchment sites to ‘fair’ in sites downstream of discharges and is considered significantly degraded, given the catchment location and geology. Poor water quality affects Life-Supporting Capacity, Contact Recreation, Amenity, Trout Fishery, Stockwater and potentially Sites of Significance – Aquatic values. Land use is predominantly Sheep & Beef (58%) and Native Cover (38%), with a very small proportion of intensive land use in Dairy and Horticulture (3% combined). There are five dairy effluent discharges in the catchment.

2.8 Summary points

47. Water quality and aquatic ecosystem health are significantly degraded in many catchments of the Region. Water quality in some rivers and lakes is amongst the poorest in New Zealand. Point sources and non-point sources contribute to water quality degradation, depending on location and river flow. Coastal water quality is also degraded and this is considered to be predominantly the result of contaminants discharged from rivers and streams into coastal waters. This degradation compromises the value of these waters as ecosystems and community assets by reducing their indigenous biological diversity, ecological function, recreational use and cultural value.

48. For water body values to be adequately provided for in much of the Region, significant improvement to point source discharge regimes and land management practices that affect water quality is required in a large number of affected catchments.

EVIDENCE

3. WATER BODY VALUES

49. Four value groups and twenty-two specific values have been proposed for the water bodies of Horizons' Region. Some values apply to all water bodies within a Water Management Zone or Sub-zone and others apply only to identified river reaches or sites. The values, value groups, management objectives and where they apply are identified within Tables D.1 and D.2 of Schedule D of the POP. These values, applied spatially over the Water Management Zones framework of McArthur *et al.* (2007a) and described in the evidence of Maree Clark, underpin all of the objectives, policies, rules and non-regulatory methods regarding the sustainable management of water resources and the control of activities on land that may affect water and the water-body values detailed below.

50. The definition of water-body values for the Region is largely a regionally relevant translation of the narrative standards for various 'classes' of water contained in Schedule 3 of the Resource Management Act (1991) into management objectives. The approach of defining water values is also recommended in the proposed National Policy Statement on freshwater. The group of management objectives for a water body, that are determined by the values defined for that water body, gives a clear direction of the Council's management focus when determining issues for resource consents on activities that may affect that water body. The Water Management Zones framework provides a geographical reference for where these 'classes of water' or values apply within the Regional setting.

3.1 A locally applicable approach

51. The water quality standards as objectives, and the additional policies and rules around the management of water and land are intrinsically linked to the values defined for each Water Management Sub-zone and the management objectives for these values. Values, and therefore the standards to protect those values, are sub-zone specific and locally applicable because they relate to the combination of values identified for that particular sub-zone.

3.2 Ecosystem values

52. The Ecosystem values include: Natural State (NS), Life-Supporting Capacity (LSC), Sites of Significance – Aquatic (SOS-A), Sites of Significance – Riparian (SOS-R) and

Native Fish Spawning (NFS). The Ecosystem group includes values which recognise the intrinsic value of freshwater ecosystems for the living communities and natural processes they sustain.

3.2.1 Natural State (NS)

53. The Natural State water body value is grouped within the Ecosystem values. The definition or management objective of the Natural State value can be found in Ausseil and Clark (2007a) and simply states "The water body is maintained in its natural state" and is a translation from the definition in Schedule 3 of the Resource Management Act (1991) (RMA). The Natural State value was applied to all rivers and streams that have sources in and flow within the Public Conservation Estate, with the exception of those where damming and diversion have significantly affected the flow regime and thereby the natural state of the water body (see Table 4 in Ausseil and Clark (2007a) for a list of rivers excluded from the Natural State value).

3.2.2 Life-Supporting Capacity (LSC)

54. The Life-Supporting Capacity value is governed by the management objective "The water body supports healthy aquatic life/ecosystems". This value gives direct effect to the purpose of the Act detailed in section 5(2)(b) and applies to all natural water bodies in the Region. Life-Supporting Capacity specifically recognises and provides for the requirements of indigenous aquatic ecosystems including, but not limited to, native fish and aquatic macroinvertebrates, with respect to water quality, water quantity, habitat quality and fish passage. The value is not intended to support or justify a return to a 'pristine' state, but recognises the need for safeguarding the life-supporting capacity of water at a satisfactory and healthy level.

55. Within this value there are eight Life-Supporting Capacity categories that are applied at the Water Management Sub-zone level. Categories were largely based on broad catchment geology and physiography (see Ausseil and Clark, 2007b for more detail on the definition of Life-Supporting Capacity classes) and were applied to better reflect the variability in aquatic ecosystems across the Region resulting from large-scale catchment differences. For example, the macroinvertebrate and native fish communities found in a stream flowing from the volcanic plateau are expected to be significantly different from those of a stream flowing from a coastal dune lake in the sand country. River types and more examples of Life-Supporting Capacity classes and their geological and riverine characteristics can be found in Ausseil and Clark (2007c, Table 6).

56. To summarise, in the absence of any significant adverse impact, the community composition of a healthy aquatic ecosystem is largely determined by a combination of the catchment geology and physiography.

3.2.3 Sites of Significance – Aquatic (SOS-A)

57. Sites of Significance – Aquatic (SOS-A) are reach and site specific values. The management objective for this value is "Sites of significance for native aquatic biodiversity are maintained or improved". Three criteria were applied to determine whether a site should be considered an SOS-A. These were: 1) the presence of one or more species that are rare or threatened at a national or regional level; 2) the presence of biodiversity 'hotspots' with particularly diverse aquatic communities; or 3) the presence of a rare or threatened aquatic habitat. Because information on the diversity of aquatic communities and habitat was sparse, only the first criterion was applied to determine the Sites of Significance - Aquatic sites proposed within Schedule D of the One Plan.

58. The 149 sites contained in Schedule D were identified by firstly defining aquatic indicator species considered to be regionally rare and/or threatened. Eight species of native fish and the aquatic *Hymenolaimus malachorhynchos* blue duck (whio) were initially determined as appropriate indicator species. Blue duck were included because their habitat requirements are largely similar to those for many native fish, as are their requirements for water quality and quantity. After an external review of the technical report on SOS-A (McArthur *et al.,* 2007b) by Dr Dave Rowe of NIWA, an additional native fish species was included (bluegill bully) due to its regional rarity. The sites themselves include a 2 km buffer upstream and downstream of the surveyed point at which indicator species were recorded, except in the case of survey points that occurred within Natural State reaches. In these instances the sites were extended to the source and to any inflowing tributaries upstream of the site to protect the probable adult and spawning habitat associated with the site.

59. In addition to the upstream and downstream habitat buffer, a twenty metre riparian buffer was applied to each bank of the site to protect any existing woody vegetation associated with the site. Riparian vegetation is particularly important to many of the rare and/or threatened native fish species, particularly lamprey and those of the *Galaxias* genus such as kōaro and giant, banded and shortjaw kōkopu, as these species either spawn within the riparian vegetation or have a spawning habitat associated with the presence of woody riparian vegetation. Most native fish are cryptic and/or nocturnal in

nature, requiring instream cover for refuge during the day. Inputs of woody debris from riparian margins are an important component of suitable instream habitat for native fish.

60. It is important to note that the majority of the rare and/or threatened indicator fish species are diadromous (migratory), requiring access to and from the sea at various life stages depending on the species. The Sites of Significance - Aquatic value does not specifically provide protection of the migratory routes of these fish, only their known habitat. The Life-Supporting Capacity value is considered to provide a minimum environmental condition suitable for migrating adult or juvenile fish throughout the year; an additional recommendation below regarding changes to the Native Fishery value would provide more targeted protection of inwardly migrating juvenile whitebait species.

61. More information of the process for determining the indicator species and the sites proposed in Schedule D can be found in McArthur *et al.* (2007b). For more detailed information on the methods of mapping blue duck distributions refer to Lambie (2007a).

3.2.4 Sites of Significance – Riparian (SOS-R)

62. Sites of Significance – Riparian (SOS-R) is a reach specific value. The management objective for this value is "The sites for native riparian biodiversity are maintained or improved". Operative planning documents already identify areas of riparian habitat that are utilised for gravel nesting by banded and black fronted dotterels. Banded dotterel are listed in the 'Gradual Decline' category of the New Zealand Threat Classification System (Hitchmough, 2002), whereas black fronted dotterels are considered uncommon or rare, rather than threatened. The riparian habitat of these two dotterel species largely overlaps. Dotterels inhabit riparian margins and estuaries outside of nesting season; however, they are most vulnerable to physical disturbance whilst nesting on gravel beaches between July and January (Lambie, 2007b). This value was extended to include other riparian habitats associated with significant bird species or populations.

63. The definition of the 42 sites and reaches identified for riparian biodiversity was undertaken by determining five indicator bird species with critical riparian habitat requirements. These species were royal spoonbill, wrybill, banded and black fronted dotterel and nankeen night heron. Sites of Significance – Riparian were determined by overlaying known distribution data for these five species with known critical habitat variables available via GIS layers at the Regional scale (ie. gravel-bed rivers or mud and silt habitats). Aerial photographs were also used to augment and validate the GIS habitat analysis. Use of a combination of both species-based and habitat-based

approaches lends additional certainty to conservationists that the habitats where the species live are accounted for in decision-making and provides assurance to resource users that sustainable use is not unnecessarily hindered by conservative policy across the Region. Further detail on the process can be found in Lambie (2007a and 2007b) and in the evidence of James Lambie to the Panel. In brief, the SOS-R are categorised into three riparian habitat values: 1) Gravel and Sand habitat for dotterel; 2) Mud/Silt habitat and estuarine roosts for wading birds; or 3) Nankeen Night Heron roosts (Whanganui River only).

3.2.5 Native Fish Spawning (NFS)

64. Reaches and sites identified for the Native Fish Spawning value currently apply only to the spawning sites of inanga (*Galaxias maculatus*). The management objective is "The water body sustains healthy native fish spawning and fry development". The value should therefore (as identified in the Horizons Council submission) be re-termed Inanga Spawning (IS) and the new management objective should read "The water body sustains healthy inanga spawning and egg development".

65. The reason for separately identifying the spawning sites of inanga from those of other native fish species is due to the habitat separation between adult inanga habitat and spawning habitat. Riverine populations of inanga are obligate estuarine spawners, relying on a cyclic tidal inundation of estuarine vegetation for spawning and egg development during high spring tides. The 25 sites were identified from schedules in operative planning documents such as the Land and Water Regional Plan and Beds of Rivers and Lakes Plan and in consultation with the Department of Conservation and Massey University Ecology Group researchers. More information on the definition and identification of the inanga spawning sites can be found in McArthur *et al.* (2007b).

3.3 Recreational and Cultural values

66. The Recreational and Cultural values include: Contact Recreation (CR), Amenity (Am), Native Fishery (NF), Mauri (MAU), Shellfish Gathering (SG), Sites of Significance – Cultural (SOS-C), Trout Fishery (TF), Trout Spawning (TS) and Aesthetics (Ae). These values are associated with recreational and cultural use (non-consumptive or non-commercial uses), and the spiritual value of water and water bodies to Māori.

3.3.1 Contact Recreation (CR)

67. The Contact Recreation value applies to all natural water bodies in the Region and is governed by the management objective "The water body is suitable for contact recreation". The suitability of all water bodies in the Region for contact recreation has long been recognised in operative planning documents such as the Regional Policy Statement and is the value most commonly identified by the general public (Ausseil and Clark, 2007a).

3.3.2 Amenity (Am)

68. The Amenity value applies to site or reach specific areas of water bodies. The management objective of this value is "The amenity values of the water bodies and their margins are maintained or improved". This value applies to the general recreational use of streams, rivers, lakes and their margins for a number of activities such as walking, fishing, hunting, swimming, or passive use. Table D.2 applies Amenity as a zone-wide value. This should be corrected to reflect the site or reach specific nature of the application of this value in Schedule D of the POP. Further information can be found in Ausseil and Clark (2007a).

3.3.3 Native Fishery (NF)

69. The Native Fishery value as it is currently identified applies to the whitebait fishery, although the management objective for this value could also be applied in future to any identified sites for the purposes of harvesting other native fish such as eel or lamprey and freshwater crayfish (kōura). The value is governed by the management objective of "The water body sustains populations of native fish that can be harvested in a sustainable manner". From a biodiversity or population management perspective, there is so little quantitative data available regarding the distribution, abundance or catch of native fish that management of a sustainable harvest is impossible. It is debatable whether whitebait fisheries are currently sustainably harvested, given the decline of adult populations of many native fish. Additionally, the harvest of these species is not under the statutory management of the Regional Council. Whitebait are managed by the Department of Conservation and freshwater eels by the Ministry of Fisheries.

70. In my opinion, the preferred value for identification within the Proposed One Plan is that of 'Whitebait Migration', for which the rules in the Plan can allow for the protection of inwardly migrating native fish in terms of habitat disturbance or water quality, whilst also

maintaining a suitable environment for the activity of recreational whitebait harvesting. If this was to be the case then this value would be more appropriately placed within the Ecosystem value group. Recommended Schedule Ba contains a modified Management Objective for the Whitebait Migration value.

3.3.4 Mauri (MAU)

71. Mauri is a value which has been applied through Schedule D to all water bodies in the Region. Recognition of mauri as a value within the Plan acknowledges mauri as the life-force or essence of the water and the spiritual relationship of Māori to water, which is exemplified by the identity and mana that the mauri of particular water bodies provides for connected iwi and hapū. Mauri can be degraded or weakened by pollutants or spiritual transgressions. To provide for the value of Mauri the management objective is "The Mauri of the water body is maintained or improved".

3.3.5 Shellfish Gathering (SG)

72. This value only applies to waters within the Seawater Management Zone of the Coastal Marine Area (CMA). A description of the management objective and sites for this value are contained within the revised Schedule H and are no longer appropriate within Schedule D. The management objective states "the water body is suitable for shellfish harvesting". The key factors affecting this value which relate directly to the management objective are that the water quality is not contaminated to a level that makes the harvest and consumption of shellfish unsafe. Influences on the diversity and abundance of shellfish populations are not included in this value, but are encompassed by the Life-Supporting Capacity value ascribed to the whole CMA in the revised Schedule H.

3.3.6 Sites of Significance – Cultural (SOS-C)

73. Water bodies are often sites of historical, spiritual and cultural significance to Māori. The Sites of Significance – Cultural value was aimed at recognising and providing for the maintenance and protection of the cultural values of any particular site identified by iwi. The management objective for this value is "Sites of significance for cultural values are maintained". No sites are currently identified within Schedule D for the Sites of Significance – Cultural value as no sites were identified to Horizons through the Plan process. At the moment this value serves as a placeholder within the POP. Should sites be identified in future through work with iwi and hapū, these sites could be added to the POP Schedules by way of a Plan change.

3.3.7 Trout Fishery (TF)

74. The Trout Fishery value has been applied to specific reaches in the Region and seeks to identify significant trout fisheries. The management objective for this value is "The water body sustains healthy rainbow and/or brown trout fisheries". This value was selected to give regard to the section 7(h) provisions of the RMA. In order to meet this management objective there are several aspects of this value which require consideration, ranging from habitat, water quality and ecological considerations to provide habitat for the trout themselves, as well as consideration of trout food sources (largely aquatic macroinvertebrates), through to the recreational and amenity aspects of providing an environment which is desirable for trout fishing (eg. clear water and low periphyton biomass).

75. The Trout Fishery value was further categorised into three classes, based on a scoring system developed by Wellington Fish and Game Council staff in consultation with Auckland-Waikato and Taranaki Fish and Game Councils. This system ranked rivers regionally according to parameters such as angler use, fish quality and angler satisfaction. Additional consideration was given to existing National and Local Water Conservation Orders and Notices relating to trout fisheries. The three classes of Trout Fishery ascribed to reaches in the Region were: 1) Outstanding Trout Fisheries (Class 1) which were fisheries protected by a National Water Conservation Order; 2) Regionally Significant Trout Fisheries (Class 2) which were fisheries with either a current Local Water Conservation Notice in place or had a regionally significant level of angler usage; and 3) Other Trout Fisheries (Class 3) which were fisheries that were recognised but had lower angler use. Further information can be found in the technical report by McArthur and Lambie (2007).

3.3.8 Trout Spawning (TS)

76. Trout require a specific level of habitat and water quality for successful spawning and fry development. To maintain the trout fisheries identified in the previous value, some protection of spawning habitat is also required. The Trout Spawning value, like the Trout Fishery value, has been applied to specific reaches and has the management objective of "The Water body meets the requirements of rainbow and brown trout spawning, larval and fry development". Like the Trout Fishery value, these reaches were identified by Wellington Fish and Game Council staff, based on historic information on spawning areas throughout the Region.

3.3.9 Aesthetics (Ae)

77. The Aesthetic value was also drawn from the RMA Schedule 3 class. The definition or management objective for this value is "The aesthetics of the water body and its margins are maintained or improved". Aesthetics is a site and reach specific value that recognises the aesthetic, landscape or natural values associated with particular water bodies. With regard to my evidence the only aspect of aesthetics to which I will make any comment is on the aspects relating to water clarity and water quality standards and the association with Local and National Water Conservation Notices and Orders and trout fisheries.

78. River reaches that were identified in the operative Regional Policy Statement but not included in Schedule F of the POP have been given this value to allow for continued recognition of the aesthetic qualities of these sites and reaches.

79. <u>Changes to the designation of the Aesthetic value:</u> The Ae value tick should be added to the values table to the middle Manawatū (Mana_10a) Water Management Sub-zone to include the reach from the upper Gorge flow recorder to the Pohangina confluence as described in POP Table D.12. The Ae value tick should be removed from Mangaramarama Mana_7e (formerly Mana_8e) and tables amended accordingly. These changes have been included in the recommended Schedule Ba and are documented in the evidence of Maree Clark.

3.4 Water Use Value Group

80. The Water Use value group encompasses four values identified as being the abstraction of water for the purposes of social or economic benefit. Essentially this value group can be linked with the other Social and/or Economic values listed below. Because these values are consumptive, there is potential for adverse effects on Ecosystem or Recreational and Cultural values as a result of these uses. It is recommended that these consumptive use values apply on a zone-wide basis (see the evidence of Maree Clark).

3.4.1 Water Supply (WS)

81. The Water Supply value is defined by the management objective "The water body is suitable as a raw drinking water source for human consumption". A raw water source means that it can be treated using current technology to a potable standard. Schedule

D identifies rivers upstream of a known water supply take for human drinking water; however it is recommended that this value (along with the industrial abstraction and irrigation values) should apply zone-wide. Additionally, the operative National Environmental Standard (NES) for sources of human drinking water provides some guidance on the identification of sources of human drinking water through the Department of Health database, but the NES will only apply to consents for discharge permits in areas upstream of drinking water supplies, rather than to all activities that have the potential to adversely impact downstream water quality. The relationship between the Water Supply value and the National Environmental Standard for sources of human drinking water will be further covered in the evidence of Barry Gilliland.

82. Generally speaking, the recommended water quality standards for the Ecosystem and Recreational and Cultural values groups will go some way towards ensuring water (after treatment) can be used as a source of raw drinking water for public supply, although at some sites localised impacts of consented (largely point sourced) and unconsented (diffuse) activities have the potential to adversely affect this value.

3.4.2 Industrial Abstraction (IA)

83. The Industrial Abstraction value has been applied to all natural water bodies except those classified as Natural State or covered by National Water Conservation Order. The management objective defining this value is “The water body is suitable as a water source for industrial abstraction”. However, the identification of this value across most water bodies of the Region does not necessarily mean that there is water available for industrial abstraction in all of these places. For evidence on the availability of water for abstraction by Water Management Zone (for whatever purpose) refer to the evidence of Dr Jon Roygard and Raelene Hurndell.

3.4.3 Irrigation (I)

84. The Irrigation value has also been applied to all natural water bodies except those classified as Natural State or covered by a National Water Conservation Order. The management objective defining this value is “The water body is suitable as a water source for irrigation”. However, the identification of this value across most water bodies of the Region does not necessarily mean that there is water available for irrigation abstraction in all of these places. For evidence on the availability of water for abstraction by Water Management Zone (for whatever purpose) refer to the evidence of Dr Jon Roygard and Raelene Hurndell.

3.4.4 Stockwater (SW)

85. The Stockwater value is defined by the management objective “The water body is suitable as a supply of drinking water for livestock”. Generally, suitability of water for livestock drinking requires a low level of faecal contamination and the absence of contaminants that may affect the palatability of the water. This value has been applied to all water bodies in the Region including artificial water bodies such as managed drainage canals. Evidence relating to the suitability of water for stock drinking water and standards for the protection of this value are included in the evidence of Drs Wilcock and Davies-Colley. Such standards are largely superseded by the standards for contact recreation, as the presence of stock is most often the greatest determinant of the suitability of water for stock drinking. Evidence on the availability of stockwater for abstraction can be found in the evidence of Dr Jon Roygard and Raelene Hurndell.

3.5 Social/Economic Value Group

86. The Social/Economic value group encompasses four values relating to the value of water bodies for the assimilation of waste, the value of flood and erosion control schemes, and the value of infrastructure in controlling the risks of flooding and erosion. As with the consumptive values there is potential for adverse effects on Ecosystem or Recreational and Cultural values as a result of activities relating to these values.

3.5.1 Capacity to Assimilate Pollution (CAP)

87. The Capacity to Assimilate Pollution value is defined by the management objective “The capacity of a water body to assimilate pollution is not exceeded”. This capacity is defined by Ausseil and Clark (2007a) as being “the amount of contaminant a water body can receive without compromising any other value”. Schedule D has identified this value as occurring in all natural water bodies except those valued for Natural State.

88. However, there are a number of Water Management Zones in the Region which have already exceeded their capacity to assimilate pollution through either point source discharges of waste, non-point source contamination from the surrounding land use, or a combination of both. Regulated rivers also pose a problem with regards to establishing suitable thresholds of assimilative capacity because the overriding controls of aquatic health rely on artificial flow regimes, also known as flushing flows. Additionally, there are a large number of small streams and tributaries with little or no capacity to assimilate pollution because the level of flow dilution available to mix and

assimilate contaminants is small or absent, particularly during dry seasons. Ecosystem, Recreational and Cultural, and Water Use value groups also exist in water bodies outside of areas defined as Natural State. There is potential for the application of this value to conflict with these values even if water quality standards are not exceeded, for example the discharge of human sewage into waters identified as valued for Mauri.

89. Rare and threatened habitats in lakes, wetlands and estuaries are also unsuitable for the application of the CAP value and in many cases the POP rules would restrict the discharge of waste into these receiving environments because of their rare and/or threatened nature and biodiversity value.

90. Water bodies can be *valued* for their capacity to assimilate pollution. However, the degree to which assimilation of pollution is, or is not, appropriate as an *activity* should never be assumed because of the CAP value status, particularly in the absence of a detailed examination of the assimilative capacity for each water quality parameter in each water body, and with respect to the other values found there. Assimilative capacity is intrinsically linked to flow and flow variability, which is constantly changing (see Roygard and McArthur, 2008 for more details on the relationship between flow and contaminant concentration). Setting a Capacity to Assimilate Pollution threshold for activities must rely on the principles of flow-related contaminant loads and must be assessed and set on a localised basis in relation to the standards for each sub-zone, not as a blanket approach.

3.5.2 Flood Control (FC)

91. The Flood Control value was applied to water bodies within existing flood/erosion control schemes and has the management objective "The integrity of existing flood and river bank erosion protection structures is not compromised". Activities carried out under this value have the potential to adversely affect Ecosystem and Recreational and Cultural values. For example, grade control structures can act as fish barriers, stopping the inward migration of native fish into Sites of Significance – Aquatic and reducing the Life-Supporting Capacity of the water body. Similarly, bank protection works for erosion control can reduce access to the river, adversely affecting the Amenity or Trout Fishery values. The locations of where these values apply are provided in the recommended Schedule Ba; for further information on this value see the evidence of Allan Cook.

3.5.3 Drainage (D)

92. The Drainage value has been applied to all existing drainage schemes and has the management objective "The integrity of existing drainage structures shall not be compromised". The maps and tables of where this value applies are contained in recommended Schedule Ba; for further information on this value refer to the evidence of Allan Cook.

3.5.4 Existing Infrastructure (EI)

93. The Existing Infrastructure value has the management objective "The integrity of existing infrastructure shall not be compromised". Existing infrastructure is defined by Ausseil and Clark (2007a) as including (but not limited to) roads, bridges, hydrological recorder stations and stopbanks. Currently, the value applies only in drainage scheme areas. This application of the Existing Infrastructure value seems to be a misprint in Schedule D, Table D.1 and Ausseil and Clark (2007a) because this infrastructure exists, and is valued, in almost every Water Management Zone and Sub-zone. I recommend the application of this value be changed to reflect the intent of the value of Existing Infrastructure wherever it legally occurs. For further information on Existing Infrastructure refer to the evidence of James Lambie.

3.6 Values not applied in the Plan

3.6.1 Hydroelectricity Generation

94. Hydroelectricity Generation was initially considered as a value for the Water Use value group. However, this was not applied through the values assessment project or within the POP because the allocation of water for hydroelectricity is included within the water allocation framework and structures for hydroelectricity generation are included within the provisions of Chapter 16. For more information on hydroelectricity in the Region please refer to the evidence of Jon Roygard and the officer's report on Beds of Rivers and Lakes.

3.6.2 Gravel Extraction

95. Gravel Extraction was also considered as a Social/Economic value and was included in the technical report on water body values by Ausseil and Clark (2007a). The management objective proposed in the technical report was "The gravel extraction

capacity of a water body is not exceeded". Gravel extraction was proposed to apply in all water bodies except for those valued for Natural State or covered by a National Water Conservation Order. Gravel extraction has the potential to conflict with Ecosystem, Recreational and Cultural and Social/Economic value groups and sustainable gravel extraction must be carefully managed in conjunction with river engineering and scheme management. However, this value was not ultimately included in the POP because a gravel allocation framework was considered the best approach for dealing with the cumulative effects of gravel extraction regionally. See the evidence of Peter Blackwood for more information on gravel management and allocation.

3.7 Protected rivers and regionally significant lakes

96. In addition to the water body values framework in Schedule D of the POP, the Plan also identifies protected rivers in Rule 16-1 and regionally significant lakes in Rule 16-3. These additional levels of significance and/or protection stem largely from recognition of these rivers and lakes for their landscape or aesthetic value in operative policy statements and plans, and also from other mechanisms such as National Water Conservation Orders or Local Water Conservation Notices. The reasons behind including each of these 'protected rivers' for Rule 16-1 and 'significant lakes' for Rule 16-3 in Chapter 16 of the POP is outlined in Table 1 below. Further evidence on this matter can be found in the planning officer's report on the Beds of Rivers and Lakes.

97. Several river sub-catchments and reaches are protected by National Water Conservation Orders or Local Water Conservation Notices, or were recognised as regionally significant landscapes in operative policy statements and plans. These sites, catchments or reaches have been given recognition as 'protected rivers' under Rule 16-1 of the Proposed One Plan. All of these sites are also valued for Aesthetics in Schedule D, because of their regionally significant scenic, wilderness and/or Trout Fishery values. It is my recommendation that rather than have a separate framework for protected rivers, these rules should be applied through the values framework of Schedule D to be consistent with other rules that relate to rivers in the Plan. As such, all rules that use the term 'protected rivers' should instead apply to all Water Management Sub-zones valued for Aesthetics. In essence this does not change the scope of the proposed rules other than to create a consistent system for the recognition of water body values across the Plan and to provide appropriately for the Aesthetic value of water bodies. Where Aesthetic values have been missed (in error) from Schedule D for some Water Management Sub-zones, minor changes to the location of this value have been recommended above in the section on Aesthetic values.

98. Evidence presented to the Panel during the Biodiversity and Natural Heritage Hearing detailed the ecological importance of wetland habitat to the Region, and provided justification for classifying wetland habitat as 'rare or threatened habitat'. In addition, this evidence explained that all examples of wetland habitat in the region are ecologically significant and meet the RMA Section 6 tests.

99. Lake Papaitonga, Lake Horowhenua and Pukepuke Lagoon are all wetland habitats of considerable ecological and cultural value. They are distinctive and highly visible on the landscape, and are generally well known to the wider community especially that of the Manawatū and Horowhenua areas. Because of these factors these three lakes and the associated wetland habitat are considered regionally significant.

100. It is my opinion that regulatory prevention of reclamation or drainage of Lake Papaitonga, Lake Horowhenua and Pukepuke Lagoon is justified. However, Rule 16-3 is unjustifiably limited in the protection it provides, as Lake Papaitonga, Lake Horowhenua and Pukepuke Lagoon are not by any means the only examples of regionally significant lakes. It is my opinion that Rule 16-3 should apply to all areas of wetland habitat covered by recommendations to the Biodiversity and Natural Heritage Hearing Panel. However, I understand such a change to Rule 16-3 is outside the scope of the submissions received on this rule.

Table 1. Protected Rivers and Significant Lakes in the Proposed One Plan and the reasons for their specific inclusion. NWCO: National Water Conservation Order; LWCO: Local Water Conservation Order; RPS: Regional Policy Statement.

Site/reach/river name and POP Rule	Significant lake/protected river (Water Management Sub-zone)	Reason for inclusion
16-1 a: the mainstem of the Manganui-o-te-ao River and the mainstems of its tributaries, the Mākatote River, the Mangaturuturu River, the Waimarino Stream and the Orautoha Stream	Manganui o te Ao River: Whai_5d Whai_5e	NWCO Values: Aesthetic, Outstanding Trout Fishery Regionally Significant Landscape (POP and Operative RPS)
16-1 b: the Upper and Middle Rangitīkei River as defined in the Water Conservation (Rangitīkei River) Order 1993, and downstream of the Middle River where the dam structure has the effect of impounding water upstream of the confluence with the Hautapu River	Rangitīkei River: Rang_1 Rang_2a Rang_2b	NWCO Values: Aesthetic, Outstanding Trout Fishery Regionally Significant Landscape (POP and Operative RPS)
16-1 c: the mainstem of the Hautapu River above its confluence with the Oraukura Stream and the mainstems of its tributaries, the Irirangi Stream and the Waiouru Stream	Upper Hautapu River: Rang_2f	LWCN Values: Aesthetic, Regionally Significant Trout Fishery Regionally Significant Landscape (Operative RPS)
16-1 d: the mainstem of the Mākurī River and the mainstem of its tributary the Mākurī-iti Stream	Mākurī River: Mana_7d	LWCN Values: Aesthetic, Regionally Significant Trout Fishery Regionally Significant Landscape (Operative RPS)
16-1 e: the mainstem of the Mangatainoka River and the mainstems of its tributaries, the Mākākahi River and its Bruce Stream tributary, the Mangaroa, Mangamaire, Mākōtukutuku and Mangaraupiu streams, and an unnamed tributary entering the Mangatainoka River at map reference NZMS 260 T25:368-654	Mangatainoka River: Mana_8a Mana_8b Mana_8c Mana_8d	LWCN Values: Aesthetic, Regionally Significant Trout Fishery Regionally Significant Landscape (Operative RPS)
16-1 f: the mainstem of the Whanganui River from its source at map reference NZMS 260 T19:383-286 to the boundary of the coastal marine area, and the mainstem of the Whakapapa River and the mainstems of its tributaries the Whakapapaiti and Whakapapanui Streams	Whanganui and Whakapapa Rivers: Whai_1 Whai_2a, Whai_2b, Whai_2c, Whai_3, Whai_4a, Whai_5a, Whai_5d, Whai_5e, Whai_6, Whai_7a	Values: Aesthetic Regionally Significant Landscape (POP and Operative RPS)

Site/reach/river name and POP Rule	Significant lake/protected river (Water Management Sub-zone)	Reason for inclusion
16-1 g: the mainstem of the Manawatū River through the Manawatū Gorge from Ballance Bridge to the confluence of the Pohangina and Manawatū Rivers	Manawatū Gorge: Mana_10a	Values: Aesthetic (see recommendation above) Regionally Significant Landscape (POP and Operative RPS)
16-1 h: the mainstem of the Pohangina River from its source to its confluence with the Manawatū River near the Manawatū Gorge	Pohangina River: Mana_10b Mana_10c Mana_10d	Values: Aesthetic Regionally Significant Landscape (Operative RPS)
16-1 i: the mainstem of the Oroua River from its source to its confluence with the Mangoira Stream at map reference NZMS 260 T22:578 378.	Oroua River: Mana_12a	Values: Aesthetic Regionally Significant Landscape (Operative RPS)
16-3 Any reclamation or drainage of the bed of the following lakes pursuant to s 13(1) RMA, excluding any existing recamations and drainage: (a) Lake Horowhenua	Lake Horowhenua: Hoki_1	Regionally Significant Lake
16-3 (b)	Lake Papaitonga: West_8	Regionally Significant Lake
16-3 (c)	Pukepuke Lagoon: West_6	Regionally Significant Lake

Note: Reach descriptions in the POP landscapes chapter, Operative RPS and POP Rules may differ slightly between documents. The table above should be used only as a general guide to the justification of protected rivers and significant lakes.

3.8 Added protection under the values framework

101. Rule 16-4 identifies an added level of protection for water bodies valued for Natural State, Sites of Significance – Aquatic and Sites of Significance – Cultural. The reason most activities involving the disturbance and placement of structures is discretionary for water bodies with these values is because the effect of these activities has the potential to be significant with respect to the sensitivity of the receiving environment described by the values assigned. For example, a Site of Significance – Aquatic that contains a population of regionally or nationally threatened native fish species or blue duck could be significantly affected by the placement of a structure within the water body, to the point where the species is no longer able to inhabit or successfully reproduce at that site. These are significant and potentially permanent effects. If there are ways to avoid, remedy or mitigate the effects of the structure or disturbance, whilst still meeting the management objective for the values in this sub-zone then this could be imposed as a condition of consent.

102. With regards to Natural State water bodies, the management objective for these water bodies is that they will be maintained in their natural state. Areas of the conservation estate that are already affected by structures such as dams have not been included in the Natural State designation because they are no longer deemed to be in a 'natural state'.

103. Sites of Significance – Aquatic have only been designated for water bodies that are known to contain regionally and/or nationally significant species which warrant this type of precautionary approach due to their threat status (as described in McArthur *et al.,* 2007b).

104. Applying the same approach to Sites of Significance – Cultural ensures that there is a mechanism in place for iwi and hapū to comment, through the resource consent process, on activities under Rule 16-4 that may impinge on the cultural significance of a particular site. As no sites have been identified thus far the practical application of this Rule for SOS-C may be somewhat redundant, however the approach still has merit and should be maintained. This is covered further in the planning officer's report on the Beds of Rivers and Lakes.

105. It is my opinion that the approach proposed by Rule 16-4 is a sound way to manage the effects of activities governed by this rule on values where the potential effects are permanent or significant because of the nature of the values themselves and that Rule 16-1 should be amended as recommended above to be consistent with this approach.

Key points: Values

i. There are twenty-two water body values identified within Schedule D of the POP. These values are grouped into Ecosystem, Recreational and Cultural, Water Use, Social and Economic values groups.

ii. Some values are region-wide and others apply at specific sites or river reaches.

iii. Management objectives for each value have been set and each water body has a group of management objectives that apply, depending on the values.

iv. Water Management Sub-zones have different assemblages of values. Water quality standards have been determined for each Water Management Sub-zone based on the values within that zone. Some rules in Chapter 16 of the POP are also based on maintaining water body values.

v. This approach means that standards and rules are applied in a locally relevant manner that links the effects of activities to the values to be protected.

Recommendations on values

1. The Native Fish Spawning (NFS) value should be renamed Inanga Spawning (IS) to reflect the utilisation of estuarine spawning habitat by this species.
2. The Native Fishery (NF) value should be renamed Whitebait Migration (WM) and moved from the Recreational and Cultural values group to the Ecosystem values group.
3. Amenity (Am) should be identified as a reach-specific value (rather than zone-wide).
4. Shellfish Gathering (SG) should be removed from Schedule D as this value only applies within the CMA and should therefore be found only within Schedule H.
5. The Trout Fishery (TF) value should be defined as a reach-specific value, rather than zone-wide.
6. Aesthetics (Ae) values should be applied to Water Management Sub-zones that are recognised as Protected Rivers in Rule 16-1. The Aesthetics value should be applied to the Middle Manawatū (Mana_10a) from the upper Gorge flow recorder to the Pohangina River confluence and removed from the Mangaramarama (Mana_7e) sub-zone.
7. Table D.12 which identifies and describes the Aesthetic value should be changed for the Whakapapa River and tributaries (Whai_2b) to reflect the wording and reaches specified as Protected Rivers in Rule 16-1.
8. Water Supply (WS), Industrial Abstraction (IA) and Irrigation (I) should be identified as zone-wide values with the exception of reaches identified as Natural State or covered by National Water Conservation Orders.
9. Existing Infrastructure (EI) should not be applied only to Drainage Areas as identified in Table D.1 but should be a zone-wide value applying to all legally existing infrastructural assets.

4. FRESHWATER QUALITY AND AQUATIC ECOSYSTEM HEALTH: STATE AND TRENDS OF RIVERS AND STREAMS

4.1 Water quality and aquatic biomonitoring

106. Horizons undertakes a number of integrated monitoring programmes with regard to water. These programmes are State of the Environment (which includes water quality and aquatic biomonitoring), a discharge monitoring programme, continuous turbidity network (SLUI monitoring), summer swimming spots monitoring and Didymo surveillance monitoring. An overview of swimming spot and lake cyanobacterial monitoring programmes can be found in the evidence of Barry Gilliland. Other aspects of the programmes are summarised in the tables below and can be found in the evidence of Dr Roygard. These summaries are based on the current state of these programme as at the end of the 2008/09 financial year. Information and data produced from these programmes has been used to formulate much of the evidence below. Specific reference to certain monitoring programmes is included within the text.

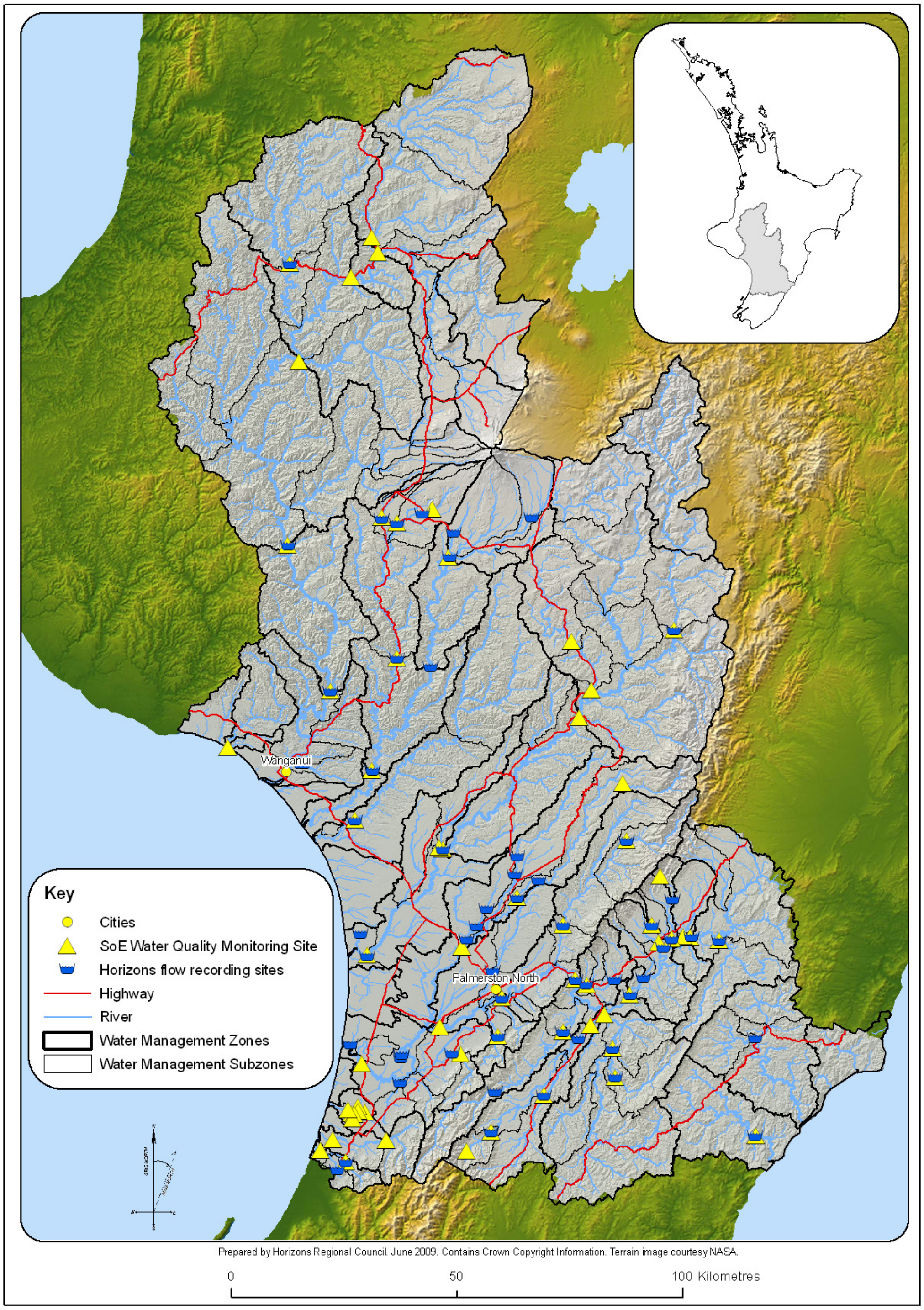
Table 2. Water Quality parameters monitored by Horizons under various programmes for rivers, lakes and coastal waters.

State of the Environment water quality monitoring (60 sites, Map 1)	Discharge monitoring programme (87 sites)	Swimming spots monitoring (13 sites)
pH[*]	pH[*]	*E. coli* (freshwater)
Temperature[*#]	Temperature[*#]	Enterococci (seawater)
Conductivity[*#]	Conductivity[*]	Faecal coliforms (seawater)
Dissolved oxygen[*#]	Dissolved oxygen[*#]	Turbidity
Black disc[*]	Black disc[*]	Black disc[*]
Turbidity[#]	Turbidity	
TSS (total suspended sediment)	TSS	
TP (total phosphorus)	TP	
TN (total nitrogen)	TN	
DRP (dissolved reactive phosphorus)	DRP	
NNN (total oxidised N)	NNN	
NH_4-N (ammoniacal nitrogen)	NH_4-N	
$N0_3$ (nitrate)	$N0_3$	
$N0_2$ (nitrite)	$N0_2$	
DTP[+] (dissolved total phosphorus)	Particulate organic matter	
Soluble TKN[+]	Soluble carbonaceous biochemical oxygen demand ($sCBOD_5$)	
Escherichia coli	*E. coli*	
	Enterococci[£]	
	Sulphite[£]	

[*] Measured in situ using hand held equipment
[#] Measured continuously at some locations
[+] Monitored for specific investigations at some sites
[£] Monitored for specific consents to assess compliance with conditions

Table 3. Biological monitoring parameters and monitoring programmes undertaken by Horizons in rivers and lakes.

Monitoring programme	No of sites	Parameters
State of the Environment (SoE) invertebrate biomonitoring	47	Physical habitat measurements Deposited sediment (quorer method) Invertebrate communities (kick net protocol C3)
SoE native fish monitoring	47	Electrofishing (using modified EPA methods) Spotlighting (using modified EPA methods) Physical habitat measurements
Periphyton monitoring	48 (both SoE and discharge sites)	Periphyton visual cover assessment (modified SHMAK Kilroy *et al.,* 2008) Chlorophyll *a* pooled sample (Kilroy *et al.,* 2008) Ash Free Dry Mass (Kilroy *et al.,* 2008)
Swimming spots monitoring	13 (4 lake sites, 4 coastal sites, 5 rivers)	Cyanobacteria (blue-green algae) cell count – lakes Benthic cyanobacteria (*Phormidium sp*.) – rivers (% benthic cover visual assessment) Cyanobacterial toxin testing (depending on cell count, % benthic cover and alert level)
Didymo surveillance	15	Quarterly monitoring using DNA detection (long-term management partners also undertake sampling in the Region)



Map 1. State of the Environment water quality and flow recording sites in Horizons' Region.

4.2 State of water quality and aquatic ecosystem health in rivers and streams

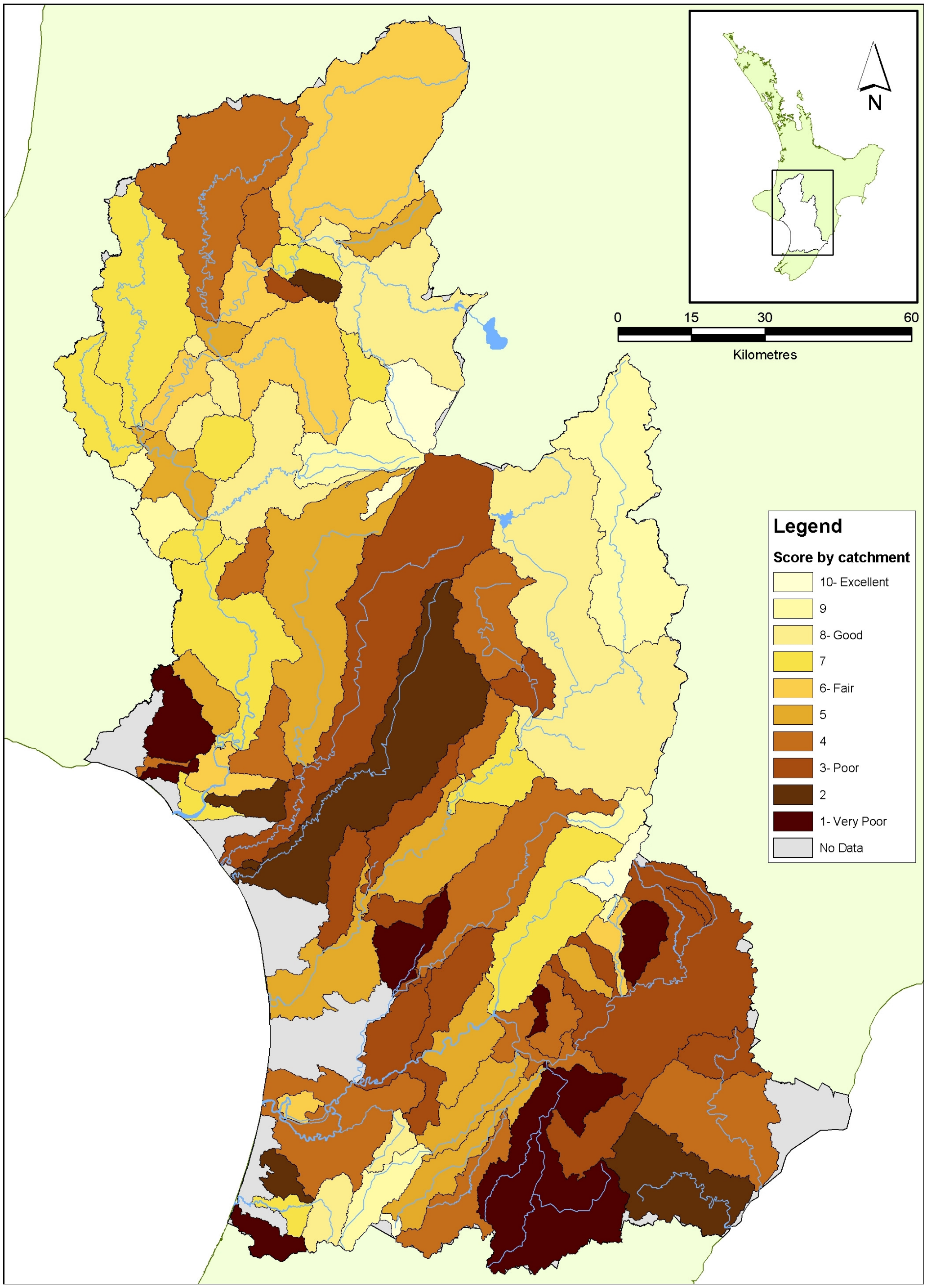
107. The 'state' of water quality refers to the current level of physicochemical and biological health of water bodies and the aquatic organisms that inhabit them. For an historic perspective on the state of water quality in Horizons' Region please refer to the evidence of Barry Gilliland.

108. Water quality state can be measured against standards, either the standards proposed in Schedule D of the Plan or national and international guidelines. Trends in water quality reflect the changes in state over time and are discussed in the following sections. Several historic reports detail the state of some of the Region's water bodies at various times (see the evidence of Barry Gilliland). The first attempt at an integrated, region-wide examination of water quality was undertaken as part of the second State of the Environment report for Horizons Regional Council, published in 2005 (Horizons, 2005). For the technical investigation of the state of water quality which underpinned the State of the Environment report, almost all water quality data for the Region, collected at varying sites between 1997 and 2004, was collated and analysed (Horizons, 2005, Chapter 4). Rudimentary water quality indicators were developed at this stage to compare water quality results against (see Table 4-2 in Horizons, 2005, Chapter 4) and the Region was split into a number of sub-catchment 'zones' to display the results for region-wide comparison. The assumptions, advantages and limitations of the approach taken in 2005 are summarised in Table 4-4 of that report and more information can be found in the evidence of Dr Jon Roygard.

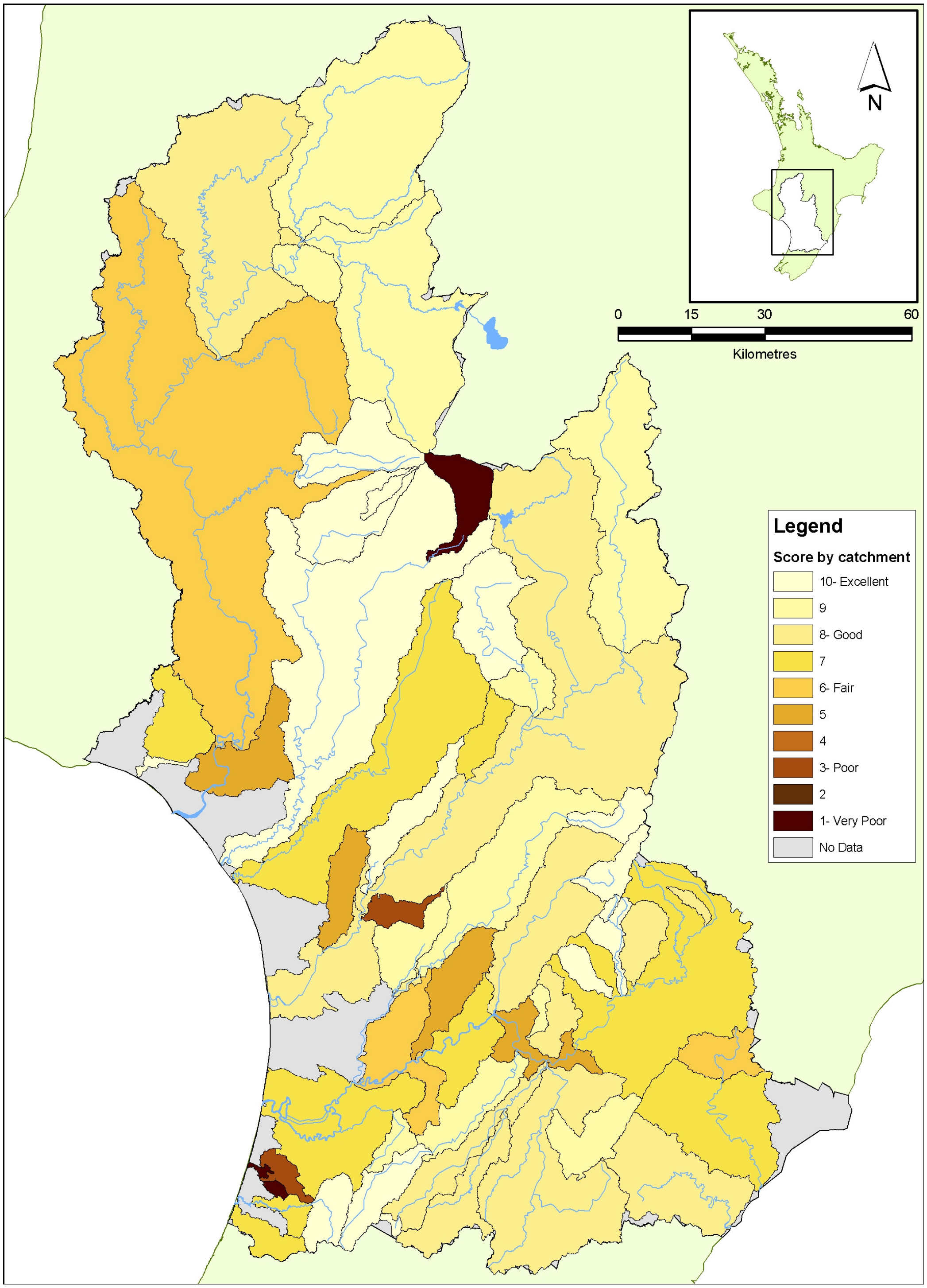
109. Findings of the 2005 State of the Environment report showed that the main issues affecting water quality in the Region were:

- faecal contamination compromising the water's recreational quality and affecting its mauri;
- nutrient enrichment causing accelerated eutrophication;
- modified physicochemical characteristics of the water and/or the presence of toxic substances compromising the life-supporting capacity of the water; and
- high turbidity, affecting aesthetic values and life-supporting capacity (also an indicator of soil erosion).

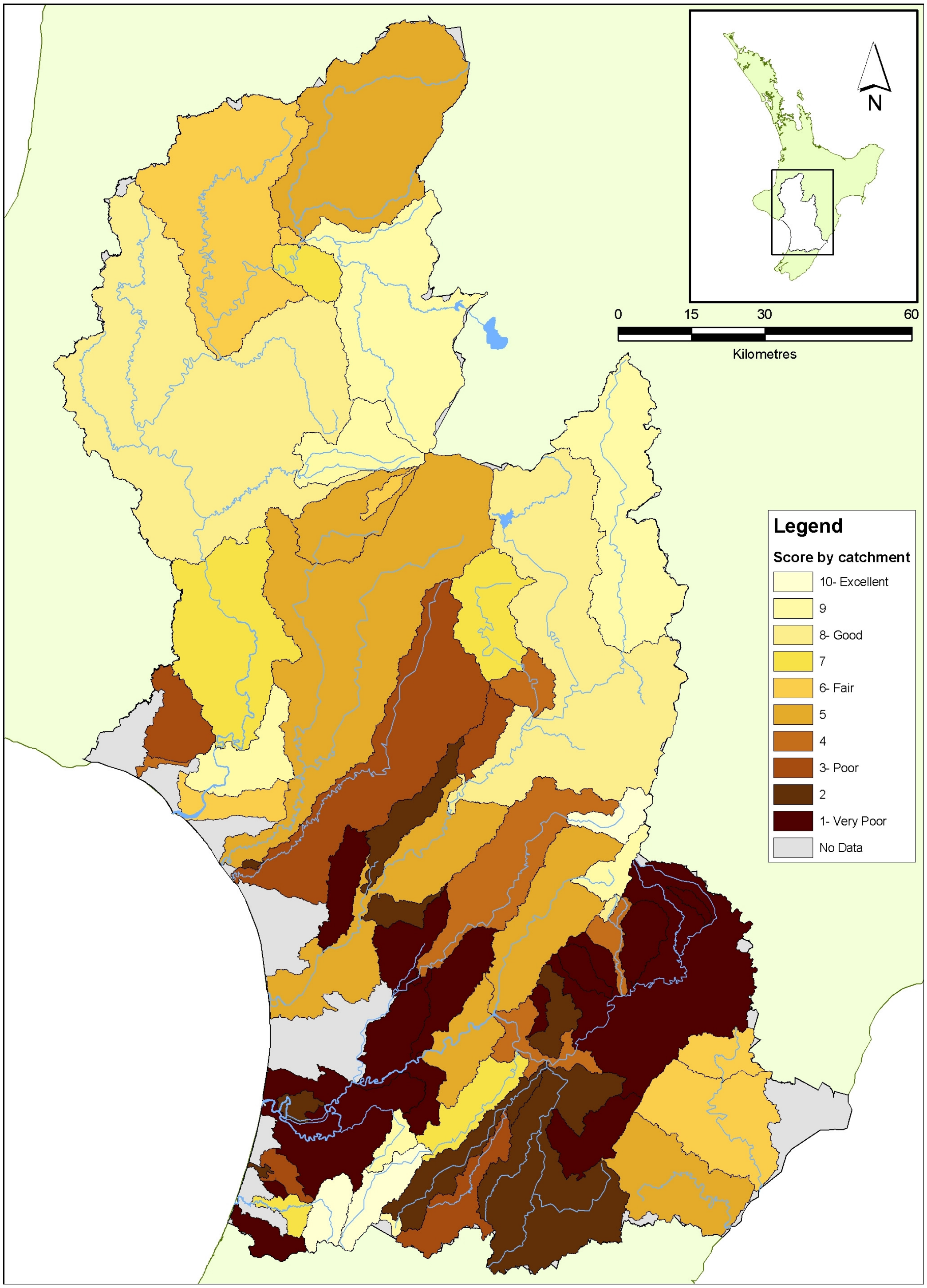
Examples of the final map outputs of this report for contact recreation and Life-Supporting Capacity are included below.



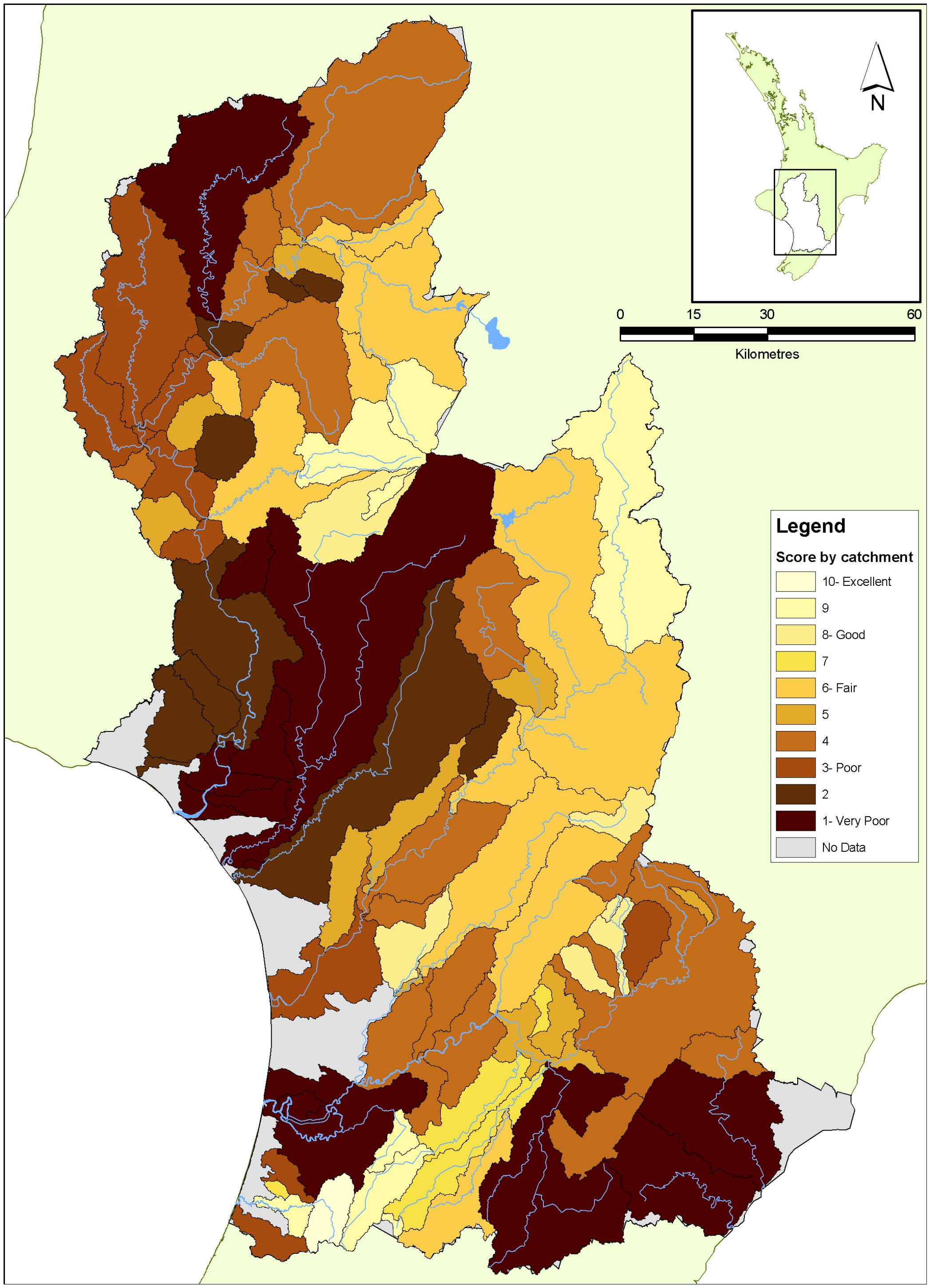
Map 2. Index of suitability for contact recreation from Horizons (2005) State of the Environment Report.



Map 3. Index of physicochemical stressors from Horizons (2005) State of the Environment Report.



Map 4. Index of nutrient enrichment from Horizons (2005) State of the Environment Report.



Map 5. Index of turbidity from Horizons (2005) State of the Environment Report.

110. Map 2 and Map 3 show the suitability for contact recreation and physicochemical stressor indices developed for the 2005 state of the environment report. The suitability for contact recreation map shows that there are a number of catchments that regularly or always score poorly for microbial (faecal) contaminants. In particular, the upper Manawatū, Tiraumea, Turakina, Makino Stream and several small coastal catchments such as the Waikawa, Kai Iwi and Mōwhānau score badly.

111. The physicochemical index shows that largely the Region is in a reasonable state with the notable exceptions being the Whangaehu, Rangitawa Stream (Rangitīkei tributary near Halcombe) and Horowhenua catchments. The State of the Environment report (Horizons, 2005) discussed these physicochemical results and concluded that the results indicate good life-supporting capacity in the Region's rivers and streams. However, it must be noted that no biological data was used to support this assertion and that this was noted as a limitation of the assessment.

112. Map 4 and Map 5 show the indices of nutrient enrichment (combined nitrogen (N) and phosphorus (P) index) and the index of turbidity developed for the 2005 State of the Environment report. The nutrient enrichment index shows that the upper and lower Manawatū, lower Oroua, Rangitīkei tributaries and the Waikawa catchments are significantly affected by nutrient enrichment at the regional scale.

113. The turbidity index shows the combined impacts of geology and land use on water quality, with highly turbid rivers in the Whanganui, Whangaehu, Turakina and upper and lower Manawatū catchments. The lower Manawatū is likely to be impacted primarily by cumulative inputs from the upper catchment and point source inputs. For further information on hill country land use in relation to erosion and declining water clarity refer to the evidence of Dr Jon Roygard and others to the Land Hearing.

114. Two key recommendations from the 2005 State of the Environment report for future monitoring and reporting of water quality information were:

- to include biomonitoring data into SoE reporting; and
- to investigate water quality trends over time.

115. As part of the water quality standards development an analysis of current state for a large number of chemical and biological parameters was undertaken from the most recently available Horizons data. Table 27 on page 144 of Ausseil and Clark (2007c) gives a relatively current account of water quality in relation to the proposed standards in Schedule D for each Water Management Sub-zone. This table also identifies gaps in

the data for each parameter in each sub-zone. Compliance with the standard was assessed using the criteria outlined by Ausseil and Clark (2007c) in section 8.2 of that report.

116. Summarising a complex matrix of data such as that presented by Ausseil and Clark (2007c) requires multivariate analysis to explain the variation in the data and similarity or dissimilarity between sites. Due to a lack of data for a number of parameters in many of the sub-zones, a simple analysis of each site based on the percentage of compliance or non-compliance with the group of standards for each management sub-zone is difficult. A graphical representation of the general proportion of compliance with each category of standards proposed by Ausseil and Clark (2007c) is included below (Figure 1).

117. Where sufficient data existed, sites with information for at least nine of the water quality parameter categories presented in Table 27 of Ausseil and Clark (2007c) have been used in the summary figure below, with the exception of dissolved oxygen (DO) saturation, biochemical oxygen demand (BOD_5) and particulate organic matter (POM). (There was little data available for these three parameters at the time of the standards report analysis by Ausseil and Clark (2007c)). Note that clarity standards for horizontal visibility proposed by Ausseil and Clark (2007c) have been used in this summary, rather than the turbidity standards proposed in Schedule D. For each Water Management Zone any insufficiencies in the data are apparent from Table 27 and the summary figure below should be read in conjunction with that table (Ausseil and Clark, 2007c).

118. The figure below shows the generally poor state of compliance with the proposed standards in many of the Water Management Sub-zones with sufficient data. Only sixteen sites had greater than 50% compliance (dashed reference line on Figure 1) with the standards for which there was data at the site. Specific discussion of compliance with proposed standards on a sub-zone by sub-zone basis is included in later sections of this evidence and in Appendix 2.

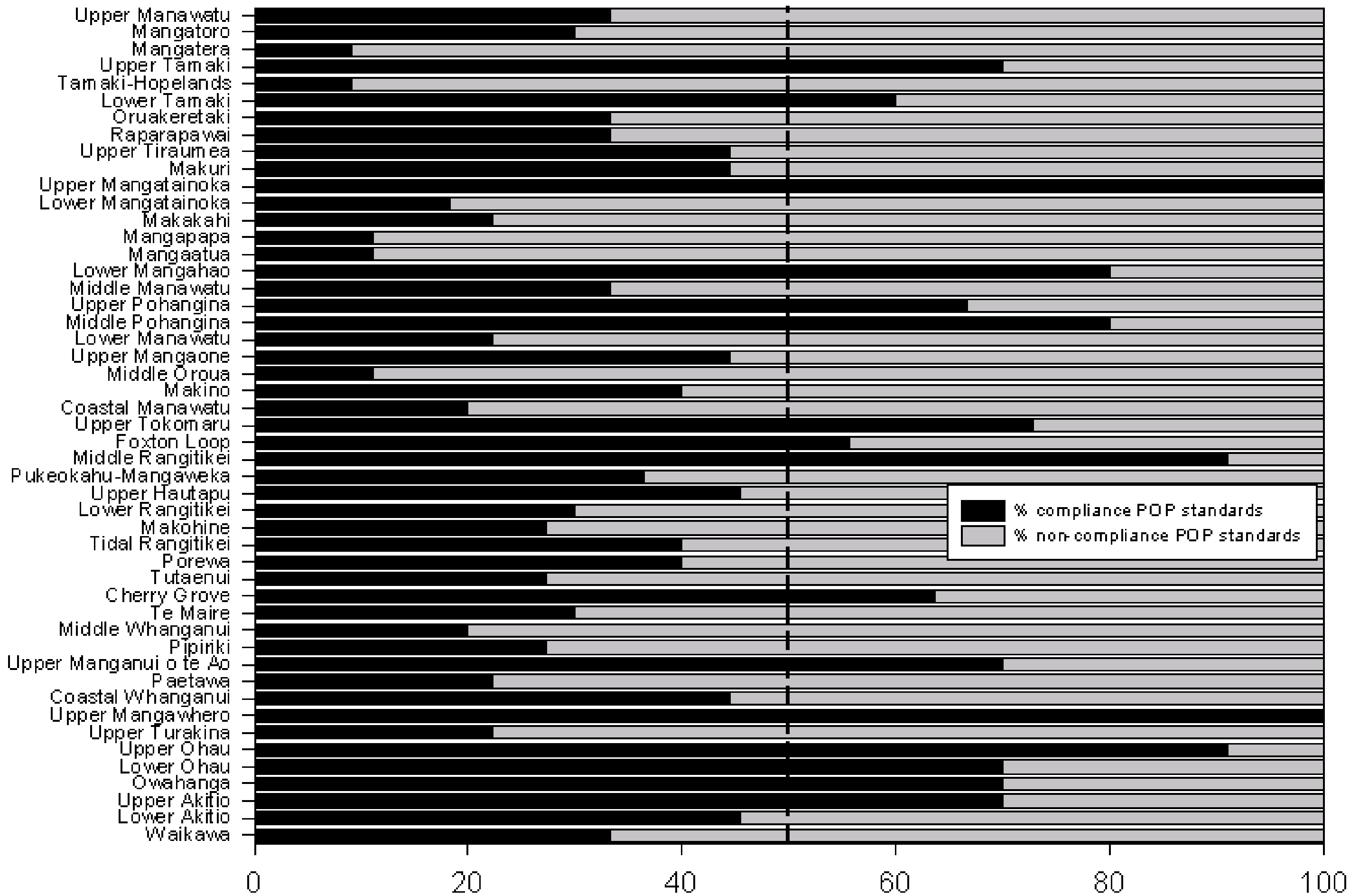


Figure 1. Proportion of compliance with POP water quality standards for 49 Water Management Sub-zones with data for at least nine standard categories, adapted from Ausseil and Clark (2007c).

4.3 National assessment of water quality state

119. In 2006, NIWA produced a report on the national state and trends in water quality based on data from the National River Water Quality Network (NRWQN), which collected data from 77 sites in rivers throughout the country between 1989 and 2005 (Scarsbrook, 2006). There are seven NRWQN sites in Horizons' Region. These are: 1) Manawatū at Weber Rd (WA7), 2) Manawatū at Teachers College (WA8), 3) Manawatū at Opiki Bridge (WA9), 4) Rangitīkei at Kākāriki (WA6), 5) Rangitīkei at Mangaweka (WA5), 6) Whanganui at Te Maire (TU1), and 7) Whanganui at Paetawa (WA4).

120. To determine the current state of water quality for the nation, Scarsbrook (2006) took the median of the twelve monthly samples for 2005 and categorised them into the 5th, 20th, 50th, 80th and 95th percentile bands for each parameter across all sites. The 50th percentile gives an 'average' national picture in terms of median water quality in 2005. The 20th and 80th percentiles were included as these percentiles bound the majority of the sites and because management decisions often follow the '80:20 rule' (whereby 20% of the sites will be associated with 80% of the water quality problems and vice versa). The 5th percentile (best rivers[1]) and 95th percentile (worst rivers[1]) were used to describe the state of the nation's best and worst rivers.

121. In general terms the current state of water quality nationally, determined from the 2005 data in Scarsbrook (2006), showed strong associations between the extent of pastoral land cover in a catchment and median nutrient and faecal indicator concentrations. Clarity was measured by black disc, so the higher the number the better the water clarity. For all other parameters the higher the number the greater the concentration of contaminants and the worse the water quality.

122. Results from Scarsbrook (2006) for the comparison of the national network sites within Horizons Region are largely comparable with the findings from the Horizons 2005 SoE report in that faecal contamination in the Region's national network sites was generally worse than the national median, and at the Manawatū at Weber (WA7) and Manawatū at Teachers College (WA8) sites faecal contamination was above the 80th percentile for all sites. Nutrient parameters showed eutrophication at many sites when compared to the national state: Manawatū at Opiki (WA9) was above the 95th percentile for ammoniacal nitrogen and dissolved reactive phosphorus, and the two remaining

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[1] For all parameters except those associated with water clarity at which the 5th percentile rivers had the LOWEST clarity and the 95th percentile rivers the HIGHEST clarity.

Manawatū sites were within the 80^{th}–95^{th} percentile ranges for total and soluble forms of nitrogen and phosphorus. Low water clarity was apparent at all sites, with all sites measuring less than the national median. Clarity was particularly bad at the Opiki and Teachers College sites on the Manawatū. Some sites within the Region also scored in the upper 50^{th}–80^{th} percentiles for water temperature, conductivity and pH.

Table 4. Summary of water quality percentile ranges for Manawatū-Wanganui river sites as reported by Scarsbrook (2006). **Bold** sites are considered among the 'worst' in the county for that parameter.

Water Quality Parameter	Site	Percentile Range
Clarity	Manawatū at Weber Rd (WA7)[2]	5^{th}–20^{th}
	Manawatū at Teachers College	**< 5^{th}**
	(WA8)	**< 5^{th}**
	Manawatū at Opiki (WA9)	5^{th}–20^{th}
	Rangitīkei at Mangaweka (WA5)	5^{th}–20^{th}
	Rangitīkei at Kākāriki (WA6)	20^{th}–50^{th}
	Whanganui at Te Maire (TU1)	20^{th}–50^{th}
	Whanganui at Paetawa (WA4)	
Total oxidised nitrogen (NNN/$N0_x$)	Manawatū at Weber Rd	80^{th}–95^{th}
	Manawatū at Teachers College	80^{th}–95^{th}
	Manawatū at Opiki	80^{th}–95^{th}
	Rangitīkei at Mangaweka	20^{th}–50^{th}
	Rangitīkei at Kākāriki	20^{th}–50^{th}
	Whanganui at Te Maire	50^{th}–80^{th}
	Whanganui at Paetawa	50^{th}–80^{th}
Ammoniacal nitrogen (NH_4-N)	Manawatū at Weber Rd	80^{th}–95^{th}
	Manawatū at Teachers College	80^{th}–95^{th}
	Manawatū at Opiki	**> 95^{th}**
	Rangitīkei at Mangaweka	5^{th}–20^{th}
	Rangitīkei at Kākāriki	5^{th}–20^{th}
	Whanganui at Te Maire	50^{th}–80^{th}
	Whanganui at Paetawa	50^{th}–80^{th}
Total nitrogen	Manawatū at Weber Rd	80^{th}–95^{th}
	Manawatū at Teachers College	80^{th}–95^{th}
	Manawatū at Opiki	80^{th}–95^{th}
	Rangitīkei at Mangaweka	20^{th}–50^{th}
	Rangitīkei at Kākāriki	20^{th}–50^{th}
	Whanganui at Te Maire	50^{th}–80^{th}
	Whanganui at Paetawa	50^{th}–80^{th}
Dissolved reactive phosphorus	Manawatū at Weber Rd	50^{th}–80^{th}
	Manawatū at Teachers College	50^{th}–80^{th}
	Manawatū at Opiki	**> 95^{th}**
	Rangitīkei at Mangaweka	20^{th}–50^{th}
	Rangitīkei at Kākāriki	20^{th}–50^{th}
	Whanganui at Te Maire	50^{th}–80^{th}
	Whanganui at Paetawa	50^{th}–80^{th}
Total phosphorus	Manawatū at Weber Rd	80^{th}–95^{th}
	Manawatū at Teachers College	80^{th}–95^{th}

2 Site labels in brackets denote the National River Water Quality Network site names used by Scarsbrook (2006).

Water Quality Parameter	Site	Percentile Range
	Manawatū at Opiki	80th–95th
	Rangitīkei at Mangaweka	20th–50th
	Rangitīkei at Kākāriki	50th–80th
	Whanganui at Te Maire	50th–80th
	Whanganui at Paetawa	50th–80th
Escherichia coli	Manawatū at Weber Rd	80th–95th
	Manawatū at Teachers College	80th–95th
	Manawatū at Opiki	50th–80th
	Rangitīkei at Mangaweka	20th–50th
	Rangitīkei at Kākāriki	50th–80th
	Whanganui at Te Maire	50th–80th
	Whanganui at Paetawa	50th–80th

123. Ballantine and Davies-Colley (2009b) were commissioned to update the state and trend analysis of Scarsbrook (2006) with a particular focus on comparing water quality state and trends in the Horizons Region with updated national trend analysis (Ballantine and Davies-Colley, 2009a) for nutrient, faecal and clarity parameters. Ballantine and Davies-Colley (2009b) noted that water quality in the Horizons Region was generally "poor" when compared with 1) POP standards (Table 7, page 19); 2) guideline trigger values from the ANZECC guidelines (2000; Table 6, page 18); and 3) the state of the nation's water quality, measured using data from the 77 national network sites. Many sites in the Manawatū catchment had the highest nutrient enrichment nationwide, and poor visual clarity. Visual clarity was also poor in the Rangitīkei and Whanganui catchments but nutrients were generally low when compared to the nation (with the exception of the Hautapu River upstream of the Rangitīkei confluence). Table 8 on page 23 of Ballantine and Davies-Colley (2009b) shows the rankings of the Horizons State of the Environment and NWQRN sites in the Region when compared to all 77 National sites.

4.4 State of aquatic ecosystem health

4.4.1 Invertebrate communities

124. Aquatic ecosystems are the community of organisms that results from the sum of all natural catchment and climate variables. The health of these communities relates to the effects of any activities (such as discharges or land use) on river water quality and in-stream biological processes. Aquatic macroinvertebrates are ideal indicators of aquatic ecosystem health in rivers and streams because they integrate all of the contributing impacts (both natural and anthropogenic) over an annual timescale. The resulting biological community will contain differing relative proportions of sensitive and tolerant aquatic taxa, which can be assessed either against a reference condition (unimpacted

‘healthy’ aquatic community in a similar environmental setting) or compared to an index of health such as the MCI.

125. Horizons, in association with Massey University, have undertaken invertebrate biomonitoring at a number of sites throughout the Region. An annual report on the results of this monitoring has been produced for Horizons by Massey University or their associates for the past decade (Table 5). Death (2009) summarises the data from the 10-year programme.

Table 5. Reference details for annual biomonitoring reports commissioned by Horizons.

Year	Reference	Authors
1999	Death, 1999	Russell Death, Massey University
2000	Charteris *et al.,* 2000	Sjaan Charteris, Russell Death, Kirsty Francis, Stephen Minchin, Rachel Boisen, Ashley Vosper
2001	Cook *et al.,* 2001	Tanya Cook, Russell Death, Kirsty Francis, Mark Hamer, Carol Nicholson
2002	Death *et al.,* 2002	Russell Death, Kate McArthur, Richard Pedley, Zoe Dewson, Ian Johnston
2003	Death *et al.,* 2003	Russell Death, Troy Makan, Kiryn Weaver, Erna Zimmerman
2004	Death *et al.,* 2004	Russell Death, Fiona Death, Rebecca Lewis
2005	Death and Death, 2005	Russell Death and Fiona Death
2006	Death and Death, 2006	Russell Death and Fiona Death
2007	Dewson *et al.,* 2007	Zoe Dewson, Russell Death and Fiona Death
2008	Death, 2009	Fiona Death, Pohangina Environmental Consulting Ltd

126. In 2008, Dr John Stark was engaged to undertake an analysis of the state and trends in macroinvertebrate indices between 1999 and 2007 and to provide recommendations to improve Horizons’ SoE biomonitoring programme (Stark, 2008). The section of Dr Stark’s report on the state of aquatic ecosystem health at a subset of 21 sites with long-term biomoniotoring data (six or more years) can be found on pages 19 to 21 of Stark (2008). The key findings regarding the state and trends of river health from Stark (2008) are reproduced below (Table 7, page 22, Stark, 2008). For all summaries relating to aquatic macroinvertebrates, results have been determined from MCI scores as recommended by Scarsbrook *et al.* (2000) and Stark and Maxted (2007). Stark (2008) discusses the rationale for using MCI in preference to QMCI or other bioindices for reporting SoE data extensively on pages 32 and 33 of that report. Trends in aquatic ecosystem health are discussed with trends in water quality in the sections below.

127. With regards to the average state of river health, based on the Macroinvertebrate Community Index values from 1999 to 2007, the following findings were apparent.

Using the MCI water quality classes of Stark and Maxted (2007), only one of the twenty-two sites was determined to have excellent water quality, five sites were classed as good, twelve as fair and three as poor. The site classed excellent was the Mangawhero at DoC Headquarters site and the three sites classed as poor were the Manawatū at 42 mile hydro/Karere Rd, Oroua at Awahuri Bridge and Manawatū at Whirokino (although this site is heavily influenced by tide and the soft-bottomed nature of the river at this site and is not particularly appropriate to traditional invertebrate sampling methods).

128. Death (2009) was also commissioned to produce a report on the long term state and trend of aquatic ecosystem health based on the invertebrate biomonitoring data between 1999 and 2008 using all data from a total of 83 sites. Death used the water quality classes of Wright-Stow and Winterbourn (2003) which use ‘fuzzy’ boundaries to determine water quality classes from MCI and QMCI values. Stark (2008) gives a clear description of the differences between the classes of Stark and Maxted (2007) and Wright-Stow and Winterbourn (2003) on pages 15 to 18 of his report.

129. The key findings of Death (2009) in relation to long-term state (determined by MCI) were that there were six sites with good water quality, 33 sites classed as mildly polluted, 34 moderately polluted sites and 20 sites in a severely polluted state.

130. Additionally, Death (2009) also documented the state of the Region’s macroinvertebrate communities for the 2008 monitoring season from thirty five sites. This was the first season in which Horizons staff collected the samples and undertook environmental measurements in the field, rather than contracting this work to Massey University or their associates. In the 2008 monitoring season Death (2008) reported that three sites had clean water, fourteen were mildly polluted and fifteen were moderately polluted. Three sites were severely polluted according to the MCI classes of Wright-Stow and Winterbourn (2003). These results are the most recently published information on the state of aquatic ecosystem health. The three sites that were determined to be severely polluted were the Manawatū at Opiki, Oroua at Awahuri and Tūtaenui at Parewanui. Notably, these three sites are downstream of major point source discharges of treated sewage effluent (Palmerston North, Feilding and Marton sewage treatment plants respectively).

4.4.2 Periphyton communities

131. With the exception of the 2008 biomonitoring survey, periphyton data has been collected once annually at the same sites as aquatic macroinvertebrate data, where the river

substrate permitted the collection of samples (ie. from gravel or cobble-bottomed rivers and streams). Periphyton biomass and algal community composition were measured from 1999 to 2007. Assessments of algal community composition ceased after the 2005 survey and algal biomass (determined by chlorophyll *a* mg/m^2) also ceased in 2007. Visual assessment of periphyton cover was undertaken via various methods over the years. Stark (2008, page 2) contains a summarised timeline of changes to the invertebrate and periphyton monitoring programmes compiled by Horizons staff.

132. The periphyton information is reported in each of the annual biomonitoring reports undertaken by Massey University or their associates from 1999 (Table 5). Death (2009) summarised this information by comparison with the New Zealand Periphyton Guidelines (Biggs, 2000) as follows:

i. For the Manawatū catchment most sites were rarely above aesthetic guideline standards (120 mg/m^2) with the exception of the Manawatū at Hopelands site which exceeded the guideline 56% of the time. Most sites were often above the 'clean water' or benthic biodiversity guideline levels (50 mg/m^2) with the exception of the Oroua River at Nelson Street.

ii. Three of the four sites in the Rangitīkei catchment were always below the 50 mg/m^2 benthic biodiversity guideline. However, the Hautapu River upstream of the Rangitīkei confluence exceeded this guideline in eight out of nine years and exceeded the aesthetic guideline (120 mg/m^2) in seven out of nine years. Notably this site is downstream of the Taihape sewage treatment plant (STP) discharge.

iii. Periphyton growth in the Whanganui and Whangaehu catchments was almost always below the benthic biodiversity guideline of 50 mg/m^2 with the exceptions of the Whanganui at Wades Landing (aka d/s Retaruke, aka Whakahoro) and the Whanganui at Pipiriki sites, which exceeded this guideline 56% of the time.

133. These results can only be considered a snapshot of the periphyton biomass within each of these catchments because sampling was undertaken once annually. Additionally, analysis methods to extract chlorophyll *a* for these surveys used acetone, rather than hot-ethanol extraction as recommended by Kilroy *et al.* (2008). As such the periphyton results reported in Death (2009) should be regarded as indicative only.

134. To better verify the state of periphyton proliferation in the Region's rivers, Horizons engaged NIWA and Massey experts to determine a monitoring programme to better quantify periphyton maximum and average biomass and cover throughout the Region's rivers and streams. The recommendations from these experts can be found in Kilroy *et al.* (2008).

Table 7 Time series of MCI values at 21 SoE biomonitoring sites in the Manawatu-Wanganui region. Sites are listed in decreasing order of stream health based on overall average MCI values. See Table 3 for key to quality classes. Sites have been assigned to quality classes based on the fixed criteria of Stark & Maxted (2007a). Trend: -ve = negative, +ve = positive, NS =- Not Significant.

River	Site	1999	2000	2001	2002	2003	2004	2005	2006	2007	Average	Trend
MANGAWHERO RIVER	DOC Headquarters	148	133	139	138	134	138	130	141	143	138	NS
RANGITIKEI RIVER	Pukeokahu	122	130	113	121	107	117	114	117	113	117	NS
WHANGANUI RIVER	Cherry Grove	112	115	97	120	97	116	99	103	102	107	NS
RANGITIKEI RIVER	Mangaweka	131	-	94	102	94	102	102	117	97	105	NS
WHANGANUI RIVER	Te Maire	103	100	97	104	110	107	106	101	100	103	NS
WHANGANUI RIVER	Downstream Retaruke conflunce	108	97	94	105	104	111	104	100	88	101	NS
OROUA RIVER	@ Nelson St	120	91	98	107	113	82	80	100	92	98	NS
RANGITIKEI RIVER	Kakariki	91	99	97	102	103	91	106	96	77	96	NS
MANAWATU RIVER	Maxwells Line / Teachers' College	116	100	95	104	98	80	75	95	93	95	-ve
MANAWATU RIVER	Hopelands Reserve	101	95	87	100	91	88	90	93	93	93	NS
MANGATERA STREAM	Confluence @ Timber Bay	105	92	99	94	60	78	91	98	-	90	NS
MANGAWHERO RIVER	Downstream Makotuku	-	101	90	76	76	94	84	89	-	87	NS
WHANGANUI RIVER	Estuary	74	84	82	80	101	99	-	-	-	87	NS
MANGATAINOKA RIVER	SH2 Bridge Mangatainoka	78	83	88	86	80	90	101	74	91	86	NS
HAUTAPU RIVER	Upstream Rangitikei River	86	92	95	87	88	81	92	70	72	85	NS
WHANGANUI RIVER	Pipiriki	68	78	61	89	89	97	96	90	90	84	NS
RANGITIKEI RIVER	Estuary	78	86	80	95	89	72	-	-	-	83	NS
MAKAKAHI RIVER	Konini	56	73	84	79	77	87	97	88	-	80	+ve
MANAWATU RIVER	Karere Rd / 42 Mile Hydro Station	105	71	66	73	87	90	71	66	59	76	NS
OROUA RIVER	Awahuri bridge	66	76	71	101	77	87	77	54	55	74	NS
MANAWATU RIVER	Whirokino	68	77	74	84	64	73	-	-	-	73	NS
Number classified 'EXCELLENT'		4	2	1	3	1	1	1	1	1	1	
Number classified 'GOOD'		7	4	1	7	6	4	5	6	3	5	
Number classified 'FAIR'		2	9	15	9	10	13	10	7	7	12	
Number classified 'POOR'		7	5	4	2	4	3	3	4	4	3	

Reproduced from Stark (2008).

4.4.3 Native fish communities

135. Phillips and Joy (2002) defined the regional state of native fish communities as high-value in forested headwater streams draining the Tararua Ranges and some small coastal streams but poor in most other waterways, particularly in the Pohangina, Whanganui, upper Manawatū and Rangitīkei Rivers. They recommended a wider identification of regional fish barriers and development of better guidelines to manage waterways for native fish.

136. McArthur *et al.* (2007b) summarises the current state of native fish communities in the Region using National Freshwater Fish Database (NFFDB) records collected since 1991. Table 3 on page 58 of that report summarises the key species and their regional, national and international threat classification, associated with determining Sites of Significance – Aquatic (SOS-A) in the POP. Additionally, the reader can refer to Appendix 4 of McArthur *et al*. (2007b) which outlines recent freshwater fish research undertaken in the Horizons Region between 1995 and 2005.

137. Since that time Horizons has begun a programme of monitoring native fish communities to assess the Sites of Significance – Aquatic valued sites and for State of the Environment purposes (Nicholson and Brown, 2008), as well as a programme to identify fish barriers (James and Joy, 2008; James and Joy, 2009). It is hoped that the development of nationally quantifiable fish monitoring protocols will further add to the knowledge on the state of native fish nationally and regionally and over time (trends).

138. Commensurate with the evidence of Fleur Maseyk on indigenous biodiversity, the areas of land cover in the Region that have been most highly modified for pastoral land uses (lowland areas) and cleared of indigenous vegetation have depauperate native fish communities with low species diversity, due to the modified nature of the terrestrial and aquatic habitats in these areas of the Region.

139. The critical habitat requirements for native fish indicator species for Sites of Significance – Aquatic are summarised in Appendix 1 of McArthur *et al.* (2007b).

4.4.4 Aquatic ecosystem metabolism

140. Ecosystem health can be defined by structural assessment (ie. assessing the health of the components of the ecosystem such as the macroinvertebrate, plant or fish communities) or by functional assessments (eg. metabolic processes within the

ecosystem, or nutrient cycling within an ecosystem). Recent work has been undertaken to assess ecosystem health using functional indicators of ecosystem metabolism in large rivers (Young *et al.*, 2008). Ecosystem metabolism rates were assessed using primary production and ecosystem respiration, determined by analysing continuous dissolved oxygen data. More information on ecosystem respiration and functional indicators can be found in the evidence of Dr Roger Young.

141. As a result of initial assessments of primary productivity and ecosystem respiration from the lower Rangitīkei and Manawatū Rivers as part of a nationwide large rivers project, Cawthron Institute were commissioned to undertake an assessment of continuous dissolved oxygen data collected from five sites in the Horizons Region (Clapcott and Young, 2009). Detailed findings are contained in Clapcott and Young's (2009) report and summarised in the evidence of Dr Young. This technique for assessing ecosystem health is still in its infancy and requires further supporting research, however the raw measurements of dissolved oxygen fluctuations, although some uncertainties in the data exist, appear to be good indicators of life-supporting capacity at the five sites. A summary of the key findings from Clapcott and Young (2009) is presented below.

142. "*Rates of gross primary production (GPP) were low at Rangitikei at Onepuhi and Manawatu at Teachers College and indicative of healthy conditions according to broad guidelines on interpretation of these measures. GPP was low to moderate at Rangitikei at Mangaweka and Mangatainoka at Pahiatua and indicative of healthy to satisfactory conditions. In contrast, GPP was consistently high at Manawatu at Hopelands and indicative of poor ecosystem health. Rates of ecosystem respiration (ER) were generally moderate to high at all sites and indicative of satisfactory to poor ecosystem health.*

The balance between GPP and ER indicated that these sites generally were relying on some organic matter from upstream or the surrounding catchment to support the rates of ER that were recorded. The only exception to this was Manawatu at Hopelands during winter when rates of GPP were two times higher than rates of ER and in-stream production may have been supporting the entire food web. The P/R ratios provided no indication of poor ecosystem health at any of the other sites, suggesting that this indicator may not be a particularly sensitive measure of large river health."

4.5 Trends in water quality and aquatic ecosystem health

4.5.1 Water quality trends

143. Water quality trend analysis is undertaken to ascertain the changes in water quality state over time. For a robust analysis of water quality trends a minimum of five years worth of water quality data or 60 observations is required (Smith *et al.,* 1996; Scarsbrook and McBride, 2007).

144. Scarsbrook (2006), in his report on the state and trends in national water quality from 1989 to 2003, noted the results were: "consistent with a continuing shift in relative importance from point source to non-point source pollution as key anthropogenic pressures on surface waters" and concluded "Resource management is shifting towards a greater emphasis on control of non-point source pollution associated with intensive agriculture. Information gained from the NRWQN supports this shift in emphasis."

145. Scarsbrook (2006) noted the following from NRWQN data (annual medians) between 1989 to 2003:

i. A steady, increasing trend in total oxidised nitrogen (N0x-N) in rivers where this nutrient was already elevated (ie. rivers with concentrations > 95^{th} percentile nationally such as the Mataura, Oreti, Waingongoro and Waihou Rivers), indicating these rivers may have become more enriched over the period analysed. The Manawatū River sites were within the 80^{th} to 95^{th} percentile band.

ii. Ammoniacal-N showed strong downward trends in most rivers except those with high ammoniacal-N concentrations (ie. > 95^{th} percentile) such as the Manawatū at Opiki.

iii. All except the least enriched rivers showed increasing trends in total N.

iv. Dissolved reactive phosphorus showed weak increasing trends in the 80^{th} to 95^{th} percentile rivers and there was a strong non-linear dissolved reactive phosphorus pattern in the > 95^{th} percentile rivers such as the Manawatū at Opiki over time, peaking in the late 1990's and then decreasing.

v. Consistent decreasing trend in BOD_5 in all rivers across the country. BOD is now only analysed in samples from three sites nationally: 1) Rangitopuni, 2) Manawatū at Opiki and 3) the lower Tarawera River.

146. Gibbard *et al.* (2006) examined water quality at 22 sites in four catchments between 1989 and 2000.

147. Table 6 shows a reproduced summary of the trend analyses of Gibbard *et al.* (2006). For non-flow adjusted data it can be seen that there are significant increasing trends in the Manawatū catchment, particularly at Hopelands and in the Oroua at Nelson St, and to a lesser extent at two of the sites in the Whanganui River catchment. When the data is flow-adjusted there are further significant increases in nitrate ($N0_3$), dissolved reactive phosphorus and turbidity at the Manawatū catchment sites.

148. National water quality state and trend information has been updated from Scarsbrook (2006) by Ballantine and Davies-Colley (2009a) in their report celebrating the 20th 'birthday' of the NRWQN programme. Results from the national analysis of water quality between 1989 and 2007 are summarised in the evidence of Dr Davies-Colley.

149. In brief, the key findings of Ballantine and Davies-Colley (2009a) were:

i. Trends were generally similar to those of Scarsbrook (2006) over the 1989 to 2007 time period and trends were all in the same direction as previously reported (although some trends were weaker or stronger than before).

ii. Significant improvements in visual clarity were observed at the national scale, although visual clarity was negatively correlated with the percent of the catchment in pastoral land cover.

iii. Strong overall increasing trends in total P, dissolved reactive phosphorus, total N and total oxidised N (N0x-N) were attributed to the expansion and intensification of pastoral agriculture.

iv. Trends or patterns examined within the overall period of analyses showed some improvements, including sites in Horizons' Region.

v. Manawatū at Teachers College (NIWA site WA8) showed recent improvements in visual clarity, dissolved reactive phosphorus and potentially total oxidised nitrogen (N0x-N).

vi. Manawatū at Opiki (NIWA site WA9) also showed recent improvements in visual clarity, dissolved reactive phosphorus, and recent declines in total N and total oxidised nitrogen (N0x-N) (since 2006).

Table 6. Summary of seasonal Kendall DRP, NO_3 and TURB trend testing by site based on flow-adjusted or non flow-adjusted data (modified from Gibbard *et al.*, 2006 and reproduced from Roygard and McArthur, 2008).

SoE Site	Non flow-adjusted			Flow-adjusted		
	DRP	NO_3	TURB	DRP	NO_3	TURB
Rangitīkei Catchment						
Rangitīkei at River Valley	↑			↑		
Hautapu upstream at Rangitīkei						
Rangitīkei at Mangaweka						
Rangitīkei at Vinegar Hill						
Rangitīkei at Kākāriki						
Rangitīkei at Scotts Ferry						
Manawatū Catchment						
Mangatera at Timber Bay	↓↓↓	↑↑				
Mākākahi at Konini		↑↑		↑↑	↑↑↑	↑↑
Mangatainoka at SH2		↑↑↑			↑↑↑	
Manawatū at Hopelands	↑↑↑	↑↑↑	↑↑	↑↑↑	↑↑↑	
Manawatū at Ashhurst Domain						
Oroua at Nelson Street	↑↑		↑↑	↑↑↑	↑↑↑	↑↑
Oroua at Awahuri Bridge				↑↑↑		↑
Manawatū at Maxwell's Line					↑↑	↑↑↑
Manawatū at 42 Mile						
Manawatū at Whirokino	↓	↑↑↑	↑↑↑			
Whanganui Catchment						
Whanganui at Retaruke						
Whanganui at Pipiriki	↑↑					↓
Whanganui at Kaiwhaiki	↑↑↑			↑↑↑		↑↑↑
Whanganui at Estuary opp. marina			↑↑			
Whangaehu Catchment						
Mangawhero at DoC National Park			↓	↑↑		↓↓↓
Mangawhero d/s of Makotuku confl.						

1. Tidal sites were not tested as part of the flow-adjusted analysis.

2. Some flow data has been supplied by Genesis Energy and NIWA.

3. Red arrows (↑) represent an increasing trend in concentration of a given water quality indicator (ie. a degradation in water quality). Green arrows (↓) represent a decreasing trend (ie. an improvement in water quality).

4. ↑/↓ indicates a significant trend (a probability of 90%)

   ↑↑/↓↓ indicates a very significant trend (a probability of 95%)

   ↑↑↑/↓↓↓ indicates a highly significant trend (a probability of 99%)

150. Horizons commissioned Ballantine and Davies-Colley (2009b), to report on the state and trends in water quality in Horizons' Region. Ballantine and Davies-Colley (2009b) found a number of 'meaningful' trends in water quality when they analysed 16 State of the Environment sites between 1989 and 2007 for trends in nutrient, clarity and faecal contaminants. They also undertook an analysis of the data between 2001 and 2008 to look at recent changes. Long-term historic data from the years 1979–1989 from an additional seven discontinued sites were analysed for nutrient levels. All state and trend results for State of the Environment sites were compared with the national state and trend results from 77 sites (Ballantine and Davies-Colley 2009a) and against the seven national network sites within the Horizons Region. Only meaningfully significant trends are discussed in the following sections. Further information can be found in the evidence of Dr Davies-Colley.

4.5.2 NRWQN trends

151. Long-term trend analysis of the seven national network sites in the Horizons' Region (1989–2007) showed increasing trends in total oxidised nitrogen (N0x-N) at a number of sites, particularly in the Manawatū catchment, and increasing dissolved reactive phosphorus for the Manawatū at Weber Road (NIWA site WA7). However the shorter term analysis of 2001–2008 data showed decreasing trends at some sites for N0x-N, *E.coli* and turbidity parameters, suggesting some water quality improvement in recent years. No trends were detected for dissolved reactive phosphorus over any of the time periods analysed.

4.5.3 SoE trends

152. Long-term State of the Environment trends for soluble inorganic nitrogen showed four meaningful decreasing trends for the Oroua at Awahuri Bridge, Hautapu u/s Rangitīkei, Mangawhero at DoC and Whanganui at Pipiriki.

153. Black disc (clarity) decreased at the Manawatū at Whirokino and Hautapu u/s Rangitīkei. Turbidity increased at the Manawatū at Whirokino and decreased at Mangatainoka at SH2, Hautapu u/s Rangitīkei, Mangawhero at DoC and Whanganui at Pipiriki.

154. *Escherichia coli* decreased at the Manawatū at Upper Gorge and Hautapu u/s Rangitīkei and increased for the Ohau at Rongomātāne.

155. SoE short-term trend analysis (2001–2008) found no trends in dissolved reactive phosphorus. However, decreasing trends in soluble inorganic nitrogen were found at six sites: Mangatainoka at SH2, Manawatū at upper Gorge, Manawatū at Whirokino, Hautapu u/s Rangitīkei, Mangawhero at Doc and Whanganui at Cherry Grove.

156. Black disc clarity increased in the Manawatū at Hopelands and decreased in the Oroua at Awahuri. Tamaki at Reserve increased for turbidity and three turbidity decreases were found at Mangatainoka at SH2, Manawatū at Hopelands and Hautapu u/s Rangitīkei.

157. *Escherichia coli* decreased at Tamaki at Reserve, Manawatū at Hopelands, Manawatū at Upper Gorge and Hautapu u/s Rangitīkei and increased in the Ohau at Rongomatane.

158. No trends were found at the seven historical sites monitored between 1979 and 1988 apart from a decrease in nitrate ($N0_3$) for the Tiraumea at Kohinui Bridge site.

4.5.4 Trends in aquatic ecosystem health

159. Trend analysis was completed by Stark (2008) and Death (2009) as detailed in the section on the state of aquatic ecosystem health above. The findings of these reports were largely consistent although each report used a different number of sites and the Stark (2008) report did not have the 2008 monitoring results that were available for the later Death (2009) analysis.

160. Stark (2008) found positive trends in macroinvertebrate communities (MCI) in the Whanganui at Te Maire and the Mākākahi at Konini and a negative trend for the Manawatū at Teachers College site. For QMCI, positive trends were found for the Whanganui at Te Maire, Pipiriki, and Estuary sites and negative trends again for the Manawatū at Teachers College, Oroua at Awahuri and Oroua at Nelson Street. However, using a false discovery rate procedure all trends were determined to be weak.

161. Death (2009) found a decreasing QMCI trend at the Manawatū at Teachers College and an increasing trend for the Whanganui at Pipiriki. With regards to MCI there was a significant decrease again for the Manawatū at Teachers College and an increasing trend for the Mākākahi at Konini. Death (2009) also examined the %EPT taxa and individuals indices and found declining %EPT taxa in the Rangitīkei at Pukeokahu and declining %EPT individuals the Whanganui at Cherry Grove.

162. Trends in macroinvertebrate communities and periphyton biomass and cover for the seven National Rivers Water Quality Network sites found within the Horizons region are described in the evidence of Dr John Quinn. Dr Quinn states "*Data for six Horizons region sites in the National River Water Quality Network over 1990 to 2006 indicate that: (i) average annual maximum cover by filamentous algae exceeded the MFE guideline of 30% at 3 sites (Whanganui at Te Maire, and Manawatu at Weber Rd (upper catchment) and Opiki (downstream of Palmerston North); and filamentous algae cover was increasing in the Whanganui River at Te Maire and the Rangitikei River at Kākāriki , whereas there was a weak declining trend at Manawatu at Weber Rd. Although these results cover a small number of sites, they indicate that there are sites within the Horizons where periphyton cover degrades aesthetic conditions.*

4.5.5 Trends in native fish communities

163. Joy (2009) used an Index of Biotic Integrity (IBI) developed for New Zealand (Joy and Death, 2004) to examine changes in freshwater fish diversity between years and decades from 1970 to 2007. The IBI approach was used because it accounts for the natural variation in native fish communities associated with the highly diadromous fish fauna. More than 22,000 NZFFDB records were analysed for the presence/absence of fish over the last 37 years and showed:

i. IBI score has significantly decreased over the last 37 years, particularly over the last decade (see Figure 4 from Joy (2009));
ii. Sites in native vegetation had significantly higher IBI scores than sites in urban or pastoral land cover. Sites in tussock had the lowest scores as these were generally at highest elevation and furthest from the sea;
iii. The biggest declines in IBI were at urban, pasture (see Figure 6 from Joy (2009)) and tussock sites with significant increases in IBI at native forest and scrub sites;
iv. Sites in exotic forestry are often considered to have less impact on aquatic ecosystems due to long periods between disturbance events caused by harvesting. However, exotic sites had lower than expected IBI scores and declines were consistent with a period of intensive harvesting in the 1990's.

164. Joy's (2009) findings indicate that freshwater ecosystem condition and indigenous biodiversity has declined nationally over the last 37 years, particularly over the last decade. The strong association between land use and fish IBI shows the influence that terrestrial degradation has on native freshwater ecosystems.

165. The results of Joy (2009) should be considered conservative, as species will decline in abundance for some time before becoming permanently absent (locally extinct) at a site. Joy (2009) also identified a strong need for national, long-term fish monitoring with quantifiable abundance data.

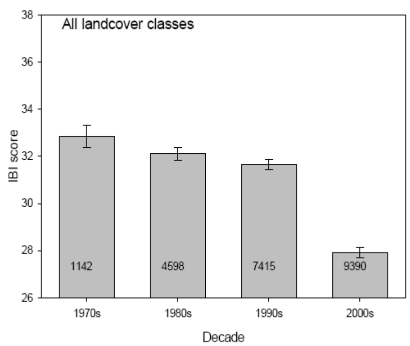


Figure 4 Average decadal IBI score for all sites (number of sites inside bars, whiskers = Standard Error)

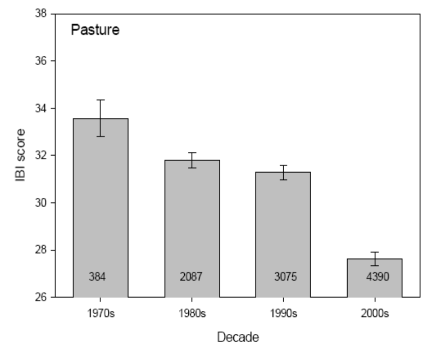


Figure 6 Average decadal IBI scores for River Environment Classification (REC) land-cover pasture sites (number of sites inside bars, whiskers = Standard Error)

Note: figures from Joy (2009).

166. As fish diversity is shown to decline with pastoral land conversion from scrub or indigenous vegetation, it is highly likely that the Region's native fish diversity will continue to degrade over time as land is converted to higher proportions of urban and pastoral land cover.

Key points: Freshwater quality and aquatic ecosystem health: State and trend of rivers and streams

i. Headwater areas of river catchments notwithstanding, the state of water quality in the Region's Rivers is poor in a number of catchments with respect to faecal contaminants, nutrient enrichment, water clarity, aquatic ecosystem health and native fish diversity.

ii. Long-term trend analysis shows that there have been significant increasing trends in nutrient concentration at a number of sites, significant decreases in water clarity, and increases in turbidity.

iii. Shorter-term trend analysis has identified some decreasing trends in nitrogen at a number of sites in recent years, particularly in the Manawatū catchment.

iv. Although these decreasing trends are positive signs, the state of water quality and aquatic ecosystem health is still very poor in catchments with higher proportions of pastoral land use or significant point source inputs.

v. The state of Horizons' rivers is poor when compared to the state of river water quality nationally and many sites do not comply with the POP water quality standards or nationally accepted guidelines.

vi. The catchments worst affected by poor water quality are: the upper and lower Manawatū, the Mangatainoka, the Mākurī, the lower Oroua, Lake Horowhenua, the lower Hautapu, the Whangaehu and the Waikawa.

vii. Water quality in the Whanganui and Rangitīkei Rivers is generally good in the upper and middle catchment reaches with respect to nutrient concentrations, but ranks poorly with regard to visual clarity.

viii. Native fish community integrity is declining nationally in catchments with pastoral or urban land cover.

5. WATER QUALITY STANDARDS: RIVERS AND STREAMS

167. 'Water quality' is a general term used to encapsulate the state of a water body in relation to a range of potential contaminants to surface water. For example, water clarity, dissolved oxygen, nutrient enrichment status and many other parameters affect the overall quality of a particular water body and the suitability of that water for various values and uses. Water quality standards are one of the integrated management tools applied through the objectives of the POP to provide for the water-body values of each Water Management Sub-zone. Some of the proposed water quality standards apply to all surface water bodies in the Region, others are more reach, site or sub-zone specific.

168. In addition to the water quality standards that apply to all rivers, lakes or seawater, Water Management Sub-zone specific standards were also derived from the set of values defined for each sub-zone. Generally speaking, all known research pertaining to standards for water quality parameters relevant to each of the defined values was reviewed and these individual standards were grouped by value with recommendations for river flow or time of year at which the standards should apply (Ausseil and Clark, 2007c, Table 21, page 96).

169. Then for each Water Management Sub-zone the standards for each value were compared and the highest standard required to meet all of the values in that sub-zone was applied for each parameter. The reason for adopting the highest standard for each parameter was to ensure that by providing for the most 'quality' demanding value, all other values would be adequately protected. This was consistent with the approach used to apply the highest minimum flow required for the most flow-demanding value or

species identified for each Water Management Sub-zone in the water allocation framework.

170. Nutrient standards (soluble inorganic nitrogen and dissolved reactive phosphorus) were assigned separately to each sub-zone on a case by case basis using the expert opinion of Dr Barry Biggs, as outlined in Ausseil and Clark (2007c, section 6.4, page 106). The nutrient standards were determined at levels which would give effect to the periphyton biomass standards for the values in each sub-zone. The desired periphyton biomass (chlorophyll *a* mg/m^2) and Quantitative Macroinvertebrate Community Index (QMCI) required to provide for the values in each sub-zone was the specific link between the sub-zone values and the nutrient standards applied, in addition to consideration of factors such as the downstream receiving environment and the current state of nutrient enrichment. In many cases the sub-zones with a common set of values were grouped together for the application of the same water quality standards.

171. In some cases the downstream receiving environment was taken into account for the determination of water quality standards for individual sub-zones, over and above the requirements of the values for that sub-zone. In setting standards for a tributary catchment, the values, substrate characteristics and water quality requirements of the mainstem Water Management Zone were taken into account so nutrient enriched water did not enter the more sensitive downstream sub-zone (from tributaries with lower water quality standards) (Ausseil and Clark, 2007c, sections 6.4.2 to 6.4.11).

172. In the Upper Manawatū sub-zone (Mana_1a) the Ecosystem and Recreational and Cultural values that apply are Life-Supporting Capacity (Hill Mixed Geology), Natural State, Site of Significance – Aquatic, Contact Recreation, Amenity, Mauri, Trout Fishery (Regionally Significant), and Trout Spawning. With respect to providing for the values listed above, the key values with associated water quality standards are the Life-Supporting Capacity class, Contact Recreation, Trout Fishery and Trout Spawning values. The Life-Supporting Capacity value encompasses water quality considerations designed to maintain water quality for native fish and aquatic macroinvertebrates, given the geological and topographic constraints of the sub-zone (ie. upland reaches are more difficult for migratory native fishes to reach but they should contain high quality aquatic macroinvertebrate communities, particularly if the substrate is hard cobble or boulder material). Trout Fishery and Trout Spawning standards are more self-explanatory and were based on the recommendations of Hay *et al.* (2006) as described by Ausseil and Clark (2007c).

5.1 Water quality parameters and definitions

173. The water quality parameters listed in the POP standards of Schedule D and their relevance to water quality, aquatic ecosystem health, values and the management objectives are briefly described below. Each parameter has the potential to have an effect on freshwater and/or aquatic ecology in isolation of, or in combination with other contaminants. The expert evidence identified with each parameter is listed below. Where interactive effects between parameters are known these are covered within the expert evidence. Water quality parameters are discussed in the order they appear within Schedule D of the POP.

5.1.1 pH

174. pH is a measure of the acidity or alkalinity of a water sample based on the hydrogen ion activity at the time of measurement, as such pH is measured using a meter *in situ*. pH has the potential to affect the toxicity of other contaminants on aquatic life. Furthermore, aquatic life is also directly affected by high or low pH beyond a determined range. For more information on pH see the evidence of Dr Bob Wilcock.

5.1.2 Temperature

175. Water temperature, measured in degrees Celsius using a meter *in situ*, can be a critical factor determining:

   i. chemical processes, such as the proportion of unionised ammonia in ammoniacal nitrogen (and thereby its toxicity to aquatic life) or the percent saturation of dissolved oxygen;
   ii. biological thresholds for survival or occurrence of aquatic species (eg. the critical threshold for *Deleatidium sp.* Mayflies is 21 -23 degrees Celsius for 96 hour exposure (Quinn *et al.,* 1994)); and/or
   iii. thresholds for key biological processes for aquatic species (eg. the critical threshold for successful development of trout eggs is 10 degrees Celsius (Hay *et al.,* 2006).

176. Maintaining water temperature within the range of critical threshold limits can minimise the mortality of or avoidance behaviour in particular species; reduce the risk of toxic effects from chemical interactions, and maximise conditions for successful reproduction. Where these critical thresholds are known for particular species or communities defined by the values in a Water Management Sub-zone, water temperature limits specific to

those values have been applied. See the evidence of Dr John Quinn for further information on the effects of temperature and the justification for the temperature standards.

5.1.3 Dissolved oxygen (DO)

177. Dissolved oxygen is measured using an *in situ* meter and reported in mg/l or g/m^3. Horizons also use continuous DO meters that remain in place, providing measurements of DO at 15 minute intervals. The saturation of dissolved oxygen in a water body is influenced particularly by altitude, reaeration at the water surface, temperature and salinity/conductivity. Dissolved oxygen concentration and saturation fluctuate diurnally depending on the level of biological activity within a water body (eg. photosynthesising organisms such as periphyton increase dissolved oxygen during the day through photosynthesis and reduce dissolved oxygen during the night due to respiration). Additionally, dissolved oxygen can be influenced by season (through the effect of season on water temperature and photosynthesis) and through biological and chemical loads to water, as these generally require oxygen for breakdown and/or respiration. The Biochemical oxygen demand (BOD) is determined by measuring the dissolved oxygen concentration in a sample prior to and after incubation in a laboratory, usually over five days. The effects of BOD are described below and in the evidence of Dr John Quinn.

178. Dissolved oxygen is critical to aquatic life, particularly for higher organisms such as invertebrates and fish. The dissolved oxygen requirement of a particular animal varies from species to species depending on the life strategy, life stage (age) and physical morphology. Dissolved oxygen standards for each Water Management Sub-zone have been determined based on the critical dissolved oxygen thresholds for species important to each of the values identified for the management zone, and in relation to maintaining the values of downstream receiving environments. The effects of reduced dissolved oxygen are covered extensively in the evidence of Dr Quinn. The relationship of dissolved oxygen to ecosystem metabolism and aquatic health is discussed in the evidence of Dr Young.

5.1.4 Biochemical oxygen demand (BOD_5)

179. Biochemical oxygen demand (BOD_5) is a five day test measuring the oxygen demand for chemical and biological processes within a water sample. BOD_5 can be total or soluble (ie. the oxygen demand created from a filtered sample of soluble matter) and can employ a carbonaceous component also. Soluble carbonaceous BOD_5 is the most

relevant analysis to determine the effects of biochemical oxygen demand on growths of sewage fungus and reduction in dissolved oxygen. The rationale for the use of this particular variant of BOD analysis is described in the evidence of Dr Quinn, along with extensive commentary on the effects of biochemical oxygen demand on dissolved oxygen and sewage fungus growth. Recommendations on specifying the variant of BOD_5 test within the Schedule D standards are included in the table of recommended Water Quality Standards (Table 11) below.

5.1.5 Particulate organic matter (POM)

180. Particulate organic matter (POM) (also known as volatile suspended solids) is a measure of the concentration of particulate organic matter in a water sample, determined by laboratory analysis. This particulate matter can be made up of plant, bacterial, fungal or algal cellular material. High concentrations of POM are common downstream of oxidation pond outfalls as a result of the discharge of cellular material from the biological function of oxidation pond treatment systems. During low flows this material can drop out of suspension in the water column and become deposited on the bed of water bodies. This has been shown to have adverse effects on aquatic macroinvertebrates at concentrations above 5 g/m^3 (Quinn and Hickey, 1993).

181. For Water Management Sub-zones with high requirements for aquatic macroinvertebrate communities (eg. outstanding or regionally significant Trout Fisheries or Natural State valued waters), the POM standard of 2.5 g/m^3 proposed in Schedule D was lower than the 5 g/m^3 threshold in order to maintain these invertebrate communities in a very healthy state. However, this concentration is below the level of analytical detection for POM at the laboratory used by Horizons (3 mg/m^3, Table 7) and also well below the level of detrimental effect determined by Quinn and Hickey (1993). The rationale for recommending a change to POM standards in these zones is included in Table 11 below and can also be found in the evidence of Dr Quinn.

5.1.6 Periphyton cover and biomass

182. Periphyton is the community of organisms that grow on the bed of water bodies. The morphology, cover, biomass and flood resistance are all influenced by the species composition of the periphyton community. Periphyton exists in natural circumstances in rivers and streams and is the productive foundation for aquatic ecosystems, providing food for many aquatic macroinvertebrates and the base of the food web for fish.

Periphyton can proliferate to nuisance levels of growth from low flows and velocities, stable substrates, nutrient enrichment, high sunlight and water temperature.

183. Periphyton adheres to various substrates in rivers, streams and lakes. Hard cobble or boulder substrates provide ideal attachment surfaces for periphyton because the flows required to scour or physically shift these substrates are high. However, given stable flows periphyton can adhere to softer sandy or fine gravel substrates, wood or submerged macrophytes.

184. Nuisance growths have the potential to:

i. adversely affect aquatic communities, changing physical stressors such as pH and dissolved oxygen;

ii. impact on recreational values (such as swimming and fishing); and

iii. reduce Aesthetic values.

Nuisance periphyton growth, depending on the dominant species within the community, can also physically clog irrigation intakes, cause toxic effects on animals and humans (in the case of benthic cyanobacteria), or make water unpalatable for stock drinking purposes.

185. The adverse effects of periphyton have been described by Biggs (2000) in the New Zealand Periphyton Guidelines. Critical thresholds of periphyton biomass and percentage cover that can adversely affect water body values such as Life-Supporting Capacity, Trout Fishery, Contact Recreation and Aesthetics, have been used to determine the periphyton standards appropriate to each Water Management Sub-zone, depending on the values in each zone. Periphyton biomass is measured by analysing for chlorophyll a/m^2 in the laboratory from a field sample and percentage cover is determined by visual assessment. More information on the factors influencing periphyton growth, nuisance proliferation and the effects of such proliferation can be found in the evidence of Dr Barry Biggs. The periphyton guidelines from Biggs (2000) have been reproduced for reference purposes by Dr Roger Young and can be found in Appendix 1 of his evidence.

186. Suspended algal growth (phytoplankton) and macroalgae that grows on the substrate can occur in lakes, coastal waters and estuaries. When suspended algae are dominated by particular species (most notably cyanobacteria), nuisance algal blooms can form, causing floating scums of suspended algal material that can be unsightly and toxic. Algal biomass standards for suspended algal concentration are proposed for lakes in Schedule D and macroalgal cover and algal biomass standards are proposed

for estuaries and coastal waters in Schedule H. Proposed changes to these standards are included in Table 12 and Table 13 below and discussion of suspended algae in coastal waters and lakes can be found in the evidence of Dr John Zeldis and Max Gibbs respectively.

5.1.7 Dissolved reactive phosphorus (DRP)

187. Dissolved reactive phosphorus (DRP) is a bioavailable and soluble form of phosphorus nutrient that can be utilised by plants, algae and periphyton to promote growth. Dissolved reactive phosphorus concentration is determined through laboratory analysis. In combination with nitrogenous nutrients and given appropriate physical conditions, periphyton will proliferate as a result of elevated concentrations of DRP. Dissolved reactive phosphorus standards were developed in a Water Management Sub-zone specific manner in consultation with Dr Biggs to limit periphyton cover and biomass in order to keep growth within the Schedule D standards and maintain the values of each sub-zone (as described above). For more information on phosphorus and the relationship of DRP to periphyton growth see the evidence of Dr Barry Biggs.

5.1.8 Soluble Inorganic Nitrogen (SIN)

188. Soluble inorganic nitrogen is the total bioavailable fraction of soluble nitrogen nutrient in water determined through laboratory analysis. Soluble inorganic nitrogen is the sum of ammoniacal nitrogen, nitrite and nitrate species (nitrogen species are discussed in the Appendix of the evidence of Dr Wilcock). In combination with DRP, SIN contributes to the growth and proliferation of periphyton, algae and aquatic plants, given satisfactory physical conditions. The ammoniacal fraction of SIN can be directly toxic to aquatic organisms (described below) and nitrate can also be toxic to humans and stock where there are elevated concentrations in drinking water. However concentrations high enough to cause adverse drinking water effects are not normally within the ranges found in surface waters.

189. Like DRP, SIN standards were developed on a sub-zone by sub-zone basis in consultation with Dr Biggs to provide for the combination of values specific to each management zone, depending on the tolerable levels of periphyton growth and biomass required to maintain those values. The effect of SIN on downstream receiving environments was also taken into account when determining standards for each Water Management Sub-zone. Further information on the effects of SIN can be found in the

evidence of Dr Barry Biggs, Max Gibbs and Dr John Zeldis and in the Appendix of Dr Wilcock's evidence.

5.1.9 Macroinvertebrate Community Index (MCI)

190. The Macroinvertebrate Community Index (MCI) and its quantitative variant the QMCI are indices of macroinvertebrate community health that relate to the impact of organic enrichment developed by Stark (1985). The original indices were developed for stony-bottomed streams on the Taranaki Ring Plain but since their development in the mid 1980s these indices have been widely applied as a useful resource management tool to describe the impact of enrichment on aquatic ecosystems (Boothroyd and Stark, 2000). The Macroinvertebrate Community Index works by allocating enrichment sensitivity scores to individual aquatic invertebrate taxa. A sample of the macroinvertebrates is collected and then the scores of the invertebrates present in the sample are summed and standardised to determine a score between 0 and 200 with a high score indicating a lesser degree of impact from enrichment.

191. The QMCI uses the same enrichment sensitivity scores for each taxa as the MCI in addition to data on the abundance of taxa, rather than just the presence/absence resolution of the MCI. A QMCI score is determined from a formula using the scores and abundance data to give a value in the range of 0 to 8, with a score of 8 indicating an unimpacted macroinvertebrate community. The QMCI is also a widely used index and there are standardised national protocols for collecting and enumerating macroinvertebrates to determine MCI or QMCI scores (Stark *et al.,* 2001; Stark and Maxted, 2007). Additionally, a soft-bottom MCI and a semi-quantitative (SQMCI) have been developed to incorporate different stream substrates and reduce sampling and enumeration effort respectively.

192. The MCI is widely considered to be the most appropriate index for State of the Environment reporting of macroinvertebrate community impact with regard to organic enrichment. The QMCI is purported to be the most appropriate index for compliance monitoring of the impacts of specific activities such as the comparison between macroinvertebrate communities upstream and downstream of a wastewater discharge. Other indices also widely employed across the country include %EPT taxa and %EPT individuals. These indices describe the proportion of Ephemeroptera (mayflies), Plecoptera (stoneflies) and Trichoptera (caddis flies) in a macroinvertebrate community. The EPT families, generally speaking, are comprised of large, enrichment sensitive taxa. The higher the proportion of EPT taxa or individuals, the less impacted the sample.

193. There are some in the aquatic sciences who do not subscribe to single index approaches as valid ways to describe macroinvertebrate communities, due to the influences of catchment scale environmental variables (such as geology) on the index value. There has been wide-ranging debate about the use of multi-metric, reference based or predictive approaches to determining the health of macroinvertebrate communities between sites. Such approaches are widely used internationally but have not been completely developed or validated in New Zealand. The predictive approach applied in Australia (AUSRIVAS) has been used as a model for predicting and assessing the condition of aquatic ecosystems within the ANZECC Guidelines (2000). However, at the time of publication of the guidelines the ANZECC authors caution the developmental nature of this approach.

194. Horizons has been involved with a number of research projects in association with Dr Russell Death and Dr Mike Joy of Massey University to explore the use of observed/expected invertebrate models and Bayesian Belief Networks (BBN). Further information on QMCI and MCI in relation to the POP standards is provided below and information can also be found in the evidence of Dr Quinn.

5.1.10 Ammoniacal nitrogen

195. Ammoniacal nitrogen is a form of soluble inorganic nitrogen; its concentration is determined through laboratory analysis of a water sample. The aspects of nutrient enrichment and bioavailability of ammoniacal nitrogen as a stimulator of periphyton growth are included within the discussion of the SIN standard above. The specific ammoniacal nitrogen standard proposed in Schedule D relates to the potentially toxic effects of unionised ammonia on fish and macroinvertebrates. Ammoniacal-N toxicity is dependant on pH and temperature (as discussed in the evidence of Drs Quinn and Wilcock).

196. At higher pH and temperature the proportion of total ammoniacal nitrogen (often referred to as ammonia) that occurs as unionised ammonia (the free or toxic form) is greater. Standards for ammoniacal-N that are precautionary, in relation to the potential pH and temperature range of a given water body, were set for each Water Management Sub-zone, depending on the applicable values and whether highly ammonia sensitive species were expected to inhabit those zones.

5.1.11 Toxicants

197. Toxicants are described as substances or contaminants that have the potential to cause adverse effects, including heavy metals, pesticide residues and other substances. The standards for toxicants proposed in Schedule D are based on the ANZECC (2000) guideline values for different levels of species protection for listed contaminants. For example, in the upper Rangitīkei the '99% species protection level' is proposed. In order to know what concentration of particular contaminants would be acceptable within this standard, Table 3.4.1 of the ANZECC (2000) guidelines should be consulted. This table shows the concentrations at which 80, 90, 95 and 99% of species will be protected from the toxic effects of a contaminant, based on all toxicology data available at the time of the guideline development.

5.1.12 Turbidity

198. Turbidity is a measure of the degree to which water loses its transparency due to the scatter of suspended particles. It is generally used as a surrogate measure for water clarity and can be correlated (on a site by site basis) with black disc measurement of horizontal visibility to determine water clarity; and total suspended sediments to determine sediment loads. Turbidity is measured in nephelometric turbidity units (NTU) using light beam attenuation through a water sample which can be undertaken *in situ* using spot or continuous meters or analysed in a laboratory from a water sample.

199. Aquatic ecosystems and species can be adversely affected by high turbidity/low clarity in a number of ways: physical abrasion of fragile gill structures by particles, reduced light for photosynthesis of periphyton or submerged macrophytes, increased water temperature and concurrent reductions in dissolved oxygen saturation as a result, and the reduced ability to sight feed or evade predators in fish and invertebrates. Aesthetic and recreational values are also affected as water becomes less clear and swimming and fishing are impacted. Horizons has a continuous turbidity monitoring network, as discussed in the evidence of Dr Roygard to the Land Hearing, which is used to monitor turbidity and to determine suspended sediment load.

200. Turbidity is highly influenced by river flow. High flow causes sediment to be washed into rivers from the landscape and turbidity as a result increases. The degree of turbidity in rivers is also highly affected by the geology of the river catchment. Recommendations on turbidity standards proposed in Schedule D are included below (Table 11 and Table

12) and extensive discussion of the optical properties of water can be found in the evidence of Dr Davies-Colley.

5.1.13 Clarity

201. Water clarity can be measured directly using a black disc (horizontal visibility) in rivers or a Secchi disc in large rivers, lakes or seawater (vertical visibility). The un-equal numerical relationship of black disc to Secchi disc is discussed in the evidence of Dr Davies-Colley. Clarity is the measure of visibility through the water, as assessed by the human eye. Like turbidity, clarity can be heavily influenced by river flow and catchment geology, for the same reasons. The black disc method utilises the horizontal visibility of the human eye through the water column to measure clarity in a way that is relevant to assessing the ability of fish to sight feed, the Aesthetic value of water, or safe swimming visibility.

202. Further discussion on clarity can be found in the evidence of Dr Davies-Colley and recommended changes to the Schedule D clarity standards are included below (Table 11).

5.1.14 *Escherichia coli*

203. *Escherichia coli* is a bacterium commonly found in the gut of warm-blooded animals. *Escherichia coli* is used as a faecal indicator bacterium (FIB) to indicate the risk of pathogenic infection from other bacteria resulting from faecal contamination of freshwater. The requirements of an indicator bacteria that make *E. coli* suitable are that it does not persist in the environment (outside the body) for long periods of time and that the presence of the indicator is closely correlated with the presence of more sinister pathogenic bacteria such as *Salmonella* and *Camplylobacter*.

204. Like turbidity and clarity, *E. coli* increases markedly as river flow increases and faecal contaminants are washed into surface waters from the landscape and/or re-suspended from sediments on river beds. Because *E. coli* concentration is so highly correlated with river flow, a flow-related *E. coli* standard has been set in Schedule D of the POP. Additionally, an advantage of the relationship between *E. coli* and flow is that safe swimming levels for many rivers are able to be predicted in real-time using river flow, rather than through microbiological testing, which provides only a delayed laboratory result (ie. minimum of 24 hours turn around).

205. The Ministry for the Environment and the Ministry of Health have produced guidelines for *E. coli* that relate to contact recreation risk from faecal contamination (MfE/MoH, 2003). These guidelines have been used as the basis for the proposed standards in Schedule D. The proportionate risk of illness in recreational water users generally is also related to degree of recreational use. Therefore during the summer bathing season when use is highest, the *E. coli* standard is more stringent than outside the bathing season when primary recreational activities such as swimming are less likely to be as prevalent.

206. Additionally, the safety of swimmers is also influenced by flow and turbidity. At higher flows, even during the summer bathing season, rivers are often unswimmable for safety or clarity reasons, so at this time recreational use is likely to be lower and thus the *E. coli* standard can be more relaxed. More information on sources of *E. coli,* other faecal contaminants and appropriate standards can be found in the evidence of Dr Davies-Colley.

5.1.15 Enterococci

207. Enterococci are the preferred faecal indicator bacteria for saline water (MfE/MoH, 2003) and are monitored either fortnightly or weekly in seawater beach sites during the summer bathing season. Enterococci was once the faecal indicator used for freshwater, hence the Manawatū Catchment Water Quality Regional Plan (MCWQRP) (1999) standards for microbiological water quality refer to enterococci, rather than *E. coli*. Enterococci are more persistent in saline waters than *E. coli*, which is why they are the indicator of choice in these systems. The relationship between *E. coli* and enterococci is discussed by Dr Davies-Colley in his evidence.

5.1.16 Faecal coliforms

208. Like *E. coli* and enterococci, faecal coliforms are another group of FIB that indicate faecal contamination of surface waters and includes a broad range of coliform bacteria, some of which are associated with the gut of warm-blooded animals. However, because faecal coliforms can also contain bacteria that are not of faecal origin this is not the indicator of most use for determining risk for contact recreation in surface waters. The faecal coliform standard proposed in Schedule D relates instead to the risk of human consumption of shellfish and the risk of paralytic shellfish poisoning from that consumption. More information on faecal coliforms as an indicator can be found in the evidence of Dr Davies-Colley.

5.1.17 Cyanobacterial toxins

209. Cyanobacterial toxins are produced by blooms of cyanobacteria, also known as blue-green algae. In the past, monitoring of such blooms and toxin production has focused on lakes. Lake closure due to cyanobacterial blooms and toxin production has been common in the Region (see the evidence of Barry Gilliland). However, in recent years benthic cyanobacteria, growing on the bed of rivers and streams, has also been found to be responsible for the production of toxins that have caused human illness and the death of dogs and stock in many parts of the country. Toxin production is not always consistent with cyanobacterial cover or biomass. Cyanobacterial blooms may not produce any toxins at all, or toxins can be produced from a bloom that was previously non-toxic. To assist with the management of the health risk from cyanobacterial toxins in both lakes and rivers, the Ministry for the Environment and the Ministry of Health have produced draft national guidelines for the monitoring of and management response to cyanobacterial blooms (MfE/MoH, 2009).

210. The draft national guideline for management of cyanobacterial blooms in both rivers and lakes recommends various alert levels based on cyanobacterial cover (in rivers) or cell biovolume (in lakes), rather than relying only on direct toxicity testing.

211. Further information on cyanobacteria in lakes can be found in the evidence of Max Gibbs. The occurrence of benthic (riverine) cyanobacterial blooms such as *Phormidium sp*. is discussed at various points throughout this evidence.

5.1.18 Total phosphorus

212. Total phosphorus standards are set for lakes and the Seawater Management Zone. Total phosphorus includes all forms of phosphorus such as DRP (discussed above), dissolved organic phosphorus (DOP) and particulate forms of phosphorus. Total phosphorus is the most appropriate phosphorus analyte to determine the enrichment of lakes and seawater because of the long residence time of nutrients in these water bodies. Inputs of total phosphorus can become biologically or chemically changed because of long-term processes in lake and coastal systems, potentially releasing bioavailable forms of phosphorus nutrient into the water body.

213. More information on total phosphorus can be found in the evidence of Dr John Zeldis and Max Gibbs. Recommendations for changes to total phosphorus standards are included below (Table 12 and Table 13).

5.1.19 Total nitrogen

214. Total nitrogen standards are set for lakes and the Seawater Management Zone. Total nitrogen includes all forms of nitrogen such as soluble inorganic nitrogen, ammoniacal-N (discussed above) and organic forms. Total nitrogen is the most appropriate nitrogen analyte used to determine the enrichment of lakes and seawater because of the long residence time in these water bodies, which eventually causes the release of bioavailable forms of nitrogen over time through chemical and biological processes.

215. More information on total nitrogen can be found in the evidence of Dr John Zeldis and Max Gibbs in relation to coastal waters and lakes. A helpful summary of the forms of nitrogen can be found in the Appendix of Dr Wilcock's evidence. Recommendations for changes to total nitrogen standards are included below (Table 12 and Table 13).

5.1.20 Deposited sediment

216. Deposited sediment is the fine particulate matter (generally inorganic) that is carried in suspension by flowing waters and is generally the product of erosive processes in the wider catchment or at the stream banks or bed. This fine sediment drops out of suspension as velocities decrease or flows drop, filling the interstitial spaces of cobble or gravel-bed rivers. These interstitial spaces are important components of the aquatic ecosystems of gravel-bed rivers and streams. They provide habitat for invertebrates and native fish and also allow the passage of oxygenated water deeply into the bed, providing oxygen to fish and invertebrates taking refuge in the hyporheic zone (between the flowing channel of the river and the groundwater or subsurface flow) or to developing eggs and fry of gravel-spawned species such as trout and native bullies.

217. Deposition of fine sediment over time can have a smothering effect on these interstitial spaces, rendering the gravel habitat unsuitable for a number of invertebrates and fish to inhabit or reproduce in. There is currently a national Envirolink Tools project in development to determine the best monitoring methods to measure deposited sediment and to provide environmental guidelines on acceptable thresholds of deposited sediment. Horizons are championing this project and have been involved in its development from the outset. Catchments with significant erosion issues are likely to have aquatic ecosystems adversely affected by deposited sediment, depending on the substrate of the river and the flow characteristics of particular reaches.

Table 7. Common detection limits for laboratory analysis of Horizons water quality data collected between (1989-2009)

Parameter	Detection limit	g/m^3 (mg/L)
DRP	5 mg/m^3	0.005 g/m^3
Total P	10 mg/m^3	0.01 g/m^3
Ammoniacal-N	5 mg/m^3	0.005 g/m^3
TOx-N (NNN)	5 mg/m^3	0.005 g/m^3
Total N	50 mg/m^3	0.05 g/m^3
POM	3000 mg/m^3	3 g/m^3
$scBOD_5$	1000 mg/m^3	1 g/m^3
Chlorophyll *a* (suspended)	2000 mg/m^3	2 g/m^3
Turbidity	0.01 NTU	n/a

5.2 Water quality standards to provide for Ecosystem values

218. Table 8 shows the relationship between each of the values in the Ecosystem Group and the derived water quality standards. With the exception of river reaches valued for their Natural State and Sites of Significance – Riparian, all other values within the Ecosystem group are related to the water quality standards derived for the Life-Supporting Capacity class of each Water Management Sub-zone. This integration of several Ecosystem values under one set of water quality standards means that the Life-Supporting Capacity standards were key to the protection of native aquatic ecosystems for each individual sub-zone.

Table 8. Relationship between Ecosystem values and water quality standards

Value	Requirement and method for protection	Water quality standard derived from
Natural State (NS)	Narrative standard reflecting the maintenance of current state should be reflected by Life-Supporting Capacity water quality standards	Narrative water quality standard for designated reaches "The natural quality of the water shall not be altered".
Life-Supporting Capacity (LSC)	Water quality requirements for native species expected for each Life-Supporting Capacity class	Highest numeric water quality standards required to protect native species known or expected in Life-Supporting Capacity geology class of each Water Management Sub-zone
Sites of Significance - Aquatic (SOS-A)	Water quality and habitat requirements for aquatic indicator species	Covered by Life-Supporting Capacity standard for Water Management Sub-zone
Sites of Significance - Riparian (SOS-R)	Habitat requirements for indicator species	n/a
Whitebait Migration (WM) (formerly Native Fishery)	Water quality and habitat requirements for juvenile whitebait species migration	Covered by Life-Supporting Capacity standard for Water Management Sub-zone
Inanga Spawning (IS formerly Native Fish Spawning)	Water quality and habitat requirements for adult inanga and egg/larval development	Covered by Life-Supporting Capacity standard for Water Management Sub-zone in Schedules D and H

5.3 Methods to define water quality standards for the Life-Supporting Capacity value

219. Three methods were used to define the water quality standards for each of the Life-Supporting Capacity classes. These methods were applied in the following priority order:

i. When known from available scientific literature and/or research the water quality requirements or tolerance ranges of key native species (either aquatic macroinvertebrates or fish) were applied to the Life-Supporting Capacity classes where these species were known to be found or expected to be according to expert opinion (see Ausseil and Clark, 2007c, Table 7, page 37).

ii. Analysis of water quality data from reference (unimpacted or slightly impacted) sites to estimate the 'natural' range in water quality parameters at sites within each Life-Supporting Capacity class. Results from this analysis were then used to validate standards determined by method (a) above, or determine an appropriate percentile of the reference data to use as a standard for each Life-Supporting Capacity class.

iii. In the absence of enough data for the first two methods, the application of national or international guidelines or trigger values that provide for a wide range of aquatic species were employed. Where this method was used consideration was given to the transferability of the standard and the organism/ecosystem type to the Life-Supporting Capacity classes of the Region.

220. The use of these three methods is consistent with the recommendations within the ANZECC guidelines (ANZECC, 2000) for deriving localised trigger values (see Figure 3.1.2 in Appendix 1 of this evidence, reproduced from ANZECC (2000)).

221. Derivation of recommended water quality standards for the protection of aquatic ecosystems in each of the Life-Supporting Capacity classes is discussed in detail by Ausseil and Clark (2007c, section 3.2.3 beginning on page 41). The water quality standards derived in this manner relate to:

- pH
- water temperature
- dissolved oxygen (DO)
- biochemical oxygen demand (BOD)
- water clarity
- QMCI
- Particulate organic matter (POM)
- chlorophyll *a* /m^2

- periphyton % cover
- ammoniacal nitrogen and
- other toxicants.

5.4 Water quality standards to provide for Recreational and Cultural values

222. Table 9 shows the relationship between each of the values in the Recreational and Cultural Group and the derived water quality standards. With the exception of river reaches valued for Native Fishery (Whitebait Migration) or Shellfish Gathering (which have been removed from this value group), all values within the Recreational and Cultural group are related to the water quality standards derived for Contact Recreation, Trout Fishery and Trout Spawning. This integration of several Recreational and Cultural values under one set of water quality standards means that the Contact Recreation, Trout fishery and Trout Spawning standards were key to the protection of Recreational and Cultural values for each individual sub-zone.

Table 9. Relationship between Recreational and Cultural values and water quality standards.

Value	Requirement and method for protection	WQ standard derived from
Contact Recreation (CR)	Visual clarity Human Health Nuisance growths	Specific water quality standards
Amenity (Am)	Public access Water clarity	Covered by visual clarity standards for Contact Recreation
Native Fishery (see Whitebait Migration in Ecosystem values Group)	n/a	n/a
Mauri (MAU)	Water quality, food gathering, habitat and spiritual aspects	Water quality aspects likely to be covered by Life-Supporting Capacity standards
Shellfish Gathering (SG) (see Schedule H water quality standards	Protection of human health from contaminated shellfish	Faecal coliform standards in recommended Schedule H
SOS-C	No sites defined - unknown	n/a
Trout Fishery (TF)	Water quality and habitat requirements depending on Trout Fishery class	Specific water quality standards for each Trout Fishery class in designated reaches
Trout Spawning (TS)	Water quality and habitat requirements	Narrative and numeric water quality standards for designated reaches
Aesthetics (Ae)	Public access Visual clarity Periphyton growth	Visual aspects and periphyton biomass and cover covered by Contact Recreation standards for Water Management Sub-zone

5.5 Methods to define water quality standards for the Contact Recreation value

223. There are four water quality aspects that relate to the value of Contact Recreation:

- visual clarity of the water
- periphyton biomass and cover
- faecal contaminants and associated health risks
- pH.

224. The recommended method to determine appropriate water quality standards to provide for the Contact Recreation value is to use established guidelines. The 2003 Microbiological Water Quality Guidelines for Marine and Freshwater Areas published by the Ministry of Health and the Ministry for the Environment (MfE, 2003; microbiological standards); the New Zealand Periphyton Guidelines for periphyton standards (Biggs, 2000); and the ANZECC guidelines for pH and visual clarity standards were deemed the most appropriate existing guidelines for this purpose. Note that these standards may be superseded by more stringent water quality standards for other values in some Water Management Sub-zones.

225. Season and river flow are relevant considerations when applying water quality standards for the protection of Contact Recreation. Most forms of contact recreation occur either during warmer months (ie. November to April) or at lower river flows (ie. < median flow). More detail on the methods for determining the water quality standards for Contact Recreation can be found in Section 4.1.3 of Ausseil and Clark (2007c) and further information is provided in the evidence of Dr Davies-Colley, Max Gibbs and Dr Zeldis.

226. Recommended water quality standards for contact recreation that incorporate the methods of Ausseil and Clark (2007c) and the expert evidence are included in the sections below.

5.6 Methods to define water quality standards for the Trout Fishery and Trout Spawning values

227. Water quality standards for the Trout Fishery value were defined to provide for adult and sub-adult brown and rainbow trout and also for their main food source - high quality aquatic macroinvertebrate communities. Egg, larval and early juvenile trout development are covered by the trout spawning standards. Through the water quality standards, different levels of trout fishery protection can be afforded to the three classes of Trout Fishery value as follows:

- Outstanding Trout Fishery (Class TF1) standards were designed to maintain the fishery at optimum trout conditions and to give effect to any water quality considerations in National Water Conservation Orders.
- Regionally Significant Trout Fishery (Class TF2) standards were designed to provide good to excellent conditions for trout and to give effect to any water quality considerations in Local Water Conservation Notices.
- Other Trout Fishery (Class TF3) standards were designed to maintain tolerable to good conditions for trout.

228. The Cawthron Institute were commissioned to recommend water quality standards for the Trout Fishery and Spawning values (Hay *et al.,* 2006). Section 4.3.2 of Ausseil and Clark (2007c) summarises the water quality standards relevant to the Trout Fishery value and section 4.4 covers the Trout Spawning considerations. Water quality standards to provide for Trout Fishery relate to the following parameters:
    - pH
    - water temperature
    - dissolved oxygen
    - biochemical oxygen demand (BOD)
    - water clarity
    - QMCI
    - periphyton biomass (chlorophyll *a*)
    - ammoniacal-N
    - other toxicants.

229. For Trout Spawning the following water quality parameters were considered for the development of standards:
    - water temperature
    - dissolved oxygen
    - suspended and deposited sediment
    - other toxicants.

230. Trout Spawning standards apply only during the spawning period defined as 1st May to 30th September (inclusive) in waters identified for Trout Spawning. This designated spawning period was designed to cover the spawning and juvenile development of brown and rainbow trout. Both species are now found ubiquitously throughout most of the Region's rivers. Further explanation is provided in Ausseil and Clark (2007c) and McArthur and Lambie (2007).

5.7 Methods to define water quality standards for the Water Use and Social/Economic values Groups

231. The quality of water required for consumptive uses varies markedly depending on the use. Setting water quality standards for the needs of consumptive users is unnecessary as the standards derived for the Ecosystem and Recreational and Cultural values will likely provide water of a reasonable quality appropriate for a wide variety of consumptive uses. Table 10 shows the relationship between the Water Use and Social/Economic value groups and the water quality standards. Water Supply and Stockwater values are likely to be the two values most affected by poor water quality due to associated human and animal health issues.

232. For domestic and public water supply the standards within the National Environmental Standard (NES) for sources of raw drinking water supersede any water quality recommendations within the POP. However, analysis of whether a consent for discharge can be granted for an activity upstream of a drinking water supply source, and the potential effects of any such discharge, still have to be considered on a case by case basis, depending on the nature of the activity and the effectiveness of the water supply treatment system. The relationship between the NES for drinking water quality and the POP is discussed in the evidence of Barry Gilliland.

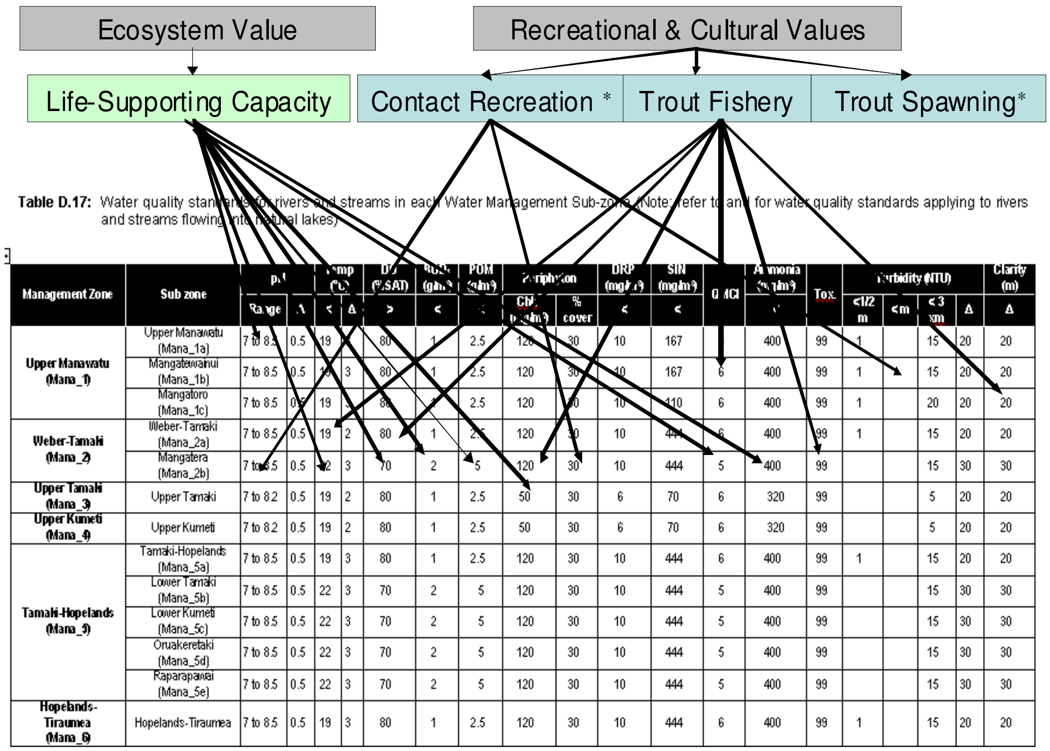
233. Consideration of standards to protect stock drinking water is given in the evidence of Drs Wilcock and Davies-Colley and recommendations based on this advice are included in the sections below.

Table 10. Relationship between Water Use, Social and Economic value groups and water quality standards.

Value	Requirement and method for protection	WQ standard derived from
Water Supply (WS)	NES considered on a case by case basis	No specific sub-zone standard set but raw (to be treated) drinking water is likely to be covered for most aspects by the recommended water quality standards to protect other values
Industrial Abstraction (IA)		Most likely to be covered by water quality standards
Irrigation (I)		Most likely to be covered by water quality standards
Stockwater (SW)	Faecal contamination Nitrate and nitrite ions Other toxicants	Covered by Contact Recreation microbiological standards and Life-Supporting Capacity standards for toxicants and nitrogen species
Capacity to Assimilate Pollution (CAP)	See recommendations in values section	n/a
Flood Control (FC)	n/a	n/a
Drainage (D)	n/a	n/a
Existing Infrastructure (EI)	n/a	n/a

5.8 Defining the water quality standards for each Water Management Sub-zone

234. With the exception of nutrient standards, which are discussed in separate sections below, the process for defining the final set of standards for each Water Management Sub-zone was continued by comparing the key values in each sub-zone and analysing the standards for each of those values to select the most stringent. Table 21 on page 96 in Ausseil and Clark (2007c) shows a summary of water quality standards by value. Figure 2 shows how the key Ecosystem and Recreational and Cultural values are related to each of the water quality standards in different Water Management Sub-zones, using the sub-zones of the Upper Manawatū as an example.



Management Zone	Sub zone	pH Range	pH Δ	Temp (°C) <	Temp (°C) Δ	DO (%SAT) >	BOD (g/m³) <	POM (g/m³) <	Periphyton Chl a (mg/m²)	Periphyton % cover	DRP (mg/m³) <	SIN (mg/m³) <	QMCI	Ammonia (g/m³) <	Tox.	Turbidity (NTU) <1/2 m	Turbidity (NTU) <m	Turbidity (NTU) <3 xm	Turbidity (NTU) Δ	Clarity (m) Δ
Upper Manawatu (Mana_1)	Upper Manawatu (Mana_1a)	7 to 8.5	0.5	19	[illegible]	80	1	2.5	120	30	10	167	[illegible]	400	99	1		15	20	20
	Mangatewainui (Mana_1b)	7 to 8.5	0.5	19	3	80	1	2.5	120	30	10	167	6	400	99	1		15	20	20
	Mangatoro (Mana_1c)	7 to 8.5	0.5	19	3	80	1	2.5	120	30	10	110	6	400	99	1		20	20	20
Weber-Tamaki (Mana_2)	Weber-Tamaki (Mana_2a)	7 to 8.5	0.5	19	2	80	1	2.5	120	30	10	444	6	400	99	1		15	20	20
	Mangatera (Mana_2b)	7 to 8.5	0.5	22	3	70	2	5	120	30	10	444	5	400	99			15	30	30
Upper Tamaki (Mana_3)	Upper Tamaki	7 to 8.2	0.5	19	2	80	1	2.5	50	30	6	70	6	320	99			5	20	20
Upper Kumeti (Mana_4)	Upper Kumeti	7 to 8.2	0.5	19	2	80	1	2.5	50	30	6	70	6	320	99			5	20	20
Tamaki-Hopelands (Mana_5)	Tamaki-Hopelands (Mana_5a)	7 to 8.5	0.5	19	3	80	1	2.5	120	30	10	444	6	400	99	1		15	20	20
	Lower Tamaki (Mana_5b)	7 to 8.5	0.5	22	3	70	2	5	120	30	10	444	5	400	99			15	30	30
	Lower Kumeti (Mana_5c)	7 to 8.5	0.5	22	3	70	2	5	120	30	10	444	5	400	99			15	30	30
	Oruakeretaki (Mana_5d)	7 to 8.5	0.5	22	3	70	2	5	120	30	10	444	5	400	99			15	30	30
	Raparapawai (Mana_5e)	7 to 8.5	0.5	22	3	70	2	5	120	30	10	444	5	400	99			15	30	30
Hopelands-Tiraumea (Mana_6)	Hopelands-Tiraumea	7 to 8.5	0.5	19	3	80	1	2.5	120	30	10	444	6	400	99	1		15	20	20

* These are key values used to develop the "Additional Water Quality standards" in Schedule D outside of Table D17

Figure 2. Example of the complex and inter-relatedness of key values and water quality standards in Schedule D of the Proposed One Plan. *Note: this diagram will be explained in a step by step manner, using a presentation of slides during the delivery of evidence at the Water Hearing.*

5.9 The development of nutrient standards: soluble inorganic nitrogen (SIN) and dissolved reactive phosphorus (DRP)

235. Concentrations of soluble nitrogen and phosphorus in excess of natural background levels can cause nutrient enrichment (also known as eutrophication) which in turn causes nuisance periphyton (algal) proliferation on the beds of lakes, rivers and streams. Nutrient enrichment can also result in the complete smothering of stream channels by aquatic weeds or contribute to the formation of algal or cyanobacterial blooms (both suspended and benthic) that can be toxic to humans and animals.

236. Periphyton (and aquatic weeds in some waterways) are the primary productive base of the aquatic food chain and are an important aspect of functioning aquatic ecosystems. However, excess growth of periphyton reduces the aesthetic and recreational appeal of water bodies and can negatively impact on many values (Biggs, 2000). For example,

the Life-Supporting Capacity and aquatic biodiversity value of rivers and streams can be decreased by smothering of the substrate by periphyton. Consumptive uses can be impacted through reduction of the potability of water for stock and human supply, or the clogging of irrigation and water supply intakes with algal, diatom or macrophyte biomass.

237. The open, un-shaded nature of most of the gravel-bed rivers and streams in Horizons' Region increases the risk of nuisance periphyton proliferation, particularly in summer when sunlight intensity is highest and river flows drop. The duration of time when environmental conditions are suitable for maximum periphyton growth, between high flow events which dislodge and wash away periphyton biomass, is known as the accrual period. Many rivers and streams currently experience considerable blooms of algal growth when suitable accrual conditions persist and soluble nutrient concentrations are high.

238. The nutrient standards in Schedule D of the Proposed One Plan were developed primarily to meet the periphyton cover and biomass standards determined for the values in each Water Management Sub-zone.

239. The New Zealand Periphyton Guideline (Biggs, 2000) was developed by Dr Biggs for the Ministry for the Environment to assist resource managers in detecting, monitoring and managing the enrichment/eutrophication of rivers and streams in New Zealand. Thresholds for maximum periphyton cover, biomass (chlorophyll *a*) and ash free dry mass (AFDM) for the protection of instream values are defined in Table 14 of the guideline (Biggs, 2000, page 102). Biggs (2000) designed a statistical model for predicting periphyton growth based on the flood frequency regime and nutrient concentrations for a given river. This model, and further information on the relationships between nutrient concentrations, flood frequency regime and periphyton growth, are discussed in the evidence of Dr Biggs.

240. Until recently, the management of periphyton and algae in the Region has relied on the theory of nutrient limitation, ie. control of the nutrient that is in the most limited supply. According to the Redfield Ratio (Redfield *et al.,* 1963) the optimum uptake ratio of N to P in plants is approximately 7:1 by weight (or 16:1 by molar ratio), so phosphorus is assumed to be the nutrient most likely in limited supply.

241. The Manawatu Catchment Water Quality Regional Plan (1999) applied this theory through the imposition of Rule 2g, which limited the concentration of allowable DRP to 15 mg/m^3 as a result of discharges to water after reasonable mixing. The intent of this

rule was to control growths of nuisance periphyton for the purposes of providing for contact recreation. The effects of periphyton proliferation on aquatic ecosystems are also discussed within the Plan's narrative. Although nitrogen is a key nutrient for periphyton growth, no rules were imposed as limitation of phosphorus was thought to provide adequate control at the time of the Plan's development.

242. In developing the water quality standards for the Proposed One Plan, Horizons staff questioned the rationale behind the phosphorus control approach. Biggs (2000) had identified that reliance on one limiting nutrient was not advisable as nutrient limitation status could change in response to a number of environmental factors. To explore whether a nutrient-limitation approach was still a viable option for the POP, Horizons and Hawkes Bay Regional Council jointly commissioned an expert panel on 'Nutrient Limitation for the Control of Periphyton', funded through an Envirolink advice grant.

243. A workshop was held with experts on nutrients and periphyton from NIWA and Massey University. The limiting nutrient workshop and reported outcomes (Wilcock *et al.,* 2006) are extensively covered in the evidence of Dr Wilcock. The key outcomes were:

i. Both nitrogen and phosphorus need to be managed in all rivers because limiting nutrient status can differ between connected catchments and within the same waterway spatially (eg. estuaries versus upland rivers) and/or seasonally. Management of only the limiting nutrient was not recommended.

ii. A high background concentration of a non-limiting nutrient can contribute to periphyton blooms if control of the limiting nutrient fails.

iii. Year-round control of N and P is needed because periphyton growth and vigour are determined by the preceding nutrient conditions and the upstream presence of residual colony-forming algal material (see flows at which the standards apply below).

iv. Not all rivers and streams will require nutrient management to reduce periphyton proliferation (eg. rivers with soft substrates). However, contaminant management is still required in most soft-bottomed river systems to: 1) reduce nutrient pools within sediments; 2) to reduce the input of other contaminants that enter waterways via the same transport paths (eg. faecal contaminants); and 3) to provide for downstream reaches with hard substrates or estuarine/coastal waters.

244. Following the workshop and report from the expert panel, the development of both N and P standards for the POP was initiated (see below).

5.9.1 Regional nutrient limitation study

245. As the expert panel determined, phosphorus limitation cannot be relied on to control periphyton. The long-term water quality record from several State of the Environment monitoring sites was used to investigate the relationships between raw concentrations of phosphorus and nitrogen. The results of the nutrient limitation investigation are documented for the Manawatū and Mangatainoka in Roygard and McArthur (2008, section 3.4.1) and the Manawatū, Mangatainoka and Rangitīkei in McArthur *et al.* (2009).

246. A key assumption underlying this work was that the N and P standards recommended by Dr Biggs (see Table 22, Ausseil and Clark, 2007c) and the standards proposed in the One Plan, were adequate to determine concentrations above which a particular nutrient becomes non-limiting. Ratios of N:P were not used in this study as the raw concentrations better reflect biologically relevant in-stream nutrient conditions. However, the ratio of N:P can easily be plotted over the concentration graph to examine both the raw concentrations and the ratios together (see the evidence of Dr Roygard).

247. Biggs (2000) and Wilcock *et al.* (2007) recommend the use of nutrient diffusing substrate (NDS) bioassays as a good way to determine nutrient limitation status at a particular site. However, there is some evidence to suggest that in the Rangitīkei catchment at least, NDS assays should only be considered a snapshot of the relative concentrations and limitation status of N and P respectively (McArthur *et al.,* 2009). Examination of long-term variation in N and P concentration (McArthur *et al.,* 2009) did not support the findings of Death *et al.,* (2007) that the limiting nutrient at sites in the Rangitīkei River was predominantly nitrogen (Figure 3).

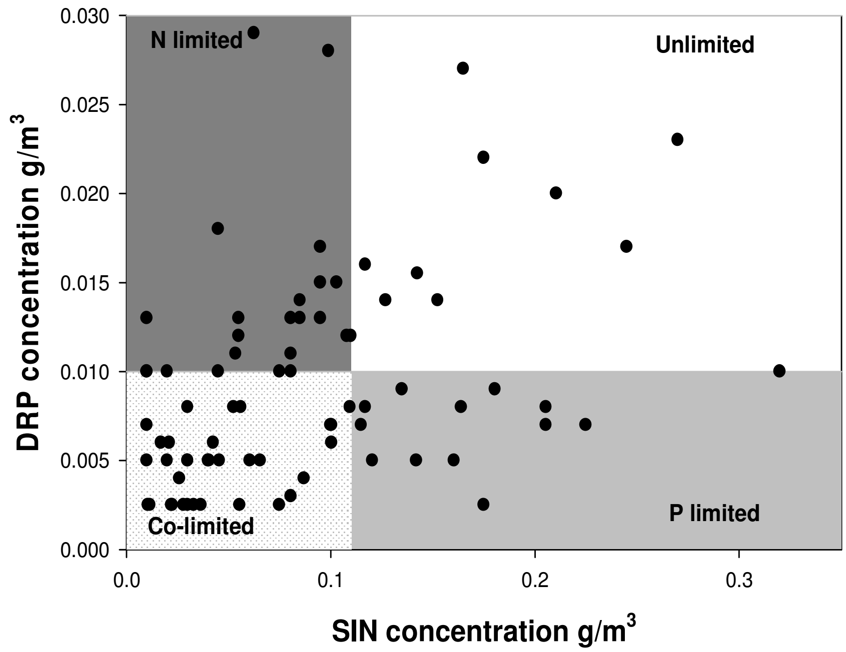


Figure 3. Soluble inorganic nitrogen and dissolved reactive phosphorus concentration from samples collected from the Rangitīkei at Mangaweka monitoring site between 1989 and 2008, displayed with potential nutrient limitation status determined using Proposed One Plan nutrient standards. *Reproduced from McArthur et al. (2009).*

248. McArthur *et al.* (2009) concluded:

i. Nutrient limitation by N or P varies with time, flow, season and sub-catchment.

ii. Managing such a dynamic system via control of one 'limiting nutrient' is likely to fail as a result of the complexities in these relationships.

iii. Management of the adverse effects of enrichment requires an approach which limits the inputs of both N and P to waterways, across all nutrient sources and under most flow conditions.

5.10 Flows at which nutrient standards apply

249. In addition to enrichment status, the other key aspect affecting periphyton biomass accrual identified by Biggs (2000) is the flow regime, and specifically the average inter-flood frequency or mean days of accrual (MDA). Further information on the relationship between periphyton, nutrient concentration and flow regime can be found in the evidence of Dr Biggs.

250. The POP defines the flows at which nutrient standards apply as being at or below the three times median flow ($3*Q_{50}$) for the river. The three times median flow statistic was used because at flows above this level there is a high likelihood of disturbance and removal/reduction of benthic periphyton growth by scouring, abrasion and movement of the bed load (substrate). The use of the three times median flow statistic is based on the work of Clausen and Biggs (1997), who determined that the accrual period of periphyton and benthic macroinvertebrate communities between three times median flow disturbance events (known as the FRE3) was an indicator of the level of interaction between the biological communities and the flow regime in a given river. Clausen and Biggs (1997) determined that rivers could be grouped according to their average FRE3 statistic (or the average time between flow disturbance events) with rivers with a lower FRE3 being more highly disturbed systems than those with a higher FRE3, which were more ecologically stable.

251. Roygard and McArthur (2008) discussed the use of the 10^{th} flow percentile as a surrogate flow disturbance measure above which nutrient standards would not apply. The use of flow percentile values (as opposed to statistics such as the median, half median and three times median) is recommended as the best approach for Schedule D and is identified in the Council submission. The reason behind recommending the use of flow exceedence percentiles rather than three times the median statistic is that percentiles approximate the period of time that a river is likely to be above a certain flow, a concept easier for any audience to grasp than other flow statistics. For a detailed description of how flow exceedence percentiles work see the box below, reproduced from Roygard and McArthur (2008).

Flow Distribution and Exceedence Percentiles

The table below displays an example of a flow distribution for the Manawatu at Hopelands site (located at the bottom of the upper Manawatu case study catchment). The 100th percentile (lowest flow recorded) is 2.005 m^3/s, the 1st percentile is 176.177 m^3/s and the 0 percentile (highest flow recorded) is 1669.642 m^3/s. The flow exceeds the 0 percentile 0% of the time and exceeds the 100th percentile flow 100 percent of the time. This flow distribution is based on the instantaneous flow record (recorded every 15 minutes) as recorded, with no averaging. [Note that the terminology used here is consistent with that of Henderson and Dietrich, 2007.]

The median flow (Q_{50}) or 50th percentile for the Manawatu at Hopelands site is 15.4 m^3/s, therefore three times the median flow (3 * Q_{50}) is 46.2 m^3/s. This flow is exceeded between 11 and 12 percent of the time according to the flow exceedence percentiles.

Table: Flow distribution for the Manawatu at Hopelands site using instantaneous data.

Exceedence percentiles

	0	1	2	3	4	5	6	7	8	9
0	1669.642	176.177	121.278	96.864	81.694	72.070	65.158	59.679	55.676	52.191
10	49.496	47.088	44.699	42.770	40.953	39.156	37.502	36.154	34.964	33.801
20	32.653	31.531	30.487	29.597	28.758	27.960	27.170	26.387	25.629	24.938
30	24.289	23.642	23.060	22.487	21.915	21.386	20.881	20.420	19.960	19.533
40	19.106	18.691	18.280	17.861	17.482	17.128	16.779	16.401	16.049	15.705
50	15.400	15.073	14.768	14.449	14.147	13.844	13.548	13.255	12.978	12.698
60	12.422	12.161	11.905	11.646	11.376	11.108	10.861	10.608	10.351	10.111
70	9.900	9.677	9.449	9.219	8.976	8.744	8.521	8.335	8.136	7.931
80	7.712	7.470	7.239	7.018	6.789	6.557	6.333	6.119	5.910	5.680
90	5.439	5.192	4.922	4.658	4.388	4.157	3.889	3.595	3.274	2.864
100	2.005									

Mean = 25.575 Std Deviation = 43.672

5473 days 07:45:00 hhmmss of data analysed

365 days 00:15:00 hhmmss of missing record

The distribution was calculated over 2000 classes in the range 2.005 to 258.751 m^3/s

Note: the flow percentiles shown in this report differ from those of Roygard et al. (2006) and Henderson and Diettrich (2007) due to the removal of the 1992 partial year.

Flow percentiles for the Manawatu at Hopelands site

To demonstrate how percentiles relate to river flows as recorded, the percentile flows that mark the boundaries of flow for the Manawatu at Hopelands site are plotted over the long-term flow record in the figures below.

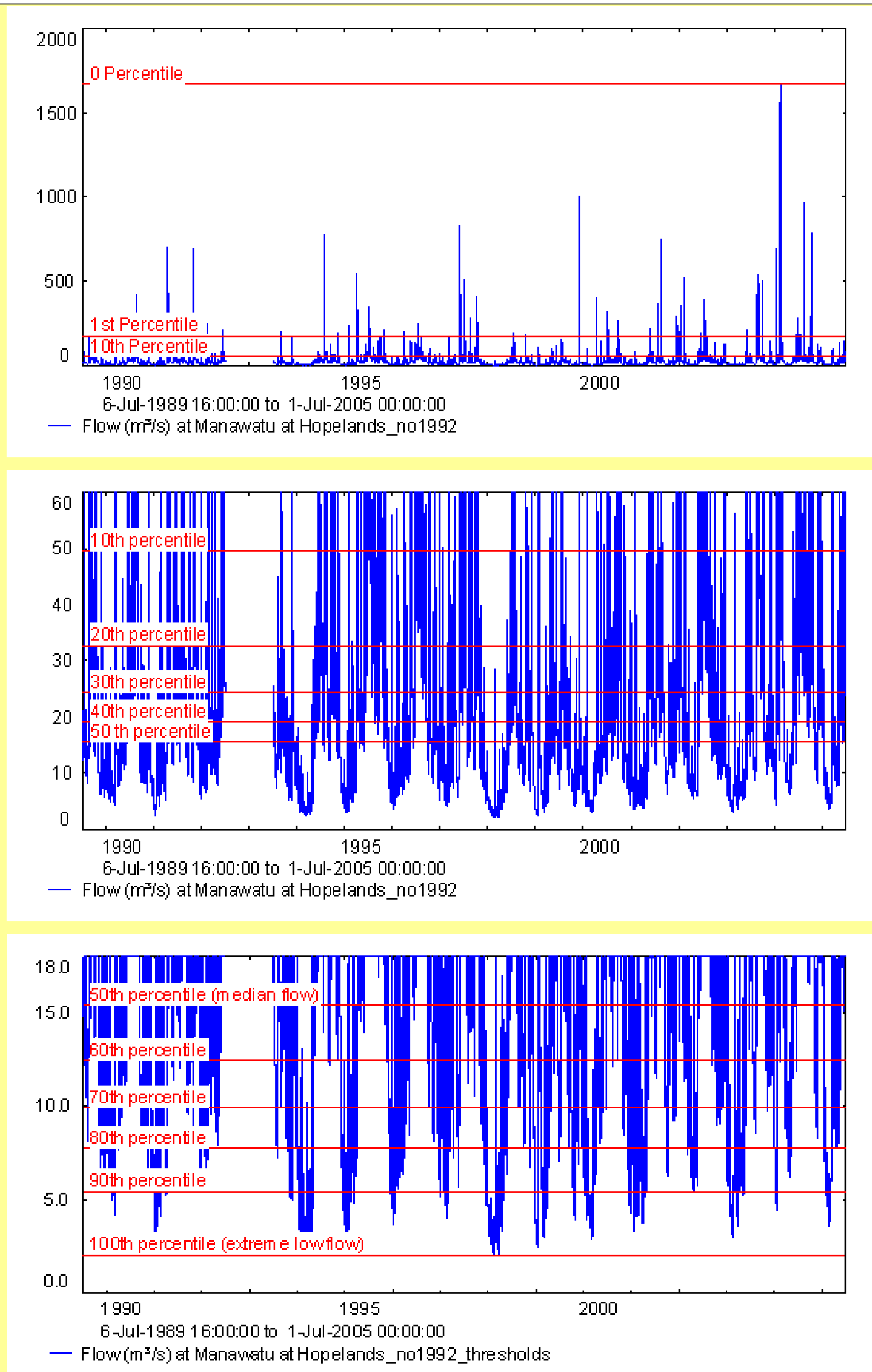


Figure: Flow record for the Manawatu at Hopelands showing instantaneous data in relation to flow percentiles.

252. Roygard and McArthur (2008, Appendix 3) also make a comparison of which flow decile range the three times median flow lies within for 63 flow sites throughout Horizons' Region (every 10^{th} percentile range is considered a decile). The three times median flow ($3*Q_{50}$) occurred within the $0–10^{th}$ flow decile category (the top 10% of flows) at 30% of flow sites regionally and within the $10^{th}–20^{th}$ decile category at 49% of the sites. A conservative flow decile limit, above which nutrient water quality standards would not apply, would be the $0–10^{th}$ decile category. Using the 20^{th} percentile flow cut off, as recommended in the Council submission, would be more permissive but may mean at some sites there is a slightly higher risk of nuisance periphyton growth if nutrients are discharged at flows which do not cause substrate disturbance around the 20^{th} percentile.

253. Annual nutrient loads and instantaneous nutrient concentrations vary markedly depending on river flow. Roygard and McArthur (2008) examined the proportion of nutrient load that would occur in the top 10^{th} flow decile in the Manawatū at Hopelands and Mangatainoka at SH2 if the nutrient concentration remained constant (ie. the Standard load limit). The results showed that at Hopelands, 41% of the SIN and DRP loads would pass by the monitoring site in the top 10 percent of flows and in the Mangatainoka 38% of the SIN and DRP load would occur in this flow decile. This is considered to be an underestimate, as concentrations of N and P are not constant and during high flow events are elevated above median levels.

5.11 Methods for determining nutrient standards and applicable flows

254. The limiting nutrient workshop determined that both N and P need to be controlled, and also that the flows at which the nutrient standards should apply were all flows less than bed disturbance events. Whilst the development of water quality standards was underway, a concurrent project to determine flow statistics for the Region's rivers and streams was also ongoing with Horizons and NIWA staff (Henderson and Diettrich, 2007). The flow statistics project aimed to document all available flow information for the Region's current and historic flow recorder sites in a consistent and usable manner. These flow statistics were used for both water allocation and water quality management and provided good guidance on flow percentiles at a large number of sites for the application of nutrient standards.

255. Four main sources or methods of technical advice were used in combination to compile potential nutrient standards and recommendations for the Water Management Zones of the Region. The four methods were:

i. the use of the periphyton model from the National Periphyton Guidelines;

ii. expert opinion from Dr Barry Biggs;
iii. the ANZECC guidelines for nutrient trigger values; and
iv. the current enrichment state, determined from Horizons' monitoring data.

256. This method of tailoring water quality standards to local conditions is strongly recommended within the ANZECC framework for application of the guidelines (ANZECC, 2000).

257. The process for determining the nutrient standard for each Water Management Zone is explored in detail in Ausseil and Clark (2007c, Section 6.3). Only a brief example of the process for choosing between options for nutrient standards is included here. In general, the expert advice of Dr Biggs was followed with regards to N and P standards; this advice included assessments based on the risk of nuisance periphyton blooms given local environmental conditions. In some instances significant relaxation of Dr Biggs' recommended standards were allowed where there was clear evidence that a particular nutrient was found to already exist in concentrations *significantly* higher than the proposed standard.

258. In locations with existing enrichment problems (ie. concentrations well in excess of ANZECC guideline values for N and/or P), the existing state was taken into account in order to set an achievable standard. Proposed standards included consideration of the potential effects of nutrients on downstream receiving environments, as per the advice of the expert panel (Wilcock *et al.,* 2007). For example, if the downstream Water Management Zone or environment had a more stringent nutrient standard than zones upstream, waters flowing into that zone would require an equally stringent standard to reduce the potential for nutrients to be transported beyond the boundaries of that zone at a concentration likely to cause adverse environmental effect on the values of the downstream zones.

259. Also weighed up was the potential for rivers to be high risk for periphyton proliferation because of their geological and morphological characteristics. For example, large, unshaded cobble or gravel-bed rivers, especially those of moderate to low gradient, have a high potential for periphyton proliferation. In these cases, relaxation of the DRP standard was not considered appropriate and a more precautionary DRP standard was applied (Ausseil and Clark, 2007c).

260. Ausseil and Clark (2007c) also note that consideration of the priority nutrient, in situations where there was a clear indication of nutrient limitation, were also taken into

account in the development of nutrient standards. In light of the results of the nutrient limitation investigation (particularly in the upper Manawatū River catchment) this approach is somewhat redundant as P is not 'clearly the limiting nutrient' at all times in the upper Manawatū. Potentially, the standards for nitrogen should have been applied more stringently in these Water Management Sub-zones. However, the extremely enriched state of the upper Manawatū (detailed in the sections above) requires the adoption of a pragmatic approach to decrease nitrogen concentrations in the river, and reduce the risk, duration and frequency of periphyton proliferation; a high standard in these circumstances would have proven unworkable.

261. The recommended nutrient standards presented in Schedule D of the POP aim to balance the need for significant improvements in water quality with the definition of a demonstrably achievable water quality target. The balance between desired state and current state is particularly relevant in catchments subject to high non-point source nutrient loads, such as the upper Manawatū and Mangatainoka Rivers (Ledein *et al.,* 2007; McArthur and Clark, 2007).

5.12 Comparison of POP and Manawatu Catchment Water Quality Regional Plan (1999)

262. The MCWQRP Rules 1 and 2 applied only to the Manawatū River catchment, with a small number of locations excluded from the Rule 2 provisions (see Annex 6 section 33.3, page 120). Ausseil and Clark (2007c) provide a detailed description of water quality standards in the operative planning framework for the Region and Table 2 (page 8) of that report summarises all of the water quality rules in the MCWQRP. A brief discussion of nutrient control in relation to the regulation of phosphorus in the MCWQRP is included in this evidence in the sections above on nutrient limitation.

263. The MCWQRP Rules were developed based on the best available science and understanding of the catchment, within the context of the water quality issues at the time (see the evidence of Barry Gilliland). The development of numeric standards within the rules of the Plan (rather than narrative standards) was a very positive step towards drawing a clear line in the sand with respect to water quality issues in the Manawatū catchment. However, some significant limitations to the MCWQRP approach required the development of a new regulatory framework for water quality in the Region as identified by Ausseil and Clark (2007c) and more implicitly in the evidence of Barry Gilliland.

264. The limitations of the MCWQRP considered relevant to the development of the POP are:

i. There was a lack of established linkages between values, management objectives, issues, standards and effects.

ii. Water quality standards were never applied to the wider Region.

iii. Rules applying to the Manawatū catchment were 'one size fits all' and did not differentiate spatially between water bodies or receiving environments (ie. headwater streams vs. large mainstem rivers, or the effect of river loads on estuarine and coastal waters).

iv. The standards sat within rules rather than at the objective or policy level, as opposed to the approach taken in the application of standards within the objectives of the POP;

v. Nitrogen was not addressed as a major contaminant of concern.

vi. Some contaminants were never measured or monitored and were consequently of little value for an Assessment of Environmental Effects.

vii. The effects of diffuse or non-point source contributions to water quality were not adequately captured within the rules.

265. In the One Plan the use of effects-based, numeric standards that are directly linked to the values and are at a locally-relevant spatial resolution is an appropriate technical progression from the use of numeric standards within the Rules of the MCWQRP.

5.13 Determining compliance with the water quality standards

266. Ausseil and Clark (2007c, section 8.2.1, page 138) define a method for assessing water quality against the water quality standards proposed in the One Plan. I recommend maintaining the use of "shall not exceed" standards (without percentiles specified) for attributes that have potential lethal effects on biota, such as maximum temperature, minimum dissolved oxygen saturation and ammoniacal nitrogen as discussed in the evidence of Dr John Quinn. However, some attributes (eg. BOD_5 and visual clarity) should be assessed at averages over defined timescales, reflecting the way these have been used to define effects on riverine values. These considerations have been included in the tables of recommended changes below (Table 11, Table 12, Table 13).

267. Sections 6.4.2 to 6.4.11 of Ausseil and Clark (2007c) detail the exact recommendations considered for the nutrient standards for each Water Management Sub-zone. Recommendations for changes to the nutrient standards proposed in Schedule D are included in the tables below.

Key points: Defining water quality standards in rivers and streams

i. Numerical water quality standards were defined parameter by parameter for each of the Ecosystem and Recreational and Cultural Values where there was supporting science for a standard.

ii. The key values for the development of water quality standards in the Ecosystem Group was the Life-Supporting Capacity value, standards providing for this value will also provide for the other Ecosystem values.

iii. Contact Recreation, Trout Fishery and Trout Spawning were the key values used in the determination of standards for Recreational and Cultural values.

iv. For each Water Management Sub-zone, the most stringent standard required for a particular water quality parameter to provide for these key values was set for that sub-zone.

v. Both nitrogen and phosphorus standards are required to control periphyton growth, year round and at all flows less than flood flows.

vi. Nutrient standards were developed based on the desired periphyton biomass and cover standards to provide for the values in each sub-zone.

vii. Nutrient standards were determined on a sub-zone by sub-zone basis using a combination of: 1) the NZ Periphyton Guideline model; 2) expert opinion from Dr Biggs; 3) consultation of the ANZECC nutrient guidelines; and 4) assessment of the current nutrient status.

viii. Nutrient standards were modified depending on the downstream receiving environment.

ix. The differences between the POP approach from the MCWQRP approach to numerical standards are: 1) there are clear links between values, standards and effects; 2) the standards apply in a locally relevant manner throughout the Region; 3) a wider range of contaminants and biological indicators has been used (including nitrogen); 4) the standards will apply to all activities that affect water rather than just to discharges.

5.14 Recommendations for water quality standards: Rivers and Streams

Table 11. Recommended changes to Schedule D Water Quality Standards of the Proposed One Plan: Rivers and streams.

Expert recommendation	Evidence link	Accept/ decline	Justification/comment
Units of measurement			
1. All units of concentration shall be expressed as grams per cubic metre (g/m^3) rather than a combination of mg/m^3 and g/m^3 other than chlorophyll *a* concentration (periphyton biomass)	Staff recommendation	Accept	Required for consistency and certainty for Plan users – see Council submission
pH			
2. pH range: no change	Dr Bob Wilcock	Accept	Standard is supported
3. Change in pH: no change	Dr Bob Wilcock	Accept	Standard is supported
Temperature			
4. Maximum temperature[3]: no change	Dr John Quinn	Accept	Standard is supported
5. Change in temperature[4]: no change	Dr John Quinn	Accept	Standard is supported
Dissolved oxygen (DO) % of saturation			
6. No change	Dr John Quinn and Dr Roger Young	Accept	Standard is supported
Biochemical oxygen demand (BOD)			
7. BOD shall be measured as average soluble carbonaceous BOD_5 measured at weekly or greater timescales (eg. monthly)	Dr John Quinn	Accept	This is the same unit of BOD ($scBOD_5$) measurement used in the Manawatu Catchment Water Quality Regional Plan Rule 1e. Dr Quinn's evidence explains why the soluble and carbonaceous BOD form is more relevant to the formation of sewage fungus
8. The BOD standard of 1 gram per cubic metre (g/m^3) shall be increased to an average $scBOD_5$ of 1.5 grams per cubic metre (g/m^3)	Dr John Quinn	Accept	The 1 g/m^3 standard is at the analytical detection limit currently used for Horizons analysis; this gives little certainty on compliance with the standard.

[3] Dr Quinn provides recommendations on the measurement of temperature that should be considered for an advice note to the standards.

[4] This standard requires an advice note stating that reductions in temperature of greater than the allowable standard resulting from restoration, such as the planting of riparian margins will be exempt for this standard.

Expert recommendation	Evidence link	Accept/ decline	Justification/comment
9. BOD shall be referred to as Bio*chemical* Oxygen Demand (not Biological)	Dr John Quinn	Accept	This is the appropriate term.
10. BOD standards shall only apply at flows less than the 20th percentile	Dr John Quinn	Accept	At flows greater than the 20th percentile sewage fungus is unlikely to attach to the substrate and form nuisance growths
Particulate organic matter (POM)			
11. The concentration of POM shall not exceed 5 grams per cubic metre (g/m^3)	Dr John Quinn	Accept	The POM standard should be 5 g/m^3 throughout the Region because this is the threshold relevant to the protection of benthic macroinvertebrate habitat (Quinn and Hickey, 1993). Note: this standard is also consistent with the MCWQRP Rule 2d for POM. The 2.5 g/m^3 standard originally proposed is below the current level of detection therefore compliance cannot be assessed.
12. The POM standard shall only apply at flows less than median (50th flow percentile)	Dr John Quinn	Accept	At flows greater than median (50th percentile) POM is unlikely to adversely effect benthic macroinvertebrates.
Periphyton			
13. Chlorophyll *a* mg/m^2: no change	Dr Barry Biggs	Accept	Standard is supported
14. % cover standard shall include % cover standard of no more than 60% by diatoms or cyanobacteria more than 0.3 cm thick	Dr Barry Biggs	Accept	This is an omission from the POP. The MCWQRP contains provisions for percent cover by both filamentous growths and mats more than 3 mm thick in Rule 2f. Percent cover by filamentous algae and diatom/cyanobacterial mats is the approach set out in the NZ Periphyton Guidelines (Biggs, 2000). Cover by diatoms and cyanobacteria can have equally detrimental effects on Contact Recreation and other water-body values.
Dissolved reactive phosphorus			
15. No change to numerical standards	Dr Barry Biggs	Accept	The standards are the most appropriate and pragmatic for the purposes of managing the cover and biomass of periphyton to a desirable level for the maintenance of the values in each Water Management Zone
16. Add "*or naturally occurring concentration in streams flowing from forested headwaters, which ever is the greater*" to the explanatory table	Dr Barry Biggs	Accept	Natural levels of DRP from some forested headwater catchments marginally exceed the standard due to natural geological inputs; this is unlikely to cause significant adverse effects.
17. The flow at which the DRP standards apply shall be changed from "*at or below three times the median flow*" to "*at or below the 20th percentile flow*"	Staff recommendation supported by Dr Barry Biggs	Accept	Dr Biggs supports the Council submission on this matter. Further analysis can be found in Appendix 3 of Roygard and McArthur (2008) and is detailed in the sections above.

Expert recommendation	Evidence link	Accept/ decline	Justification/comment
Soluble inorganic nitrogen			
18. No change to numerical standards	Dr Barry Biggs	Accept	The standards are the most appropriate and pragmatic for the purposes of managing the cover and biomass of periphyton to a desirable level for the maintenance of the values in each Water Management Zone[5]
19. Add "*or naturally occurring concentration in streams flowing from forested headwaters, which ever is the greater*" to the explanatory table	Dr Barry Biggs	Accept	Natural levels of SIN from some forested headwater catchments marginally exceed the standard; this is unlikely to cause significant adverse effects.
20. The flow at which the SIN standards apply shall be changed from "*at or below three times the median flow*" to " *at or below the 20th percentile flow*"	Staff recommendation supported by Dr Barry Biggs	Accept	Dr Biggs supports the Council submission on this matter. Further analysis can be found in Appendix 3 of Roygard and McArthur (2008) and is detailed in the sections above.
Quantitative Macroinvertebrate Community Index			
21. Change QMCI to MCI and use 100 and 120 MCI standards in place of the 5 and 6 QMCI standards (respectively)[6, 7]	Dr John Quinn	Accept	MCI is well accepted as the appropriate macroinvertebrate index for monitoring the health of rivers and streams in a State of the Environment context, rather than QMCI (Stark and Maxted, 2007; Stark, 2008). MCI should remain a standard in Schedule D but be redefined as applying only in relation to State of the Environment monitoring. Applying a biotic index as a standard within the POP provides for the monitoring of a number of other stressors which can adversely affect aquatic ecosystems but which are not easily or directly measurable in themselves, such as deposited sediment.
22. No more than a 20% reduction in QMCI score from upstream to downstream of discharges to water[8]	Staff recommendation	Accept	Staff recommendation: QMCI is the most appropriate index to use for assessing the impact of discharges of organic waste on aquatic macroinvertebrates. A technical description of appropriate sampling methods to ensure samples are collected in a consistent manner regionally is required. A 20% reduction in QMCI is a significant change in aquatic health that is twice the margin of error on QMCI samples collected using appropriate methods (John Stark, *pers. comm.*).

5 Notwithstanding this, the SIN standard for the Mangaore Water Management Sub-zone (Mana_13d) should read 167 mg/m^3 rather than 165 mg/m^3. The latter is an error in the Schedule D table.
6 It should be made clear within Schedule D that this standard only applies to State of the Environment monitoring for each Water Management Sub-zone.
7 In cases where the stream or river habitat is suitable for the application of the soft-bottomed variant of the MCI (sb-MCI) then the standards shall apply to the results of that survey instead.

Expert recommendation	Evidence link	Accept/ decline	Justification/comment
			Discharges to water should not be able to have this degree of adverse effect on the Life-Supporting Capacity value.
Ammoniacal nitrogen			
23. No change to numeric standards	Dr Bob Wilcock	Accept	Standards are suitable for ensuring aquatic species are not adversely affected by ammoniacal-N toxicity.
24. Shall always be referred to as ammoniacal nitrogen in the POP not 'ammonia'	Dr Bob Wilcock	Accept	This is the appropriate term to use.
Toxicity			
25. No change	Dr Bob Wilcock	Accept	Standard is supported
Turbidity/Clarity			
26. Turbidity standards shall be removed from Schedule D	Dr Rob Davies-Colley	Accept	Turbidity is not appropriate as a standard as it is only a surrogate measure of water clarity. Direct measurement of horizontal visibility using black disc is recommended
27. Change in clarity standards shall remain but explanatory note shall read "shall not be *reduced* by more than…" rather than *changed* by more than.	Dr Rob Davies-Colley	Accept	Change in clarity is an important optical consideration for rivers and streams. A positive change in clarity should be allowed by the standard.
28. Horizontal visibility (black disc) standards from Ausseil and Clark (2007c) Table 24 at flows less than median (50th percentile) shall be inserted into Schedule D	Dr Rob Davies-Colley	Accept	Water clarity is the most appropriate standard to use to protect the optical properties of water for the maintenance of the values. Using a black disc to determine horizontal visibility is the most appropriate method for determining water clarity. This is consistent with the use of the black disc method to measure horizontal visibility in the MCWQRP rule 1 (a. ii).
29. No clarity standards shall be applied for flows less than ½ median (25th percentile) or 3 times the median (20th percentile)	Dr Rob Davies-Colley	Accept	Clarity standards at higher flows are less likely to be relevant to the protection of the values. The 50th percentile flow is appropriate to protect the visual aspects of water clarity associated with Contact Recreation and is consistent with the flow for the application of the summer season *E. coli* standard.

[8] It should be made clear within Schedule D that this standard applies specifically to point source discharges to water at the first appropriate site below the mixing zone.

Expert recommendation	Evidence link	Accept/ decline	Justification/comment
Faecal indicator bacteria (*E. coli*)			
30. No change	Dr Rob Davies-Colley	Accept	Standards are supported
31. No requirement for Stockwater standards to be added to the POP	Dr Bob Wilcock and Dr Rob Davies-Colley	Accept	This standard is already adequately provided for by the contact recreation standard.
Cyanobacterial toxins			
32. Remove from Schedule D	None		This toxin standard is not consistent with the draft recommendation of the National Guidelines on Cyanobacterial Toxicity (MfE/MoH, 2009). Once national guideline values are finalised these should be adopted as cyanobacterial cover standards for the protection of lake and river water quality values.
Trout spawning			
33. No change	None		Standards are supported

6. LAKE WATER QUALITY

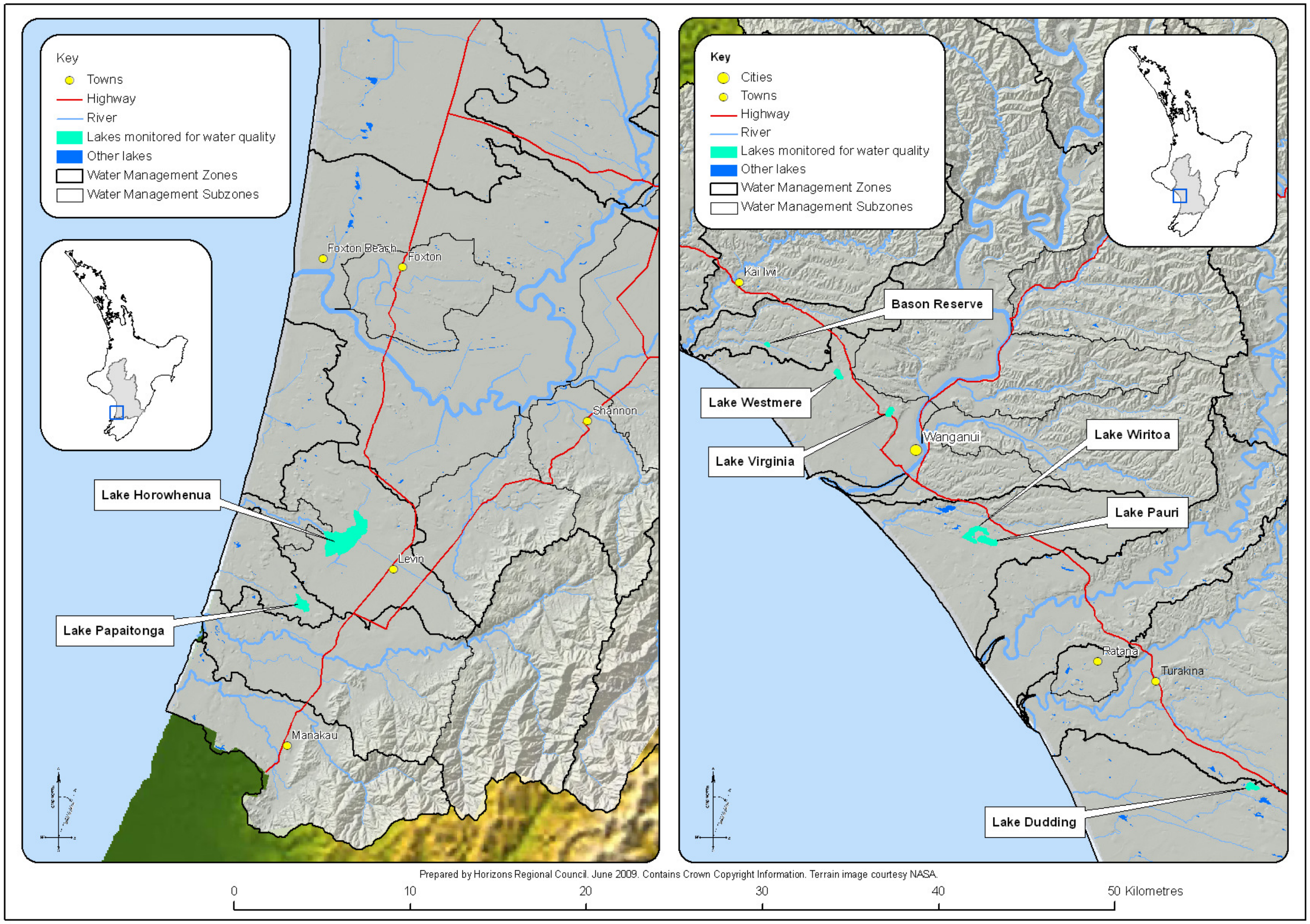
268. The evidence of Max Gibbs describes the processes controlling and contributing to lake water quality generally with specific reference to the lakes of the Region. Mr Gibbs has also assessed all available results from lake water quality monitoring against the Proposed One Plan standards. The lake water quality data collected and provided to Max Gibbs is detailed below and summarized in Table 4 of his evidence.

269. SoE water quality monitoring of lakes has been undertaken on a monthly basis since February 1998 at the Region's largest lake, Lake Horowhenua. Samples are collected from three sites on the lake and a composite of these samples is analysed to provide integrated water quality results for each parameter.

270. As part of the bathing beaches programme, monitoring of the coastal dune lakes Dudding, Wiritoa and Pauri for faecal contaminants and turbidity has also been undertaken since November 1998. Summer cyanobacterial monitoring commenced in November 2004 (as discussed in the evidence of Barry Gilliland). During the 2007/2008 summer bathing season (November to April) additional SoE monitoring was undertaken at six coastal dune lakes (Dudding, Wiritoa, Pauri, Virginia, Westmere and Bason Reserve). As part of an investigation into the interactions between ground and surface water quality and quantity in the Horowhenua area, further water quality data was collected between April and September 2008 from a number of sites at and around Lakes Papaitonga and Horowhenua (Map 6). Monitoring results from all programmes are displayed in the figures below.

271. Unlike river systems there is currently no lake equivalent to the NRWQN, although a national lakes monitoring programme was run from 1993 to 1998 but was abandoned after five years due to lack of funding. Lakes Dudding and Horowhenua were included in this monitoring programme which was undertaken by the DSIR (later NIWA). Reporting on the national state of lake water quality has been undertaken by the Ministry for the Environment subsequently using water quality data collated from Regional Council monitoring of lake water quality and trophic condition. Lake water quality monitoring in the Horizons Region is strongly recommended for incorporation into the SoE programme to monitor changes in trophic state and water quality over time.

272. Recommended changes to the Schedule D water quality standards for lakes in the POP are detailed in Table 12 as a result of expert evidence and analysis of lake water quality since the Schedule D standards were proposed.



Map 6. Lakes with water quality data collected over various time periods in Horizons' Region.

6.1 Nutrient concentrations

273. As discussed in the evidence of Max Gibbs the depth of a lake can have an overriding influence on the nutrient status of lakes depending on the dissolved oxygen availability, or lack thereof in the case of thermally stratified lakes. For example, shallow lakes (c. < 5 m in depth) that do not undergo stable thermal stratification in summer are often fully mixed throughout much of the year and thus well-oxygenated (in theory) and do not experience the anoxic conditions at the lake bed that occur in thermally stratified deep lakes. Lake Horowhenua and potentially other shallow dune lakes in the Region may have high concentrations of DRP available during summer due to low dissolved oxygen availability.

274. The trophic condition of lakes is determined by measuring total nitrogen and phosphorus concentrations, Secchi depth (clarity) and chlorophyll *a* concentration. The trophic condition is an expression of the eutrophication status of a lake and is also influenced by physical characteristics, including depth (see Max Gibbs' evidence, Table 3).

275. Figure 4 shows the total phosphorus concentrations from surface sampling of eight lakes as described above. With the exception of the 10^{th} percentile of samples from Lake Wiritoa, all samples collected from lakes exceeded the Proposed One Plan standards for total phosphorus. Lakes Westmere, Pauri and Horowhenua had significantly elevated total P concentrations, particularly in the top percentile ranges of the data. Lakes Papaitonga and Basin Reserve (an artificial lake in the Mōwhānau Water Management Sub-zone) also had elevated median concentrations of total phosphorus when compared to lakes Virginia, Wiritoa and Dudding.

276. Total nitrogen concentrations in Figure 5 again show almost all samples are elevated above the Proposed One Plan standard. Lakes Westmere, Pauri, Horowhenua and Papaitonga have significantly elevated median total N concentrations, with Lake Papaitonga showing the highest range in total N. Considering the partially forested margin of this lake, the nitrogen concentrations may be highly influenced by groundwater inputs.

277. Three outlying observations of total P and total N were removed from Pauri (3.05 gP/m^3, 26.6 gN/m^3 on 10/12/2007), Horowhenua (1.75 gP/m^3, 16.2 gN/m^3 on 24/1/2008) and Westmere (1.27 gP/m^3, 10.4 gN/m^3 on 22/1/2008) to assist with plotting the data at a legible scale on the graphs below. Each of these high nutrient observations coincided with high algal biomass or cyanobacterial cell counts, significantly elevated turbidity and,

in the cases of Pauri and Horowhenua, extremely high BOD, indicating prolific algal bloom and subsequent die-off conditions.

278. Figure 6 shows that ammoniacal nitrogen concentrations are within POP standards for most lakes most of the time, with the notable exception of Lake Papaitonga and some outlying observations from Lakes Horowhenua and Pauri. The POP ammoniacal-N standard relates to the potential for toxicity to aquatic life from unionized ammonia, depending on pH and temperature (see earlier sections and the evidence of Dr Bob Wilcock). Lake Papaitonga and its tributaries are listed as aquatic sites of significance (SOS-A) for brown mudfish and banded kōkopu in Schedule D of the POP. Given the elevated ammoniacal-N concentrations found in the small number of samples from Lake Papaitonga in the 2008 survey, the risk of toxic conditions, with the potential to affect native fish resident within the lake and in-flowing tributaries or migrating into the lake catchment as juveniles, is of some concern. Ammoniacal-N can be released from the lake floor sediments under anoxic conditions (see evidence of Max Gibbs) or enter the lake from reduced groundwater.

279. Chlorophyll *a* concentration has been measured on occasion since 1998 at Lake Horowhenua (n = 96). Figure 7 shows that the range of chlorophyll *a* concentration exceeds all standards (both POP and standards recommended by Max Gibbs) for approximately 50% of the samples. Note that a logarithmic scale has been used to plot the data so results increase significantly in concentration up the y-axis.

280. Dissolved reactive phosphorus, although not subject to a plan standard for lakes under the POP, is shown in Figure 8. Bason Reserve, Pauri, Papaitonga and in particular Lake Horowhenua have high concentrations of DRP. High DRP concentrations in lakes can result from anoxic conditions and phosphorus release from the lake floor sediments (see evidence of Max Gibbs). Soluble inorganic nitrogen concentrations are high at Bason Reserve, Lake Horowhenua and Lake Papaitonga with extremely elevated median concentrations at Lake Papaitonga, consistent with the results for ammoniacal-N, indicating the potential for anoxic conditions within Lake Papaitonga in 2008 (Figure 9).

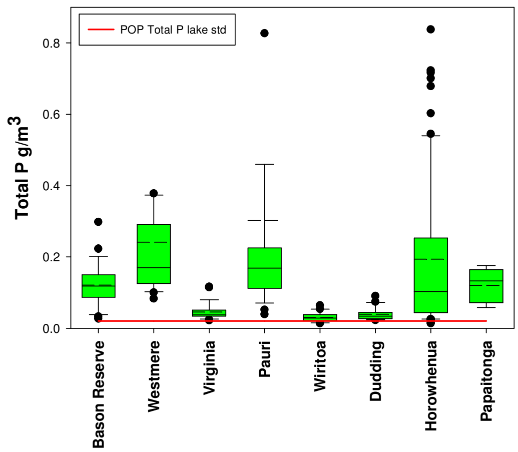


Figure 4. Total phosphorus (P) concentrations in water quality samples collected from eight lakes in Horizons' Region. Samples were collected weekly over the 2007/2008 summer bathing season (1st November – 30th April) at Bason Reserve, Westmere, Virginia, Pauri, Wiritoa and Dudding, monthly at Lake Horowhenua since April 1998 and fortnightly between April and September 2008 at Lake Papaitonga. Note: three outliers have been removed from the graph (see text)[9].

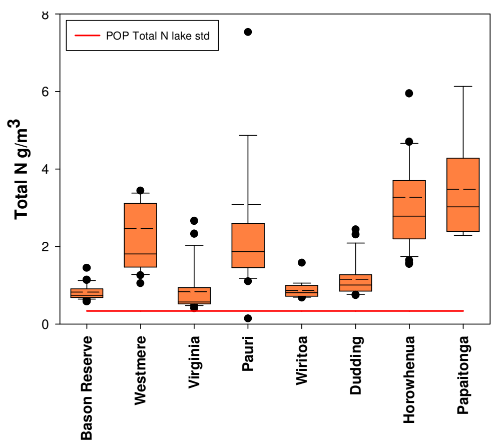


Figure 5. Total nitrogen (N) concentrations in water quality samples collected from eight lakes in Horizons' Region. Samples were collected weekly over the 2007/2008 summer bathing season (1st November – 30th April) at Bason Reserve, Westmere, Virginia, Pauri, Wiritoa and Dudding, monthly at Lake Horowhenua since April 1998 and fortnightly between April and September 2008 at Lake Papaitonga. Note: three outliers have been removed from the graph (see text)[9].

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9 For all box plots throughout this evidence the following is a guide to the statistical relevance of the plots: boxes represent upper and lower quartiles with median (straight) and mean (dashed) mid point lines, whiskers are 10th (lowest) and 90th (highest) percentiles of the water quality data and black dots are outlying observations.

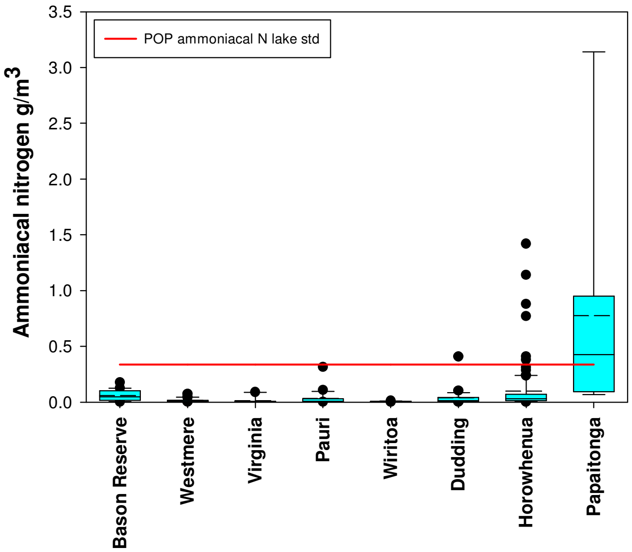

Figure 6. Ammoniacal nitrogen concentrations in water quality samples collected from eight lakes in Horizons' Region. Samples were collected weekly over the 2007/2008 summer bathing season (1st November – 30th April) at Bason Reserve, Westmere, Virginia, Pauri, Wiritoa and Dudding, monthly at Lake Horowhenua since April 1998 and fortnightly between April and September 2008 at Lake Papaitonga[9].

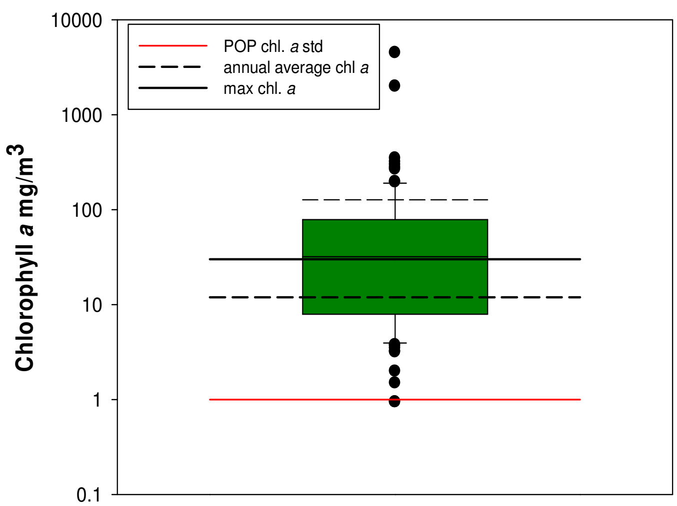

Figure 7. Log_{10} chlorophyll *a* concentrations from Lake Horowhenua, measured since 1998. Red line is the Proposed One Plan annual average standard for chlorophyll *a*[9]. Solid black and dashed black lines are standards recommended by Max Gibbs for annual average and maximum chlorophyll *a* concentrations (see below).

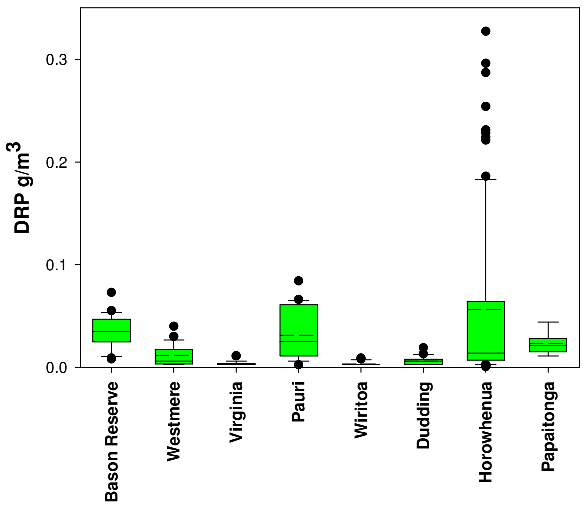

Figure 8. Dissolved reactive phosphorus (DRP) concentrations in water quality samples collected from eight lakes in Horizons' Region. Samples were collected weekly over the 2007/2008 summer bathing season (1st November – 30th April) at Bason Reserve, Westmere, Virginia, Pauri, Wiritoa and Dudding, monthly at Lake Horowhenua since April 1998 and fortnightly between April and September 2008 at Lake Papaitonga. One outlier has been removed from Lake Horowhenua (0.583 gDRP/m^3 on 1/2/2006)[9].

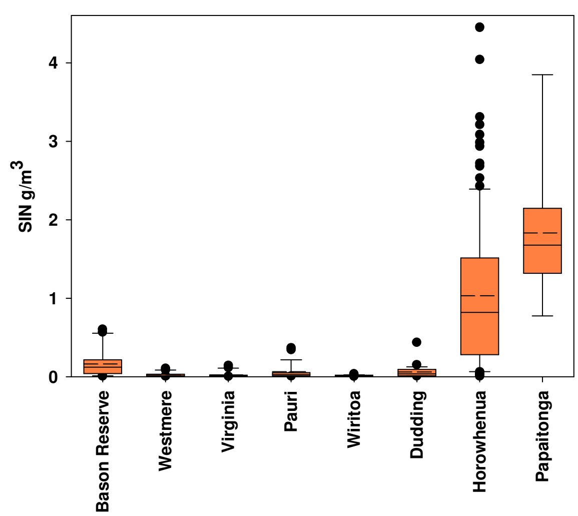

Figure 9. Soluble inorganic nitrogen (SIN) concentrations in water quality samples collected from eight lakes in Horizons' Region. Samples were collected weekly over the 2007/2008 summer bathing season (1st November – 30th April) at Bason Reserve, Westmere, Virginia, Pauri, Wiritoa and Dudding, monthly at Lake Horowhenua since April 1998 and fortnightly between April and September 2008 at Lake Papaitonga[9].

6.2 Physical stressors

281. pH and temperature can directly stress aquatic life in lakes, furthermore, the toxicity of unionised ammonia is dependant on pH and temperature. pH is often influenced by the biochemical processes within lakes, such as algal bloom formation (see the evidence of Max Gibbs). Figure 10 shows that pH values for Bason Reserve and Lake Papaitonga are largely within the POP standards for lakes. Median values for Virginia, Pauri and Wiritoa are also within the POP standard range. Median pH was elevated above the upper limit of the standard at Westmere and Horowhenua and below the lower limit of the standard at Dudding. Values at many sites exceed pH of 8, at which ammonium can become unionized ammonia and be toxic to aquatic life.

282. Although there is no temperature range standard within the POP, there is a temperature change standard. Lake Papaitonga was significantly cooler than the other lake sites (Figure 11) although these samples were collected at a different time of year and are likely to be influenced by ambient air temperature at the time of measurement. Any activity that has the potential to affect lake water temperatures should be assessed against the standard for change to lake water temperatures (eg. vegetation clearance around lake margins).

283. The turbidity standard for lakes in the POP applies only to changes in turbidity greater than 20%. Turbidity is not an appropriate parameter for determining water clarity (see evidence of Dr Davies-Colley and Max Gibbs). Lake Pauri had a number of extremely high turbidity values which were removed from the dataset to assist with plotting the data on a legible scale (Figure 12). These high turbidity results also coincided with recorded cyanobacterial blooms in the lake, algal cells are likely to be the source of high turbidity in lake samples over summer. Lake Horowhenua also had some elevated turbidity observations which were associated with high chlorophyll *a* concentrations. Alternative water clarity standards for lakes are recommended in the section below. Cyanobacterial and algal blooms have the potential to significantly affect values associated with water clarity as well as the potential for toxic effects on Contact Recreation and Stockwater values.

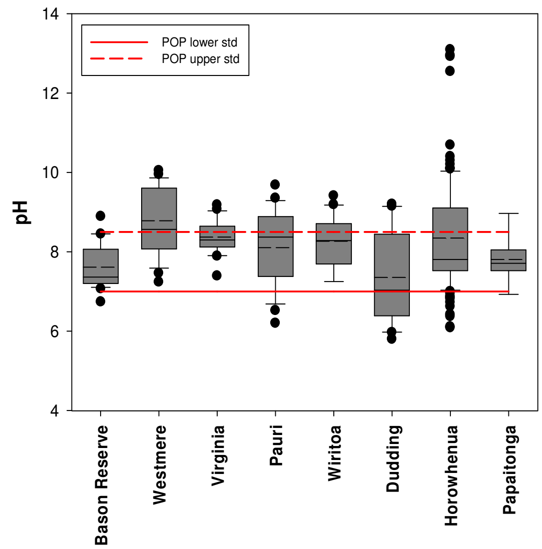

Figure 10. pH in water quality samples collected from eight lakes in Horizons' Region. Samples were collected weekly over the 2007/2008 summer bathing season (1st November – 30th April) at Bason Reserve, Westmere, Virginia, Pauri, Wiritoa and Dudding, monthly at Lake Horowhenua since April 1998 and fortnightly between April and September 2008 at Lake Papaitonga[9].

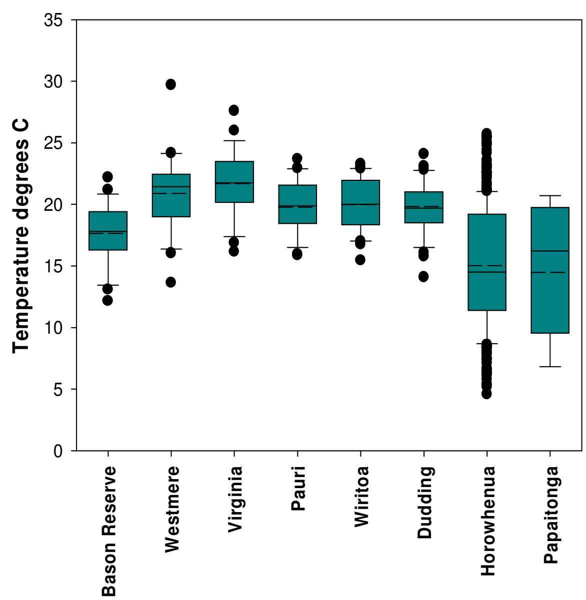

Figure 11. Surface water temperature from eight lakes in Horizons' Region. Readings were taken weekly over the 2007/2008 summer bathing season (1st November – 30th April) at Bason Reserve, Westmere, Virginia, Pauri, Wiritoa and Dudding, occasionally at Lake Horowhenua since April 1998 and fortnightly between April and September 2008 at Lake Papaitonga[9].

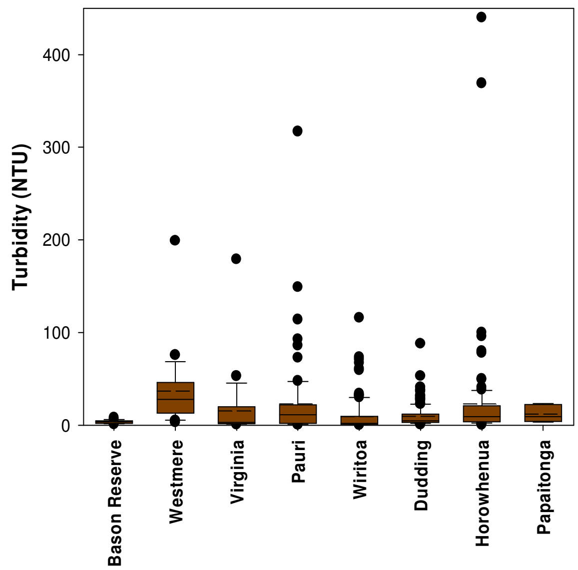

Figure 12. Turbidity readings from eight lakes in Horizons' Region. Readings were taken weekly over the 2007/2008 summer bathing season (1st November – 30th April) at Bason Reserve, Westmere, Virginia, Pauri, Wiritoa and Dudding, occasionally at Lake Horowhenua since April 1998 and fortnightly between April and September 2008 at Lake Papaitonga. Four outlying observations have been removed from Lake Pauri (8000 NTU on 2nd and 14th April 2007, 2741 on 23rd April 2007 and 1590 on 15th March 2006)[9].

6.3 Faecal contaminants

284. *Escherichia coli* samples were generally collected from these lakes during the summer bathing season, with the exception of some of the samples from Lake Papaitonga and Lake Horowhenua (Figure 13). The 90th percentile *E. coli* values for Pauri, Wiritoa, Dudding and Horowhenua and the median value for Bason Reserve were all below the summer POP standard. Lakes Virginia and Westmere were often unsuitable for contact recreation. The median value for Lake Papaitonga was below the winter POP *E. coli* standard.

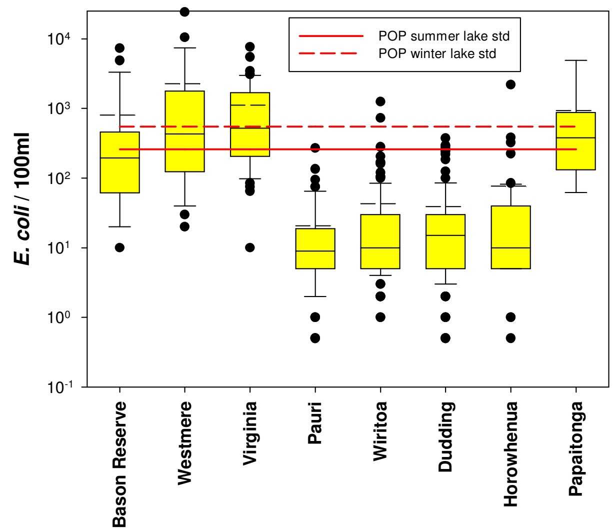

Figure 13: Log $_{10}$ *Escherichia coli* in water quality samples collected from eight lakes in Horizons' Region. Samples were collected weekly over the 2007/2008 summer bathing season (1st November – 30th April) at Bason Reserve, Westmere, Virginia, Pauri, Wiritoa and Dudding, monthly at Lake Horowhenua since April 1998 and fortnightly between April and September 2008 at Lake Papaitonga[9,10].

[10] Note: Logarithmic scale to base 10 (Log_{10}) means that for each point on the y-axis the concentration of Faecal Indicator Bacteria increases ten-fold (i.e. $10^1 = 10$, $10^2 = 100$, $10^3 = 1000$ etc).

Key points: Lake water quality

i. Lakes undergo significant natural variations as a result of seasonal influences, physical characteristics, trophic condition and water source (surface or groundwater) (see evidence of Max Gibbs).

ii. Water quality monitoring for most lakes has been limited, with the exception of Lake Horowhenua.

iii. Monitoring results suggest most coastal lakes are eutrophic, and many are super or hypertrophic (see evidence of Max Gibbs).

iv. Available monitoring data shows these lakes are unlikely to meet the Proposed One Plan standards for water quality due to their trophic level.

v. Ammoniacal-N is elevated in Lake Papaitonga and occasionally in Lake Horowhenua to levels that are potentially toxic to aquatic life.

vi. pH range is occasionally above levels that will cause high concentrations of ammoniacal-N to become toxic (as unionised ammonia).

vii. Lakes Pauri, Wiritoa, Dudding and Horowhenua are generally safe for contact recreation, while Bason Reserve and Lakes Westmere, Virginia and Papaitonga are often not suitable.

viii. Trophic level and nutrient cycling within lakes causes algal bloom events which can include potentially toxic cyanobacterial blooms.

ix. Cyanobacterial blooms and subsequent toxin release (see Barry Gilliland's evidence) significantly reduces the Contact Recreation and Amenity value of many of the Region's lakes every year.

x. SoE monitoring of lakes is required to determine trophic status and to monitor for changes in trophic state over time.

xi. Deep and shallow lakes are quite different; standards for water quality should be relevant to the key differences in lake type.

6.4 Recommendations for water quality standards: Lakes

Table 12. Recommended changes to Schedule D Water Quality Standards of the Proposed One Plan: Lakes

Expert recommendation: lakes	Evidence link	Accept/decline	Justification/comment
Standards for rivers and streams flowing into lake catchments			
1. Remove Table D.20 from Schedule D	Max Gibbs	Accept	These standards are unnecessary as all rivers and streams should have the standards applied for each Water Management Sub-zone through Table D.17. The Table D.20 standards will not provide any further protection to lake water quality.
Water Management Zones where lake standards apply			
2. Remove Table D.18 from Schedule D and the reference to "*lowland"* lakes from the water quality standards	Staff recommendation	Accept	Applying water quality standards only to lakes within the Water Management Sub-zones listed in Table D.18 (without any definition of what constitutes a lake or what should be exempt) implies that water quality standards apply to all open, non-flowing water bodies within these management zones (eg. stockwater, waste water or sediment control ponds). Conversely, this will also mean threatened habitats (such as lakes and lagoons described in Schedule E.1) will not be captured by the water quality standards in Water Management Zones outside those defined in Table D.18. Using the term "*lowland"* in the heading of the lake standards implies that water quality management of threatened lake habitats is only required near the coast. The significance of threatened lake and lagoon habitats has been discussed extensively in the evidence of Fleur Maseyk during the hearings on Biodiversity.
3. Require water quality standards only to apply to lakes that are not excluded by the provisional determination on Schedule E in Table E.2(b) clauses iv to ix.	Staff recommendation	Accept	Including the exemptions from Table E.2(b) clauses iv to ix ensures that water quality and biodiversity are approached in a consistent manner within the POP, and that water quality standards are only applied in situations that are relevant for management by Horizons. The lake standards and depth classification recommended by Max Gibbs provides lake water quality standards that are more specific to lake type (eg. deep vs. shallow) and thus can apply to all natural lakes in the Region, rather than the blanket application of standards for lowland lakes currently proposed in Schedule D.

Expert recommendation: lakes	Evidence link	Accept/decline	Justification/comment
Definition of deep vs. shallow lakes			
4. "*Deep*" lakes are defined as those which undergo stable thermal stratification in summer. All other lakes are defined as "*shallow*"	Max Gibbs	Accept	Not all lakes are of the same lake type within the Region. 'Shallow' (c. < 5 m) lakes are naturally in a more advanced stage of eutrophy and therefore the mesotrophic standards applicable to 'deep' lakes (the current lake standards in Schedule D of the POP) are inappropriate to the 'shallow' lake type. Applying more spatially relevant lake standards dependant on lake type is entirely consistent with the approach used to determine standards for different rivers and streams.
pH			
5. The pH of the water shall be within the range 6.5 to 8.5	Max Gibbs	Accept	This is the appropriate range for lake types within Horizons' Region
6. Change in pH: this standard shall be removed from Schedule D	Max Gibbs	Accept	Variation in pH is often beyond the range of the pH change standard due to naturally occurring lake processes
Temperature			
7. The temperature change standard shall be removed from Schedule D	Max Gibbs	Accept	Variation in temperature both at the lake surface and through the depth profile of the lake is often due to naturally occurring lake processes
Dissolved oxygen			
8. The dissolved oxygen standard shall be removed from Schedule D	Max Gibbs	Accept	Variation in dissolved oxygen is largely associated with temperature profile and thermal stratification from naturally occurring lake processes
Biochemical oxygen demand			
9. The BOD standard for lakes shall be removed from Schedule D	Max Gibbs	Accept	Biochemical oxygen demand is also associated with variation in naturally occurring lake processes related to dissolved oxygen
Algal biomass			
10. The average annual algal biomass shall not exceed 5 mg chlorophyll *a*/m^3 in *deep* lakes and no sample shall exceed 15 mg chlorophyll *a*/m^3	Max Gibbs	Accept	A mesotrophic condition is a realistic objective for deeper lakes (c. > 5 m). These standards are appropriate to protect the values of mesotrophic lakes.
11. The average annual algal biomass shall not exceed 12 mg chlorophyll *a* /m^3 in *shallow* lakes and no sample shall exceed 30 mg chlorophyll *a*/m^3	Max Gibbs	Accept	Shallow lakes are more likely to be naturally eutrophic and the recommended standards should provide for the trophic status whilst still setting standards for water quality that are appropriate to protect the values of shallow lakes.
Total phosphorus			
12. The annual average total phosphorus concentration shall not exceed 20 mg/m^3 in *deep* lakes	Max Gibbs	Accept	A mesotrophic condition is a realistic objective for the water quality of deeper lakes (c. > 5 m). These standards are appropriate to protect the values of mesotrophic lakes.

Expert recommendation: lakes	Evidence link	Accept/decline	Justification/comment
13. The annual average total phosphorus concentration shall not exceed 43 mg/m³ in *shallow* lakes	Max Gibbs	Accept	A eutrophic condition is a more realistic objective for the water quality of shallow lakes (c. < 5 m). These standards are appropriate to protect the values of shallow lakes.
Total nitrogen			
14. The annual average total nitrogen concentration shall not exceed 337 mg/m³ in *deep* lakes	Max Gibbs	Accept	A mesotrophic condition is a realistic objective for the water quality of deeper lakes (c. > 5 m). These standards are appropriate to protect the values of mesotrophic lakes.
15. The annual average total nitrogen concentration shall not exceed 735 mg/m³ in *shallow* lakes	Max Gibbs	Accept	A eutrophic condition is a more realistic objective for the water quality of shallow lakes (c. < 5 m). These standards are appropriate to protect the values of shallow lakes
Ammoniacal nitrogen			
16. The concentration of ammoniacal nitrogen shall not exceed 400 mg/m³ and shall only apply when lake pH exceeds 8.5 within the epilimnion[11] in *shallow* lakes or within 2 m of the water surface in *deep* lakes	Max Gibbs	Accept	The ammoniacal nitrogen standard for toxicity in lakes should be consistent with that for rivers and streams. Below the specified pH limit (8.5) ammoniacal-N is unlikely to exist in toxic unionised ammonia form.
17. When pH is less than 8.5 no ammoniacal nitrogen standard shall apply	Max Gibbs	Accept	Ammoniacal-N varies greatly within lakes due to naturally occurring lake processes, as long as pH is below the specified limit of 8.5, toxicity effects on aquatic life should be avoided
Toxicants			
18. No change	Max Gibbs	Accept	The standard is supported
Water clarity			
19. The clarity of the water measured as Secchi depth or horizontal sighting of a 200 mm black disc[12] shall not be less than 2.8 m and shall not be reduced by more than 20% in *deep* lakes	Max Gibbs and Dr Rob Davies-Colley	Accept	The standard is appropriate only to deep lakes.
20. The clarity of the water measured as Secchi depth or horizontal sighting of a 200 mm black disc[12] shall	Max Gibbs and Dr Rob Davies-	Accept	The standard in Schedule D is not appropriate to shallow lakes as many of these lakes are shallower than the standard depth for clarity and thus will always be

[11] The epilimnion is defined as the layer of warmer water at the lake surface.

[12] The Horizontal black disc sighting method is not directly equivalent to Secchi depth measurement, horizontal black disc is approximately 25% lower in magnitude than Secchi depth and results should be adjusted accordingly.

Expert recommendation: lakes	Evidence link	Accept/decline	Justification/comment
not be less than 0.8 m and shall not be reduced by more than 20% in *shallow* lakes	Colley		less than the standard by their physical nature. Additionally, shallow lakes will have a tendency to have lower water clarity, associated with their more eutrophic state. The 0.8 m clarity standard is designed to provide for contact recreation by protecting the safety of wading adult bathers in shallow lakes.
Turbidity			
21. The turbidity standard shall be removed from Schedule D	Max Gibbs and Dr Rob Davies-Colley	Accept	Turbidity is not appropriate for the measurement of water clarity or the optical properties of lakes. Clarity should be directly measured using Secchi depth or horizontal visibility (black disc) equivalent[12].
Euphotic depth			
22. Euphotic depth shall not be reduced by more than 10%	Dr Rob Davies-Colley	Accept	This standard is recommended to protect the light habitat of submerged lake macrophytes, which may not be protected simply by the imposition of clarity standards. Native submerged macrophyte communities are important aspects of lake ecosystems.
Faecal indicator bacteria			
23. Summer *E. coli* standard: no change	Max Gibbs and Dr Rob Davies-Colley	Accept	The standard is supported
24. Winter *E. coli* standard: remove reference to "*year round*" from the standard	Staff recommendation	Accept	The reference to year round is an error and does not make any sense in relation to the winter *E. coli* standard. Otherwise the standard is supported by Dr Davies-Colley and Max Gibbs.
Cyanotoxins			
25. Remove the standard for cyanobacterial toxins from Schedule D	Staff recommendation	Accept	This toxin standard is not consistent with the draft recommendation of the National Guidelines on Cyanobacterial Toxicity (MfE/MoH, 2009). Once national guideline values are finalised these should be adopted as cyanobacterial standards for the protection of lake and river water quality values.

7. WATER QUALITY IN THE COASTAL MARINE AREA (CMA)

7.1 Coastal Water Management Zones and Sub-zones: Recommended Schedule H

285. Schedule H of the POP detailed the CMA zones and protection areas. As a result of hearings for the Coast Chapter of the POP, it was necessary to separate the provisions relating to waters within the CMA from the Water provisions of the Plan. Schedule H now contains the water values and standards associated with the CMA that were formerly found in Schedule D and associated with the Water Chapter.

286. As a result of the removal of water-body values and standards within the CMA from Schedule D and subsequent inclusion of values and standards within the CMA in Schedule H, reorganisation of the values, Water Management Zones and water quality standards has been required that affects both Schedules D and H. The recommended Schedules Ba and D (track changes version) outlined in the evidence of Maree Clark include all changes made to remove the CMA water-body values and standards from the schedules associated with the Water Chapter. An earlier recommended Schedule H was presented in the final officer's report on Coast, though a small number of amendments have been required and technical recommendations made since the provision of that version to the Panel. The further revised Schedule H appended to the report for the Water Chapter, incorporates matters raised in the evidence of myself, Dr John Zeldis and Dr Rob Davies-Colley.

287. In summary, Schedule H now contains the values and standards for all water bodies within the Coastal Marine Area (CMA). These water bodies are divided into:

   i. one **Seawater Management Zone** which comprises the entire CMA other than the Estuary Water Management Sub-zones; and
   ii. thirteen **Estuary Water Management Sub-Zones** associated with specified estuarine waters. The term sub-zone is used because the estuary waters are part of a larger Water Management Zone for that river (including streams).

288. Recommended Table H.2 lists the values and management objectives within the Seawater and Estuary Water Management Sub-Zones. An analysis of which values were applied to water bodies within the CMA areas of the former Water Management Zones and Sub-zones in Schedule D was undertaken, in order to reassign these values to the new zones in the CMA and carry these values through into the recommended Schedule H. Recommended Table H.3 lists the Seawater Management Zone and Estuary Sub-Zones and the specific values that apply to each. There are fewer values in revised Table H.3 than were found in the comparable table within Schedule D (Table

D.2) because some of the values listed in Schedule D are not applicable to the coastal environment. Additionally, because the estuarine sub-zones are physically smaller, the focus for determining the values has been narrowed, requiring the addition of values not previously ascribed to some Estuary Management Sub-zones and resulting in all values being applied as 'sub-zone wide'. Values in the CMA therefore apply to the whole estuary sub-zone rather than to specific reaches or sites as they did in Schedule D of the POP.

7.2 Recommendations for values in Schedule H

289. The following paragraphs outline the recommended changes to the values in Schedule H. These changes are detailed in the track changes version of the recommended Schedule.

290. The Amenity (Am) value should be assigned to all of the Estuarine Water Management Sub-zones along with Inanga Spawning and Whitebait Migration.

291. All estuaries are sites for Native Fish Spawning (recommended to be renamed Inanga Spawning) and Native Fishery (recommended to be renamed Whitebait Migration) as these are the only sites where these activities occur. Based on this I recommend all Estuary Water Management Sub-zones be managed for these values. Estuaries are also high Amenity value sites where people access and interact with the boundary environment between rivers and the sea.

292. Existing infrastructure (EI) has been missed out of Schedule H – this value should be added into Table H.2.

293. The Capacity to Assimilate Pollution (CAP) value had been removed from the Estuary Water Management Sub-zones because allowing estuaries to be used for the assimilation of pollution is inconsistent with the management of estuaries as wetlands with high biodiversity values in Schedule E.

294. The Estuary Water Management Sub-zones have been given zone codes consistent with the labelling for the Water Management Zones and Sub-zones in Schedule D to which each estuary relates. The sub-zone label 'CMA' has been added as a suffix of the zone code to differentiate them from the river sub-zone codes (see the maps of Estuary Water Management Zones in the evidence of Maree Clark).

7.3 Coastal water quality

295. The evidence of Dr John Zeldis identifies the state of coastal nutrient enrichment in relation to international and national concerns on this issue. Dr Zeldis states that the lowland reaches of major rivers in the Horizons Region are among the most nutrient laden in New Zealand. This assessment is based on an analysis using the FINZ database to derive the annual estuarine total nitrogen loads relative to all North Island rivers. In addition, Dr Zeldis has examined monitoring data collected from lower river State of the Environment sites in the Manawatū, Rangitīkei, and Whanganui Rivers over varying timescales dating back to 1989. In an analysis of water quality trends, Gibbard *et al.* (2006) found that the Manawatū at Whirokino site in the lower reaches of the Manawatū River showed a highly significant increasing trend in nitrate and turbidity between 1989 and 2004. Further trend analysis of a longer dataset for this site shows that the increasing turbidity trend and decreasing clarity trend for the Manawatū at Whirokino are still significant (Ballantine and Davies-Colley, 2009b).

296. Water quality standards in lower river systems, estuaries and coastal waters have been determined to reduce the effects of eutrophication on the lower river systems themselves, and on the downstream estuarine and coastal marine receiving environments. Dr Zeldis has described the potential effects of coastal and estuarine eutrophication and the importance of setting standards to control water quality at the coast. Dr Zeldis also determined the potential susceptibility of estuaries in the Horizons Region for eutrophication as 'medium' but went on to state that there was currently little overt evidence of eutrophication for the Region's major estuaries, due largely to estuarine physiography[13] in the Region. However, the high sediment loads carried by the Region's major rivers, as well as increasing turbidity the Manawatū (Ballantine and Davies-Colley, 2009b) and Whanganui (Gibbard *et al.,* 2006), means physiography may not remain a reliable mechanism to prevent estuarine eutrophication in major rivers with extremely elevated nutrient loads into the future. If estuarine sediment build-up creates larger areas of inter-tidal mudflats and/or increases residence time within estuaries, eutrophication impacts may become more apparent.

297. The impact of high loads of exported nutrients from rivers and estuaries to coastal marine systems is difficult to quantify given the low availability of coastal water quality monitoring data. This is an issue faced by coastal and estuarine scientists nationally.

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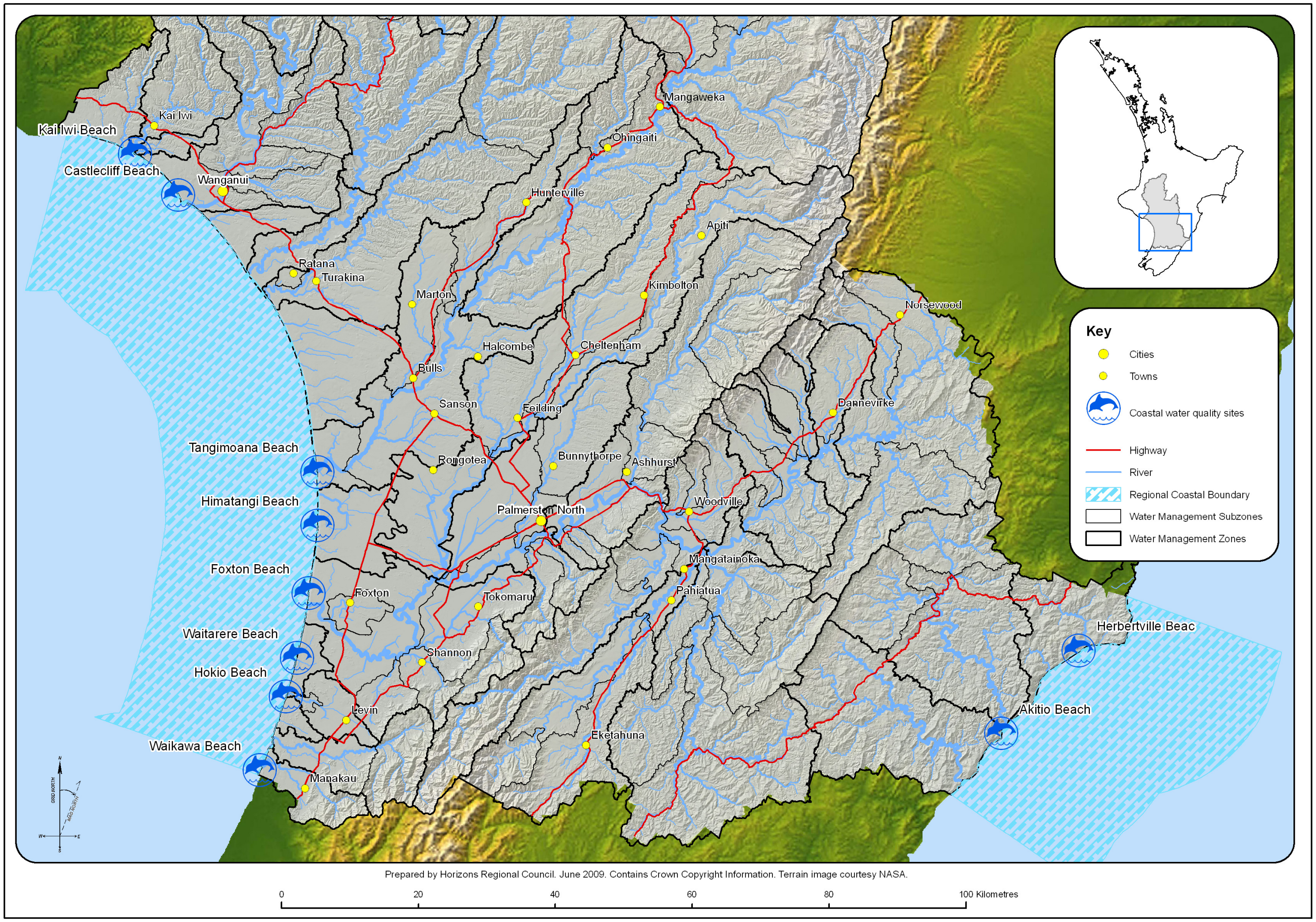
[13] Estuarine physiography relates to the size and shape of the estuary, which determines the available area of inter-tidal shore (ie. for the growth of nuisance macroalgae).

298. Horizons has undertaken monitoring of seawater at coastal bathing beaches for State of the Environment and contact recreation monitoring purposes for a number of years. Most of this monitoring has been of indicators of faecal contaminants such as enterrococci or faecal coliforms, in relation to health risks for contact recreation and shellfish gathering.

299. Over the 2007/2008 summer bathing season (1st November to 30th April), an additional suite of water quality nutrient parameters were collected weekly to allow some assessment of seawater eutrophication at coastal beaches. Six beaches were sampled (Map 7). The Akitio Beach site is the only site on the East Coast of the Region and only six samples were collected from this site. The five other beach sites spanned the West Coast of the Region from north to south. The Whanganui River enters the Seawater Management Zone just south of Castlecliff Beach, the Rangitīkei River reaches the Seawater Management Zone north of Himatangi Beach, the Manawatū River enters the Seawater Management Zone immediately south of Foxton Beach and north of the Waitarere Beach site (Map 7). The predominant currents in the Seawater Management Zone on the West Coast are longshore and to the south.



Map 7. Coastal beach water quality and swimming spot monitoring sites in Horizons' Region.

7.4 Nutrients

300. Nutrients contribute to the eutrophication and enrichment of estuaries and seawater. The 2007/2008 total phosphorus and nitrogen beach monitoring results (Figure 14 and Figure 15) show nutrient concentrations were considerably elevated above the Proposed One Plan standards for seawater quality at all sites. Although these standards are near to the levels of analytical detection for the Horizons dataset, they are supported and considered appropriate by Dr Zeldis.

301. Foxton and Akitio Beach [14] sites had high mean and 75th percentile total P concentrations and the Foxton Beach site also had a high 90th percentile concentration for total P. For total N, all sites exceeded the Proposed One Plan coastal water quality standards. The mean and 75th percentiles of total N concentration were highest at Kai Iwi, Foxton and Waitarere Beaches, with 90th percentiles also high at Foxton and Waitarere. Ammoniacal nitrogen results measured between November 2007 and April 2008 were always within the Proposed One Plan standard (Figure 16).

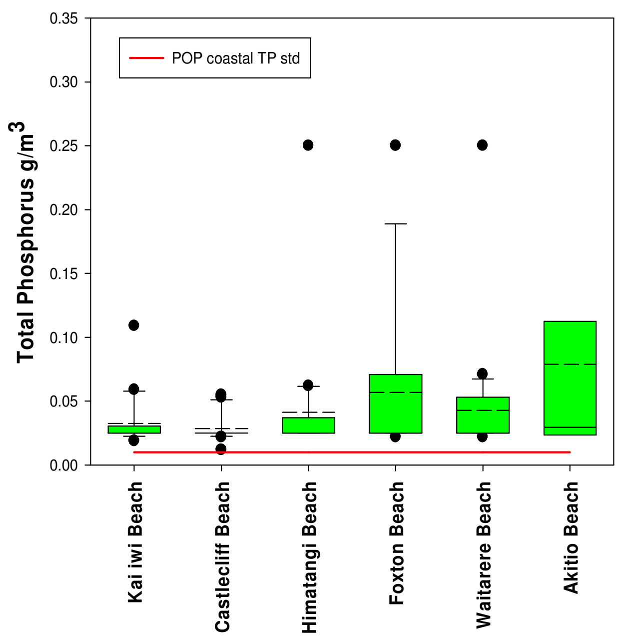


Figure 14. Total phosphorus (TP) concentration in seawater collected from six beaches in the Horizons Region between November 2007 and April 2008[9].

[14] Note: the Akitio Beach results should be interpreted with caution as these were from only 6 samples taken over the 2007/2008 bathing season.

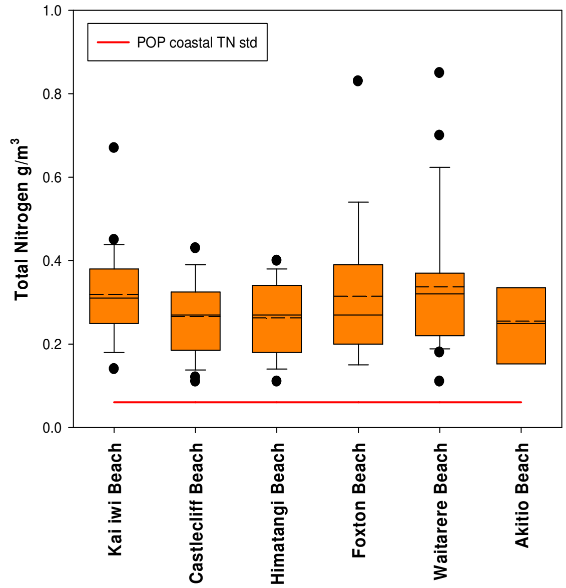


Figure 15. Total nitrogen (TN) concentration in seawater collected from six beaches in the Horizons Region between November 2007 and April 2008[9].

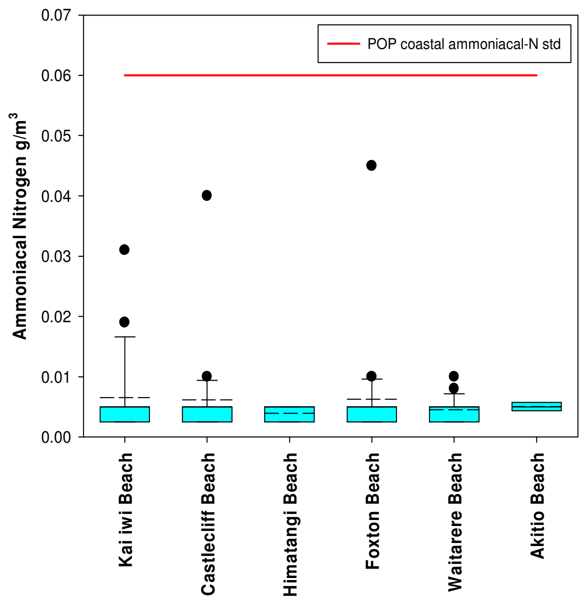


Figure 16. Ammoniacal nitrogen concentration in seawater collected from six beaches in the Horizons Region between November 2007 and April 2008[9].

7.5 Faecal contaminants

302. Enterococci are the preferred faecal indicator bacteria to determine the risk of illness from contact recreation due to faecal contamination in coastal waters (MfE, 2003) due to the rapid die off of *E. coli* in saline waters. Enterococci samples were collected from ten beaches over a range of summer bathing seasons (1st November to 30th April). Monitoring was undertaken by MidCentral Health over the 1994/1995 bathing season and, with the exception of Tangimoana Beach, all sites have been monitored each summer by Horizons since November 1998. Monitoring was discontinued at Waikawa and Hokio Beaches in 2005 and only nineteen samples in total have been collected from Herbertville Beach. At all sites excluding Kai Iwi and Hokio Beaches, the 90th percentile for enterococci was within the POP standard for coastal waters (Figure 17).

303. Faecal coliforms are also monitored as an indicator of risk of illness to humans from the ingestion of shellfish contaminated by faecal pollutants in coastal waters (MfE, 2003). Faecal coliforms were not collected over the 2007/2008 summer bathing season but data exists for a number of sites collected between 2003 and 2009 over the summer period, with an additional twelve samples collected in 1992 at Foxton Beach for a Manawatū Estuary investigation (McBride *et al.,* 1992). The POP standard for faecal coliforms states that the median concentration shall not exceed 14/100 ml and that the 90th percentile shall not exceed 42/100 ml, the standard applies year round to protect shellfish gatherers. Figure 18 shows that Kai Iwi, Himatangi, Waitarere, Hokio and Waikawa Beaches exceed the median standard and all sites exceed the 90th percentile standard for faecal coliforms.

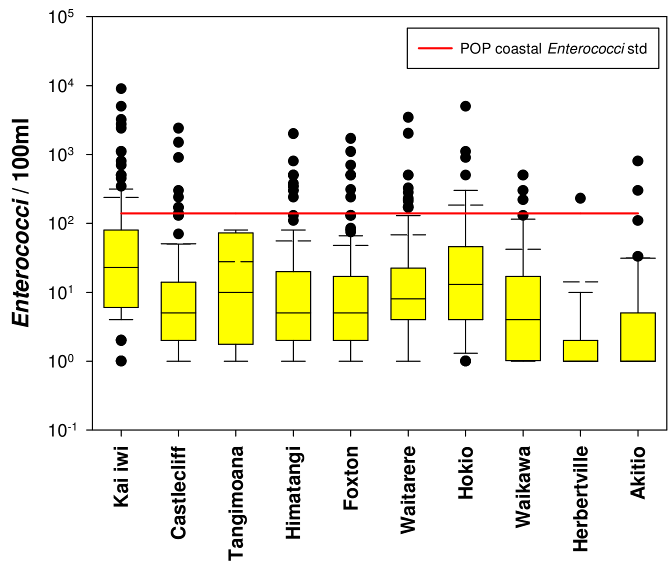


Figure 17. Log$_{10}$ enterococci in seawater collected from ten beaches in the Horizons Region at varying timescales during the summer bathing season (1st November – 30th April) between December 1993 and February 2009[9, 10].

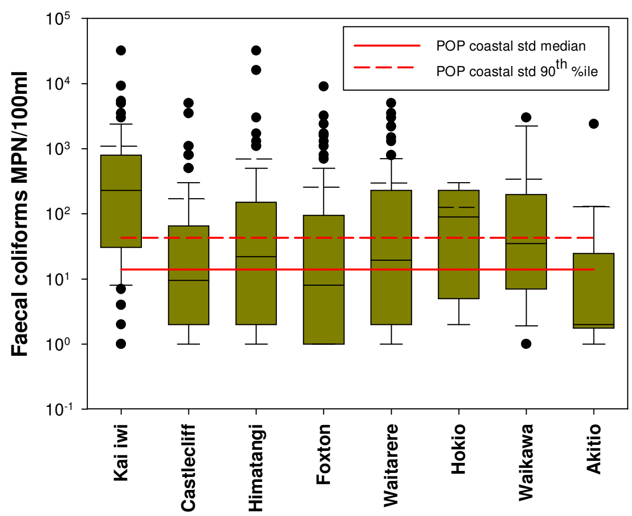


Figure 18. Log$_{10}$ faecal coliforms in seawater collected from eight beaches in the Horizons Region during the summer bathing season (1st November – 30th April) between November 2003 and February 2009[9, 10].

7.6 Turbidity

304. The POP standards for water clarity and turbidity in the Seawater Management Zone are currently proposed as measures of change in Secchi depth measurement and turbidity of no more than 20%. Clarity (measured by Secchi depth) has not been measured in coastal waters. However, turbidity data has been collected over varying timescales from eight beach sites throughout the region since November 1999 (Figure 19). Turbidity was generally very low at the east coast Akitio Beach site and elevated at Kai Iwi and Castlecliff beaches north of the Whanganui River mouth and also high at Waitarere, Hokio and Waikawa Beaches south of the Manawatū River mouth. Hokio Beach had the highest median and 90th percentile values for turbidity.

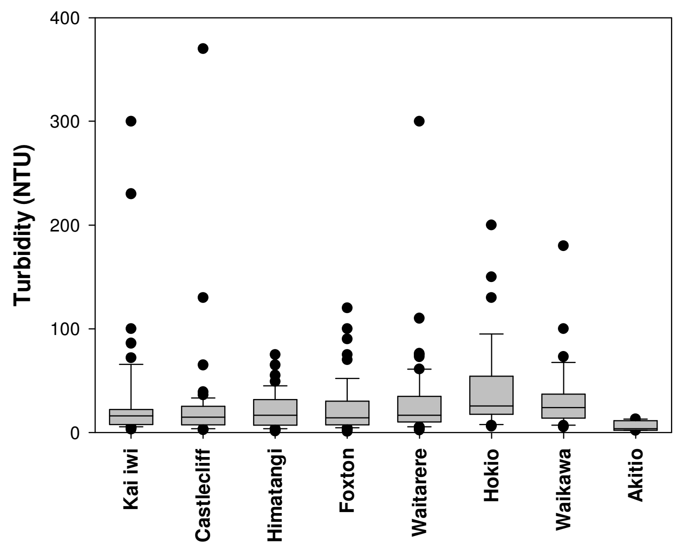


Figure 19. Turbidity of marine waters measured at eight beach sites in Horizons' Region over varying timescales during the summer bathing season (1st November – 30th April) between November 1999 and April 2008[9].

7.7 Sources of contamination in the Coastal Marine Area

305. Water quality in the Seawater Management Zone and the Water Management Estuary Sub-zones can be adversely affected by activities in a number of ways:

   i. direct point source contamination from industrial or domestic sewage outfalls to estuaries or seawater;
   ii. contamination from upstream river and lake systems (both point and non-point source in origin) flowing to estuaries and the sea; and

iii. contamination via groundwater outflows to estuaries or the sea from non-point source inputs such as intensive coastal land use.

306. The only significant point source discharge to the Seawater Management Zone is the discharge from the Wanganui sewage treatment plant which has an ocean outfall some 1.8 km offshore from Wanganui. There are also a number of discharges to the CMA area, largely stormwater in nature and mainly to Estuarine Water Management Sub-zones. The Foxton STP discharges to the Foxton Loop several hundred metres from the boundary of the CMA for the Manawatū Estuary and there is an application currently in progress for the discharge of dairy factory condensate to the Whanganui Estuary within the CMA boundary.

307. Other than the point source inputs mentioned above, pollutants such as nutrient, faecal or sediment contaminants to the CMA are largely derived from direct inputs from lakes and rivers or indirect inputs from land use via groundwater. For example, turbidity measured in the Seawater Management Zone can be caused by suspended sediments or algal material within the water column. High turbidity at sites associated with the Kai Iwi, Mōwhānau, Whanganui and Manawatū Rivers are not surprising given the elevated concentrations of suspended sediments discharged from these rivers. The high turbidity measured at the Hokio Beach site may be indicative of the discharge of suspended algal material from Lake Horowhenua to the sea via the Hokio Stream. Although there are no results specifically supporting this, Lake Horowhenua is frequently subject to significant algal proliferations and high concentrations of cyanobacterial cells in lake water during the summer bathing season (see evidence of Barry Gilliland and Max Gibbs).

308. The most effective ways of managing estuarine and coastal water quality to ensure coastal values are provided for are improvements in river and lake water quality through management of point and non-point sourced contaminants to rivers and coastal lake target catchments, setting of water quality standards for lower rivers that provide adequate protection for the estuarine and coastal receiving environments of those rivers, setting of water quality standards in estuaries and the sea and the control of activities such as direct point source inputs to the CMA.

Key points: Water Quality in the Coastal Marine Area (CMA)

i. Values, management objectives and standards for estuary areas within the CMA have been removed from Schedule D and are now listed within Schedule H.

ii. There are now two key management units within the CMA: 1) the Seawater Management Zone; and 2) Estuary Water Management Sub-zones.

iii. Coastal water quality data from bathing beaches was collected over the 2007/2008 summer.

iv. This data shows that the shallow coastal waters are highly enriched by both phosphorus and nitrogen.

v. Nutrient concentrations significantly exceed POP water quality standards at all sites for coastal waters.

vi. It is likely that coastal waters are predominantly affected by the discharge of nutrients and sediment from the large river catchments of the Region.

vii. These rivers carry some of the highest nutrient loads to the coastal environment in the country.

viii. The risk of eutrophication in the Region's estuaries is only limited by their physiography. This may change in future due to the high sediment loads carried into estuaries from rivers, potentially increasing the risk of eutrophication effects like macroalgal blooms in estuaries.

ix. Most sites (with the exceptions of Hokio and Kai Iwi beaches) met the enterococci POP standards for Contact Recreation.

x. All sites exceeded the POP faecal coliform standards for Shellfish Gathering;

xi. Turbidity was often high at most sites.

xii. Regular monitoring data is required with concurrent conductivity and nutrient monitoring to better determine the sources of nutrient enrichment in coastal waters.

7.8 Recommendations on general conditions for Permitted and Controlled Activities in the CMA

309. Table 17.1 of the POP describes standard conditions for Permitted Activities in the CMA. In the shift of the estuarine sub-zone values from Schedule D to Schedule H some of the Permitted Activity conditions from proposed Chapter 16 should have been moved into recommended Chapter 17. In particular the values relating to Inanga Spawning (Native Fish Spawning) should be provided for in this table of general conditions. Table 17.1 should contain the value 'Inanga Spawning' and a general condition which reads "the use of mobile machinery in or on the foreshore in a manner that disturbs the foreshore

and/or inanga spawning grounds shall not take place in a river/estuarine waters between 1 February and 1 May."

310. References to Native Fishery in this table are recommended to be changed to 'Whitebait Migration' to be consistent with the recommended changes to the values in Schedule Ba. The dates for exclusion in the recommended Condition should also be changed to reflect the whitebait migration season (consistent with the recommendation in Chapter 16 with regards to this value). The Condition currently excludes works between 1 October and 30 November but should in fact exclude works between 15 August and 30 November as described in the evidence of James Lambie on the related table in Chapter 16.

311. Provisions in Table 17.1 for (a) flood flows and floating debris, (f) materials no longer required, (i) and (j) archeological sites should be in Table 17.1 under different value headings as they do not pertain to maintaining the Life-Supporting Capacity or any other Ecosystem value. This is also consistent with the evidence of James Lambie on Table 16.1.

312. The General Condition requiring that there be no removal of woody debris less than 2 m^3 in size, recommended by James Lambie to be moved from the Trout Fishery value into the Region-wide LSC Value in Table 16.1, is also relevant in the Coastal Marine Area for the same reasons as those stated in his evidence. If recommended changes to Table 16.1 are adopted around this provision they should also be added to Table 17.1 in the same manner.

313. Any other changes to Table 16.1 relevant to the values in the CMA should also be transferred where appropriate into the Table 17.1 Conditions.

7.9 Reasonable mixing zone: CMA

314. The following advice is provided in response to the question from the Panel on the definition of a zone of reasonable mixing for Permitted discharges of stormwater under provision 17-30 and Controlled discharges of stormwater under provision 17-31. The key parameters of concern likely to arise from discharges of stormwater meeting the Permitted or Controlled criteria are:

i. minimum horizontal visibility (clarity) less than the standard;
ii. reduction in horizontal visibility (clarity) greater than the standard;
iii. reduction in euphotic depth;

iv. potential to exceed the toxicant standards; and

v. addition of faecal contaminants exceeding standards for the protection of Contact Recreation and Shellfish Gathering values.

315. Reductions in visual clarity and euphotic depth will depend on the state of the receiving water clarity. For example, a discharge of stormwater to the Manawatū Estuary that occurs during high river flows is unlikely to have a measurable effect on the degraded state of the water clarity. Conversely, if rainfall is localised at the coast and the stormwater discharge occurs during low river flows (a less likely situation than the former) the impact of such a discharge could be quite significant, depending on the tidal influence at the time of discharge. Generally speaking, reductions in clarity parameters resulting from stormwater discharges are likely to be temporary and minor in terms of their impact on aquatic ecosystems.

316. The potential for toxicants and faecal contaminants to exist, even in stormwater discharges which meet the Permitted and Controlled criteria, is significant in my opinion. Contaminants of this nature can accumulate in stormwater prior to discharge (particularly in the first flush after a long dry spell) and have the potential to have significant effects on the values in the CMA (Ecosystem and Recreational and Cultural), depending on the receiving water quality and the circumstances at the time of discharge. Even temporary discharges of these contaminants at high concentrations relative to the receiving environment may have temporary or long-term localised effects.

317. Without specific knowledge of the quality of the discharge or the receiving environment at the time of discharge, quantifying a reasonable mixing zone becomes an arbitrary assessment. The potential for faecal contaminants to affect Shellfish Gathering is a problem already identified in the section on coastal water quality above. For example if stormwater has the potential to contaminate shellfish in the vicinity of the discharge and signs are required to warn the public not to collect shellfish for x days after a rainfall event, is this a minor effect? If not, a precautionary mixing zone should be applied in my opinion.

7.10 Recommendations for water quality standards: Coastal Marine Area

318. Expert evidence provided by Dr John Zeldis was based on the recommended Schedule H values and standards presented to the Hearing Panel during the hearing on Coast and the standards that would have applied to estuarine areas of Water Management Sub-zones in Schedule D. Recommendations noted below relate to changes to be

made to that version of Schedule H and the proposed version of Schedule D. These changes are reflected in the recommended Schedule H track changes version and are detailed in Table 13 below.

Table 13. Recommended changes to Schedule H Water Quality Standards of the Proposed One Plan: Coastal Marine Area

Expert recommendation: coast	Evidence link	Accept/decline	Justification/comment
General			
1. The footnote regarding volcanic or lahar activity be removed from Schedule H	Staff recommendation	Accept	This footnote is inappropriate to the coastal environment.
pH			
2. pH range: be removed from Schedule H	Dr John Zeldis	Accept	pH is unlikely to be negatively affected by activities in the coastal environment due to the buffering effect of seawater, therefore the standard is considered unnecessary.
3. pH change: be removed from Schedule H	Dr John Zeldis	Accept	pH is unlikely to be negatively affected by activities in the coastal environment due to the buffering effect of seawater, therefore the standard is considered unnecessary.
Temperature change			
4. Temperature change be removed from Schedule H	Dr John Zeldis	Accept	Temperature is unlikely to be negatively affected by activities in the coastal environment due to the thermal inertia of seawater; therefore the standard is considered unnecessary.
Dissolved oxygen			
5. Dissolved oxygen in Seawater Management Zones: no change	Dr John Zeldis	Accept	The 90% of saturation standard as written in Schedule D is supported
6. Dissolved oxygen in Estuary Management Sub-zones be increased to 70% of saturation	Dr John Zeldis	Accept	To avoid the potential for hypoxia to occur in estuaries, the minimum dissolved oxygen saturation should be 70% rather than 60% as proposed in the recommended Schedule H. This requires changing the dissolved oxygen percent of saturation recommended for Estuary Management Sub-zones Whai_7CMA (Whanganui Estuary), Hoki_1CMA (Hokio Estuary), and West_3CMA (Mōwhānau Estuary).
Biochemical oxygen demand (BOD)			
7. BOD be removed from Schedule H	Dr John Zeldis	Accept	BOD standards are considered unnecessary because the dissolved oxygen of estuaries and seawater is adequately protected by the dissolved oxygen standards. (Coastal and estuarine waters are not subject to growths of sewage fungus from elevated BOD in the same manner as rivers and streams).
Particulate organic matter (POM)			
8. POM be removed from Schedule H	Dr John Zeldis	Accept	POM is inappropriate to the coastal environment.
Periphyton and phytoplankton			
9. Seawater Algal Biomass as chlorophyll *a*/m^3 should be raised from 1 mg/m^3	Dr John Zeldis	Decline	This standard is based on the ANZECC (2000) guideline for South-East Australian coastal waters (no New Zealand trigger value has been defined). Without evidential basis for change, particularly in light of the elevated nutrient concentrations apparent in coastal marine waters and the lack of chlorophyll *a* data for the coast, it is not

Expert recommendation: coast	Evidence link	Accept/decline	Justification/comment
			recommended that this standard be raised.
10. Estuary Sub-zone Algal Biomass as chlorophyll *a* mg/m^2 and percent cover shall be removed from Schedule H	Dr John Zeldis	Accept	These standards have been carried over from the river standards and are inappropriate in the coastal environment.
11. Estuary Sub-zone 4 mg chlorophyll *a*/m^3 shall be added to the Estuary Sub-zones	Staff Recommendation	Accept	This standard for estuaries is from the ANZECC (2000) guideline for South-East Australian estuaries and is consistent with the approach taken for the Seawater chlorophyll *a* standard.
12. Estuary Sub-zone macro-algal cover shall not exceed 20% of shore surface	Dr John Zeldis	Accept	Macroalgal blooms have occurred in the Manawatū Estuary in the past but there is little evidence of macroalgal blooms occurring more recently or at any other estuaries. A macroalgal standard is appropriate to ensure estuary productivity does not suddenly change, causing effects on the Life-Supporting Capacity.
Dissolved reactive phosphorus			
13. No change to estuary standards	Dr John Zeldis	Accept	The standards are supported.
Soluble inorganic nitrogen			
14. The 444 mg/m^3 SIN standard in the Manawatū Estuary Sub-zone shall be reduced to 167 mg/m^3	Dr John Zeldis	Decline	The reduced SIN standard (167 mg/m^3) is inconsistent with the lower Manawatū River SIN standard of 444 mg/m^3 and therefore is unlikely to be achievable in the Manawatū Estuary, particularly given the data presented by Dr Zeldis on nitrogen loads discharged from the Region's river systems. The pragmatic method applied to determining nutrient standards for rivers and streams where the state of the water quality was significantly far from the recommended standard should also be used in this instance. Some relaxation of the SIN standard to provide a demonstrably achievable target is needed and therefore it is the Council's recommendation that the standard remain at 444 mg/m^3.
15. No change to the SIN standard for any other Estuary Sub-zone	Dr John Zeldis	Accept	The standards are supported
Total phosphorus			
16. No change	Dr John Zeldis	Accept	The standard is supported.
Total nitrogen			
17. No change	Dr John Zeldis	Accept	The standard is supported.
Quantitative Macroinvertebrate Community Index			
18. The standard be removed from Schedule H	Staff Recommendation	Accept	The standard is inappropriate to the coastal environment.

Expert recommendation: coast	Evidence link	Accept/decline	Justification/comment
Ammoniacal nitrogen			
19. The standard shall refer to ammoniacal nitrogen throughout Schedule H	Dr Bob Wilcock	Accept	This is the appropriate term.
20. No change to the standard	Dr John Zeldis	Accept	The standards are supported.
Toxicants			
21. No change to the standard	Dr John Zeldis	Accept	The standards are supported.
Turbidity			
22. Turbidity be removed from Schedule H	Dr Rob Davies-Colley	Accept	Turbidity is not an appropriate measure of the optical properties of water. Clarity as determined by horizontal visibility by black disc or equivalent Secchi depth standards are more appropriate[12].
Clarity			
23. A minimum clarity standard of 1.6 m shall apply to coastal waters	Dr Rob Davies-Colley and Dr John Zeldis	Accept in part	This standard will provide protection for Contact Recreation values in Seawater and is accepted for the Seawater Management Zone. However, estuaries are unlikely to be able to meet such a minimum standard due to their natural physical characteristics (see evidence of Dr Zeldis) are therefore a minimum clarity standard is declined for the Estuary Sub-zones
24. No more than 20% reduction in horizontal visibility	Dr Rob Davies-Colley and Dr John Zeldis	Accept	This standard is appropriate to both Seawater and Estuary zones and sub-zones.
Euphotic Depth			
25. Maximum reduction in euphotic depth of 10%	Dr Rob Davies-Colley and Dr John Zeldis	Accept	This is to protect the light climate of coastal aquatic plants such as seagrass.
Faecal indicator bacteria			
26. Enterococci standards Seawater: no change	Dr Rob Davies-Colley and Dr John Zeldis	Accept	The standards are supported.
27. Faecal coliform standards Seawater: no change	Dr Rob Davies-Colley and Dr John Zeldis	Accept	The standards are supported.
28. Estuaries: when water in Estuary Sub-zones > 200 µS/cm the enterococci standards for the Seawater Management	Dr John Zeldis	Decline	Seawater conductivity is approximately 49,285 µS/cm and the median conductivity for the Manawatū River at Whirokino is 182 µS/cm (see the evidence of Hisham Zarour in relation to salinity/conductivity units). Therefore 200 µS/cm will not provide

Expert recommendation: coast	Evidence link	Accept/decline	Justification/comment
Zone shall apply			a certain threshold to determine when an estuary is under a predominantly saline influence from the incoming tide (requiring enterococci standards to apply rather than *E. coli* standards). Additionally, this standard requires in-the-field determination of which faecal indicator parameter to analyse, dependant on conductivity reading at the time of sampling, an impractical requirement for bathing beaches monitoring. According to the evidence of John Zeldis, the estuaries of the Region are predominantly influenced by river flows and residence time in estuaries is short. Therefore it is appropriate to set faecal indicator bacteria standards in estuaries that are consistent with river standards. Additionally, river flow-related risk assessment of *E. coli* concentration, in relation to suitability for contact recreation, is more likely to correlate well with estuarine *E. coli* concentrations (ie. when river flow is elevated, estuaries are likely to exceed *E. coli* standards and be risky for contact recreation in the same manner as rivers).
29. Estuaries: when water in Estuary Sub-zones is < 200 μS/cm the *E.coli* standards for rivers and streams shall apply	Dr John Zeldis	Decline	See discussion above.
30. Estuaries: The zone-wide water quality standards for rivers and streams relating to *E. coli* apply to all Estuary Sub-zones in Schedule H	Staff recommendation (support for the use of *E. coli* is provided in the evidence of Dr Davies-Colley)	Accept	See discussion above. Standards should use the same wording and flow and season requirements as for rivers and streams.
Cyanotoxins			
31. Cyanotoxin standards be removed from Schedule H	Staff recommendation	Accept	This toxin standard is not consistent with the draft recommendation of the National Guidelines on Cyanobacterial Toxicity (MfE/MoH, 2009). Once national guideline values are finalised these should be adopted as cyanobacterial standards for the protection of lake and river water quality values.

8. SOURCES OF CONTAMINANTS AND EFFECTS ON VALUES

8.1 Contaminant sources

319. Freshwater contaminant sources fall into three basic categories:

i. Natural: concentrations of nutrients resulting from lithology, geology or land cover in largely unimpacted catchments (ie. forested headwaters in natural state);

ii. Point sources: contaminants directly added to water from discrete end-of-pipe sources; and

iii. Non-point sources: diffuse contaminants that enter water via surface and sub-surface flow from the landscape (ie. run-off and leaching).

Roygard and McArthur (2008) define point and non-point sources for the purposes of water quality management in section 4.1 page 53 of that report.

8.2 Water Management Sub-zones that do not meet the standards

320. Ausseil and Clark (2007c) assessed each Water Management Sub-zone against each standard for which there was sufficient data (Table 27, page 144). There were approximately 55 Water Management Sub-zones that did not meet either one or both nutrient standards and many which failed the contact recreation standards for *E. coli,* based on data available at the time that report was published.

321. Water Management Sub-zones that do not meet either the nutrient or *E. coli* standards are detailed in Appendix 2 along with information on the sources of contaminants contributing to breaches of standards at low (less then median) and high (greater than median) flows. To assess the combined effects of physicochemical conditions on the Life-Supporting Capacity in each sub-zone, the MCI score is also noted and the reference sources for information are included.

322. An analysis of how many Water Management Sub-zones (WMSZ) do or do not meet the standards, or have insufficient data for the assessment of water quality against the proposed standards is required for Policies 6-3, 6-4 and 6-5. Table 14 summarises the number of WMSZ that fall into each of the three Policy categories for nutrient concentrations at low (less than median) or high (greater than median) flows, faecal indicator bacteria at flows suitable for contact recreation and Life-Supporting Capacity measured against the recommended MCI standards for each sub-zone.

323. Table 14 shows there are few sub-zones that do comply with the POP water quality standard at high flows for phosphorus (15% of all sub-zones) or nitrogen (9% of all sub-

zones). At lower flows water quality is better for a greater number of sub-zones (phosphorus 22% and nitrogen 17% of all sub-zones). Contact Recreation is suitable at 26% of all sub-zones, but this suitability does not account for other water quality issues that affect contact recreation such as poor clarity, high periphyton or the presence of cyanobacterial blooms. Life-Supporting Capacity (measured using MCI as an indicator of aquatic ecosystem health) meets the recommended standards at only 16% of sites.

324. Removing all sub-zones with insufficient data from the analysis, the proportions of compliance increase to:

- 34% for phosphorus at low flows,
- 28% for phosphorus at high flows,
- 27% for nitrogen at low flows,
- 17% for nitrogen at high flows,
- 42% for Contact Recreation suitability (*E. coli*), and
- 29% for Life-Supporting Capacity (measured by MCI).

325. The data shows that there are a number of Water Management sub-zones that fit the criteria for Policy 6-4 as requiring enhancement of water quality. There are also a large number of sub-zones that fit the criteria of Policy 6-5 due to insufficient water quality data (between 36% and 47% depending on the parameter of interest). More nutrient data is required, particularly at higher flows for a number of sub-zones.

Table 14. Number of Water Management Sub-zones (out of a total of 124) that meet the POP water quality standards, do not meet the standards or have insufficient data in relation to DRP, SIN, Contact Recreation suitability and Life-Supporting Capacity (MCI) based on summarised data from Appendix 2.

No of Sub-zones where:	P low flows[15]	P high flows	N low flows	N high flows	Contact Recreation (FIB source)	Life-Supporting Capacity (MCI)
Water Quality Standards are met (Policy 6-3)	27	19	21	11	32	20
Water Quality Standards are not met (Policy 6-4)	52	48	58	55	45	49
Existing Water Quality is unknown (Policy 6-5)	45	57	45	58	47	55

[15] For lake Water Management Zones the standards were determined to be met or not met across both low and high flow assessment criteria for simplicity of analysis.

326. The following sections discuss data specific to sub-zones that do not meet the standards because of point or non-point source contributions to water quality.

8.3 Water Management Sub-zones affected by point source contaminants

327. McArthur and Clark (2007) examined the contributions of point source and non-point source soluble nitrogen and phosphorus at low flows in rivers receiving point source discharges. Table 15 reproduced from McArthur and Clark (2007) outlines the point source discharges that exceed nutrient standards at low flows. The findings of this investigation and data collected through the discharge monitoring programme show that the Water Management Sub-zones subject to problem point source inputs are:

- Mangatera
- Tamaki – Hopelands (Manawatū mainstem)
- Mākākahi
- Lower Mangatainoka
- Mangaatua
- Lower Manawatū
- Middle Oroua
- Lower Oroua
- Foxton Loop
- Coastal Manawatū
- Lower Hautapu
- Coastal Rangitīkei
- Tidal Rangitīkei
- Porewa
- Tūtaenui
- Whanganui at Te Maire
- Upper Whangaehu
- Middle Whangaehu
- Lower Whangaehu
- Lower Makotuku
- Upper Mangawhero
- Lower Mangawhero.

Table 15. Summary of 44 significant discharges to water and compliance with proposed water quality standards for nitrogen and phosphorus in the Horizons Region between 1993 and 2006 at flows less than half median (reproduced from McArthur and Clark, 2007, page 72).

Discharge to surface water	SIN		DRP	
	meets SIN standard at MALF	meets SIN standard at ½ median*	meets DRP standard at MALF	meets DRP standard at ½ median*
Norsewood STP	✓	✓	✓	✓
Dannevirke STP	✓	✓	✗	✗
PPCS (Oringi)	✓	✓	✓	✓
Eketahuna STP	✓	✓	✓	✓
Fonterra (Pahiatua)	✓	✓	✓	✓
Pahiatua STP	✓	✓	✗	✗
DB Breweries	✓	✓	✗	✗
Woodville STP	✗	✓	✗	✗
Ashhurst STP	✓	✓	✓	✓
Aokautere STP	✓	✓	✓	✓
PNCC STP	✗	✓	✗	✗
Longburn STP	✓	✓	✓	✓
Fonterra (Longburn)	-	-	-	-
NZ Pharmaceuticals	✓	✓	✓	✓
Kimbolton STP	✓	✓	✓	✓
Affco Manawatū Ltd	✗	✓	✗	✗
Feilding STP	✗	✗	✗	✗
Awahuri STP☹	-	-	-	-
Rongotea STP☹	-	-	-	-
Tokomaru STP☹	-	-	-	-
Shannon STP☹	-	-	-	-
Foxton STP☹	-	-	-	-
PPCS (Shannon)	✓	✓	✓	✓
Taihape STP	✓	✓	✗	✗
Mangaweka STP	✓	✓	✓	✓
Hunterville STP	✗	✓	✗	✗
Halcombe STP	✗	✗	✗	✗
Feltex	-	-	-	-
Marton STP	✗	✗	✗	✗
Bulls STP	✓	✓	✓	✓
Riverlands (Manawatu Ltd)	✓	✓	✓	✓
Ohakea STP☹	-	-	-	-
Sanson STP☹	-	-	-	-
National Park STP☹	-	-	-	-
Taumarunui STP	✓	✓	✗	✓

* or 75th percentile flow at sites affected by the Tongariro Power Development (TPD)

☹ No flow available at point of discharge to compare with standard

Discharge to surface water	SIN		DRP	
	meets SIN standard at MALF	meets SIN standard at ½ median*	meets DRP standard at MALF	meets DRP standard at ½ median*
Ohura Prison STP	✓	✓	✓	✓
Pipiriki STP	✓	✓	✓	✓
Winstone Pulp	✓	✓	✗	✗
Waiouru Army Camp STP	✗	✗	✗	✗
Rangataua STP⊗	-	-	-	-
Ohakune STP	✗	✗	✗	✗
Raetihi STP	✗	✓	✗	✗
Pongaroa STP	✓	✓	✗	✓

Key: ✗:Does not meet the standard; ✓: Meets the DRP standard; ✓: Meets the SIN standard

328. The point source discharges that contribute significantly to the exceedence of nutrient and *E. coli* standards are summarised in Table 16 below. In order to meet the water quality standards of the POP, significant changes in discharge regime or the ultimate receiving environment of these wastewater discharges will need to occur in a number of Water Management Sub-zones. Changes to discharge regimes can be focussed on meeting water quality standards at critical times or river flows, based on the flow-related water quality information that has been collected.

329. An updated analysis of the effects of contaminant sources on water quality at the Water Management Sub-zone level was completed for this evidence. All available data was analysed in relation to the key contaminants of concern (nitrogen, phosphorus, faecal bacteria) and Life-Supporting Capacity (indicated by MCI score) at monitoring sites as near as possible to the bottom of all Water Management Sub-zones. This substantial analysis and the sources of data used are detailed in Appendix 2. All discussion of point and non-point source contamination in the following sections is based on the results in Appendix 2.

330. Table 16 below summarises the data in relation to point source discharges with a significant effect at the sub-zone wide level (Map 8). A significant effect in this instance was determined as the average of all available data at low (less than median) or high flows (greater than median) that exceeded the POP standards.

331. Out of seven discharges listed in Table 16 as contributing to poor water quality in the Manawatū River catchment, all are non-complying with the operative MCWQRP standards in Rule 2 for phosphorus and/or periphyton biomass and cover, either through exemption from the Plan standards or because they are operating outside their consents

and are in the process of resource consent renewal. Four of the seven Manawatū discharges listed have been through resource consent renewal since 2000 and have been granted non-complying status with the Rule 2 standards of the MCWQRP, largely by arguing 'exceptional circumstances'. Appendix 2 highlights the fact that these discharges are still adversely affecting the nutrient, *E. coli* and sometimes the life-supporting capacity status of a number of Water Management Sub-zones, depending on the flow, to the detriment of the Region's water quality and aquatic biodiversity (see state and trend sections above).

Table 16. Point source discharges that contribute significantly to contamination of surface waters either locally or on a sub-zone wide basis in Horizons' Region. *Note: other discharges (eg. Sanson and Halcombe STP) also have localised effects but lack the data to enable a complete assessment at the Water Management Sub-zone level.*

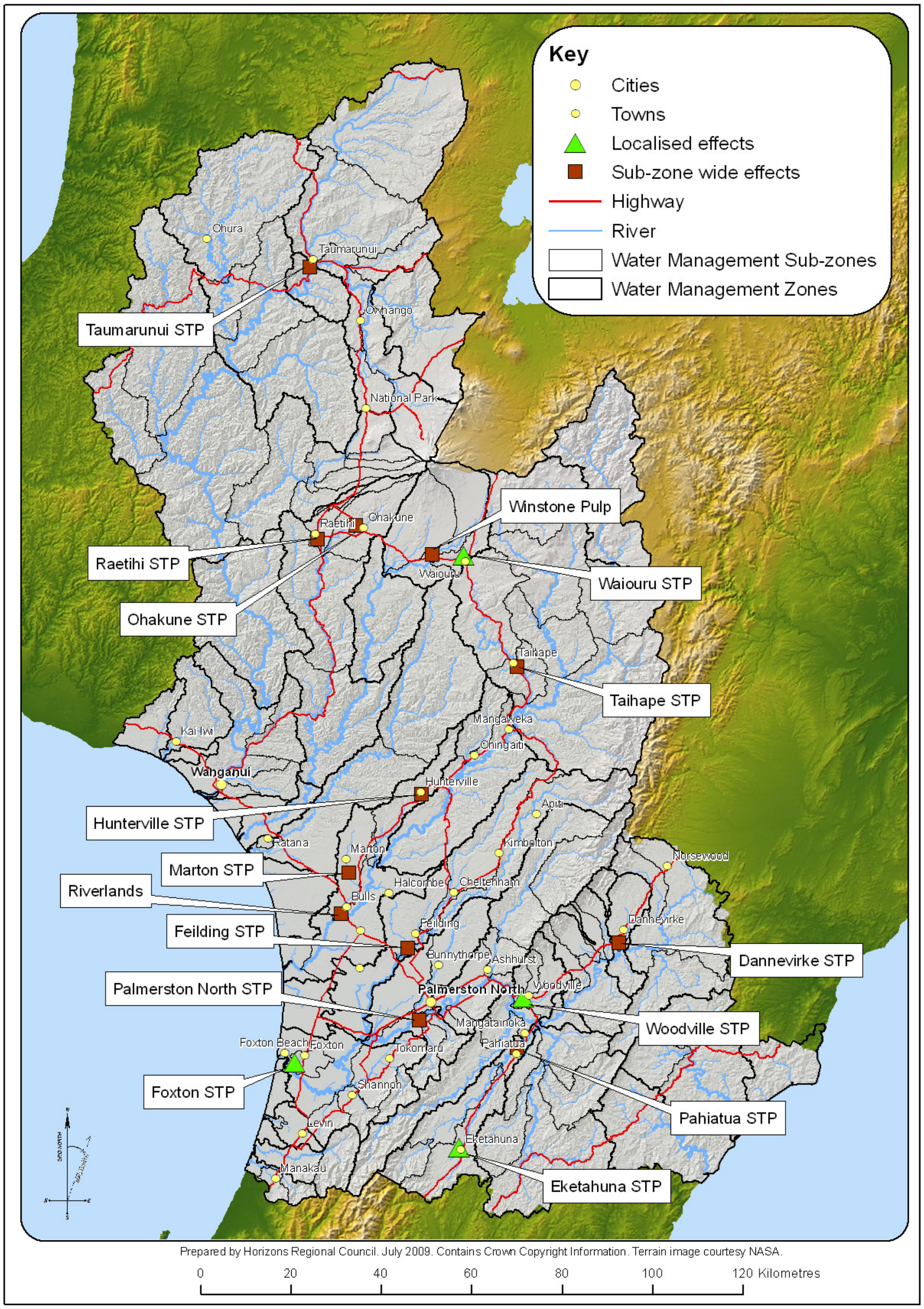
Discharge name	Nitrogen contributor	Phosphorus contributor	*E. coli* contributor	Local or sub-zone wide impact?	WMSZ
Dannevirke STP	✓	✓		Sub-zone wide	Mana_2b
Pahiatua STP		✓		Sub-zone wide	Mana_8c
Eketahuna STP		✓		Local	Mana_8d
Woodville STP	✓	✓		Local	Mana_9c
Palmerston North STP[16]	✓	✓	✓	Sub-zone wide	Mana_11a
Feilding STP	✓	✓		Sub-zone wide	Mana_12b
Foxton STP		✓		Local	Mana_13f
Taihape STP	✓	✓		Sub-zone wide	Rang_2g
Riverlands[17]	✓	✓	✓	Sub-zone wide	Rang_4a
Hunterville STP	✓	✓	✓	Sub-zone wide	Rang_4c
Marton STP	✓	✓	✓	Sub-zone wide	Rang_4d
Taumarunui STP	✓			Sub-zone wide	Whai_3
Waiouru STP	✓	✓	✓	Local	Whau_1b
Winstone Pulp[18]	✓	✓	✓	Sub-zone wide	Whau_1a
Raetihi STP	✓		✓	Sub-zone wide[19]	Whau_3c
Ohakune STP	✓	✓		Sub-zone wide[19]	Whau_3d

16 Longburn STP, Fonterra Longburn and NZ Pharmaceuticals also contribute in this sub-zone. PNCC STP makes the most significant contribution (McArthur and Clark, 2007).

17 Bulls STP, Halcombe STP, Sanson STP and Ohakea STP also contribute in this sub-zone. Riverlands makes the most significant contribution (McArthur and Clark, 2007).

18 Winstone Pulp has a significantly detrimental effect on LSC at a sub-zone wide level due to elevated BOD in the discharge.

19 Combined effect of both discharges on sub-zone.



Map 8. Discharges to water that cause localised and sub-zone wide effects on water quality.

8.4 Determining non-point sourced nutrient enrichment

332. In accounting accurately for point source contaminant inputs, the non-point sourced inputs are able to be calculated from the measured in-river loads or concentrations not attributable to point sources. By the process of eliminating the point source contributions, all remaining contaminants are either non-point or naturally sourced. Measurements of contaminant concentrations at 'reference' sites flowing from forested headwater catchments (eg. the Tamaki at Reserve site in a tributary of the upper Manawatū) enable the determination of 'naturally sourced' contaminant concentrations. Using a number of reference sites from different catchment geologies/lithologies gives an expected range for natural contaminant concentrations across the Region. Eliminating the naturally sourced contaminant concentrations is generally not required in Water Management Zones with significant water quality issues, as the concentrations likely to be naturally sourced are minute by comparison with non-point sourced contributions in most cases.

8.5 Where is non-point source contamination an issue?

333. Appendix 2 details the Water Management Sub-zones where non-point sources are the key contributors to poor water quality according to monitoring data available from the State of the Environment and discharge monitoring programmes at low and high flows for nitrogen and phosphorus and flows suitable for Contact Recreation for *E. coli*. In all cases (except the Pukeokahu – Mangaweka Sub-zone (Rang_2b) of the Rangitīkei catchment) where contact recreation is affected by faecal contamination, the sub-zones with elevated faecal contaminants also have water quality issues associated with nitrogen, phosphorus or both. The lists below summarise the complex information in Appendix 2 by catchment.

334. The main sub-catchments affected by non-point source contaminants in the Manawatū catchment are:

- Upper Manawatū
- Upper Gorge
- Mangatewainui
- Mangatoro
- Mangatera
- Tamaki
- Kumeti
- Oruakeretaki

- Raparapawai
- Mangapapa
- Mangaatua
- Tiraumea
- Mākurī
- Mangatainoka
- Mākākahi
- Middle Manawatū
- Lower Manawatū
- Coastal Manawatū
- Middle Pohangina
- Mangaone
- Makino
- Oroua
- Tokomaru
- Foxton Loop.

335. Non-point source contamination of the Rangitīkei catchment affects the following rivers:

- Mākōhine
- Porewa
- Tūtaenui
- Tidal Rangitīkei.

336. Non-point source contamination of the Whanganui catchment affects:

- Whanganui at Cherry Grove
- Pipiriki
- Paetawa
- Lower Whanganui
- Coastal Whanganui
- Piopiotea
- Lower Ongarue
- Upper Ohura.

337. In the Whangaehu catchment non-point sources affect water quality in the following rivers:

- Middle Whangaehu
- Lower Whangaehu

- Tokiahuru
- Makotuku
- Mangawhero.

338. In other smaller catchments around the region, non-point sources cause poor water quality in the:

- Turakina
- Lower Ohau
- Kai Iwi
- Mōwhānau
- Kaitoke Lakes, Southern Whanganui Lakes
- Lake Papaitonga
- Waikawa
- Manakau
- Lake Horowhenua
- Hokio Stream
- Owāhanga
- Lower Akitio.

339. From these lists of affected catchments in the sections above, catchments not identified as target catchments for FARM strategy management of non-point source contamination in the POP include:

- Tiraumea
- Mākurī
- Middle Manawatū
- Lower Manawatū
- Coastal Manawatū
- Middle Pohangina
- Mangaone
- Makino
- Oroua
- Tokomaru
- Foxton Loop
- Mākōhine
- Whanganui mainstem
- Piopiotea
- Ongarue

- Ohura
- Middle Whangaehu
- Lower Whangaehu
- Tokiahuru
- Turakina
- Ohau
- Kai Iwi
- Owāhanga
- Akitio.

340. The results of a number of studies (Scarsbrook, 2006; Ballantine and Davies-Colley, 2009 a and 2009 b) clearly show that there is a general association between pastoral land cover and poor water quality and that extensive land uses such as sheep and beef farming also have a negative impact on water quality. In general, if the catchment land use is examined (Clark and Roygard, 2008) in conjunction with the summary water quality data in Appendix 2 for the non-point source affected catchments listed above, it is clear that where land is not as intensively used (ie. for dairying, commercial vegetable growing, cropping or irrigated sheep and beef), water quality issues are less severe.

8.6 Calculating nutrient loads to determine land use effects on water quality

341. Roygard and McArthur (2008) examined two catchments subject to significant point source and non-point source nutrient loads: the upper Manawatū and Mangatainoka River catchments. Roygard and McArthur (2008) defined an approach for examining catchments subject to both point and non-point source pollution and distinguishing between which sources affect which parameters (ie. phosphorus or nitrogen) under different flow scenarios. In brief, Roygard and McArthur (2008) recommend the following seven-step method for determining relative nutrient contributions and investigating management solutions (these methods are further discussed in the evidence of Dr Roygard):

i. Determine the Standard load limit for the catchment based on flow record and concentration-based water quality standards (tonnes/year).

ii. Determine the average annual Measured load (tonnes/year) and compare to the Standard load limit.

iii. Describe the significant point source nutrient inputs and estimate the non-point source loads (tonnes/year).

iv. Calculate the relative inputs of point source and non-point source using Measured loads and point source load estimates.

v. Estimate the potential for non-point source load improvements and describe the combined best management practice for point source and non-point source loads.

vi. Calculate the projected non-point source target loads from Rule 13-1 of the Proposed One Plan, based on Land Use Capability (LUC) class.

vii. Recommend an approach for point source management, given the non-point source loads under various nutrient management scenarios.

342. The process of determining annual loads from point sources and from measured State of the Environment data is required because land use inputs and subsequent management solutions are generally determined and applied on an annual scale, whereas discharges and in-river contaminants are commonly measured as instantaneous concentrations.

343. The ability to calculate nutrient inputs as both annual loads and instream concentrations at various river flows is a fundamental aspect of integrating the management of point and non-point sourced contributors to poor water quality.

344. Roygard and McArthur (2008) modelled a range of nutrient loads, for various land use and best management practice scenarios (see Chapters 7 and 8 of Roygard and McArthur (2008)). I then used these loads to re-calculate instream nutrient concentrations (over the ten flow decile categories) for the upper Manawatū and Mangatainoka Rivers for the purposes of the assessment by Dr Barry Biggs to determine the relative effects of changes in nutrient load on instream periphyton biomass.

345. Dr Biggs estimated that maximum monthly periphyton biomass in the upper Manawatū and Mangatainoka Rivers would reduce by 30–75% if current annual nutrient loads were reduced to the Standard load limits calculated by Roygard and McArthur (2008). Such a reduction would have a significant positive effect on values such as Contact Recreation, Life-Supporting Capacity and Trout Fishery as well as Aesthetic and Amenity values.

346. With respect to reductions in periphyton biomass, the greater the reduction in average monthly biomass and cover, the more time a given waterway will be suitable for values such as Contact Recreation, Life-Supporting Capacity, Aesthetics, Amenity or Trout Fishery.

8.7 Sources and effects of faecal indicator bacteria

347. With regard to determining the sources of faecal contaminants to water, much can be determined by examining the concentration of contaminants in relation to flow (see the evidence of Dr Davies-Colley). Direct faecal inputs, in the absence of any human faecal contaminant sources (ie. point source discharges or septic tank contamination) are most likely to be sourced from stock access to streams and will be apparent at elevated concentrations during low or stable flow conditions. Indirect faecal inputs, sourced from run-off from animal faeces in the surrounding catchment landscape or the poor management of dairyshed effluent, will increase in concentration as a result of rainfall, run off into streams and increased stream or river flow.

348. Catchments with contributions of non-point sourced faecal contaminants (see Appendix 2) include:

- Upper Manawatū and tributaries
- Tiraumea and Mākurī
- Middle and lower Manawatū and some tributaries
- The tidal and lower Rangitīkei and tributaries
- Some tributaries of the Whanganui
- The Whangaehu
- Turakina
- Kai Iwi
- Mōwhānau
- Waikawa
- Lake Papaitonga
- Akitio River.

349. Best management practices to reduce direct and indirect non-point source faecal contamination are addressed in the evidence of Dr Rob Davies-Colley and Dr Bob Wilcock. Direct inputs of faecal contaminants are likely to have directly negative impacts on Contact Recreation and Shellfish Gathering. Direct faecal contamination from stock access will occur at low flows, when water is commonly utilised for Contact Recreation, increasing the risk of affect on the value from this faecal vector.

350. The effect of indirect, catchment-sourced faecal contaminants (see the evidence of Dr Davies-Colley) on values such as Contact Recreation and Shellfish Gathering will depend on the catchment characteristics and flow regime. In small catchments faecal contamination from rainfall events will make contact recreation risky for only short

periods after river or stream flow has receded, as discussed in the evidence of Barry Gilliland on swimming spot monitoring. In large catchments such as the Manawatū however, the faecal contamination from indirect sources following a rainfall event may take several days to clear before contact recreation is suitable because of the time it takes for water to travel through this large river system.

351. The lag effect on shellfish gathering as a result of the discharge of high concentrations of faecal contaminants to the coastal environment following rainfall events is largely unknown in the Region and requires further investigation, particularly given the poor performance of coastal water quality in relation to faecal coliforms (Figure 18).

Key points: Sources of contaminants and effects on water quality

i. Contributing sources to poor water quality can vary between natural, point source and non-point sources depending on catchment geology, flow regime, land use and the scale and nature of point source discharges.

ii. A large number of Water Management Sub-zones do not meet the POP standards for nutrients or faecal indicator bacteria at different flows as the result of point or non-point sources.

iii. Discharges that contribute to sub-zone wide effects on nutrient and *E.coli* concentrations include: Dannevirke STP, Pahiatua STP, Palmerston North STP, Feilding STP, Taihape STP, Riverlands, Hunterville STP, Marton STP, Taumarunui STP, Winstone Pulp and the combined effects of Ohakune and Raetihi STPs.

iv. Other discharges that have more localised effects include: Eketahuna STP, Woodville STP, Foxton STP and Waiouru STP.

v. There are also a large number of sub-zones that are adversely affected by non-point sources of contamination, including: the Manawatū catchment (and tributaries), Coastal Rangitīkei (and some tributaries), Whanganui mainstem (and some tributaries), Whangaehu mainstem (and some tributaries) and the Turakina, lower Ohau, Coastal lakes, Waikawa, and East Coast rivers.

vi. A number of the sub-zones affected by non-point source contaminants are included in the POP as target catchments for the management of intensive land use operations.

vii. Some land use affected sub-zones are not included as target catchments, and in many of these sub-zones, pastoral land use generally, rather than purely intensive land use, is the cause of the water quality issues.

viii. The effects of reductions in nutrient load to meet water quality standards were examined in two case study catchments and Dr Biggs predicted significant improvements in periphyton biomass, which would also improve waterways for Contact Recreation, Life-Supporting Capacity and Trout Fishery values.

ix. Non-point source faecal inputs are classed as direct (from stock access to water) or indirect (from run-off from the landscape). Direct faecal inputs negatively impact on contact recreation because they can occur at low flows when swimming is common.

x. Indirect faecal inputs can affect contact recreation and shellfish gathering for longer periods while flows recede and rivers clear.

9. TARGET CATCHMENTS FOR FARM STRATEGY MANAGEMENT

352. Under the Proposed One Plan, resource consent will be required for intensive land use operations such as dairying, irrigated sheep and beef, cropping or commercial vegetable growing within target catchments. The Proposed One Plan defines nitrogen output limits for intensive land uses in these target catchments to achieve water quality outcomes via Rule 13-1 (see POP Table 13.2). The output limits are to be phased in over time depending on Water Management Zone, as determined within the Plan (Table 13.1).

353. An application for resource consent under Rule 13-1 will require the preparation of a Farmer Applied Resource Management (FARM) strategy. The purpose of the FARM strategy is to group the consent requirements under the Plan into a whole-farm package for improved manageability (ie. "one farm, one consent") and environmental outcomes. A key component of any FARM strategy is to minimise the environmental impacts associated with nitrogen, phosphorus, faecal contamination and sediment on freshwater resources from intensive land uses. Dr Andrew Manderson provides evidence on the FARM strategy workbook.

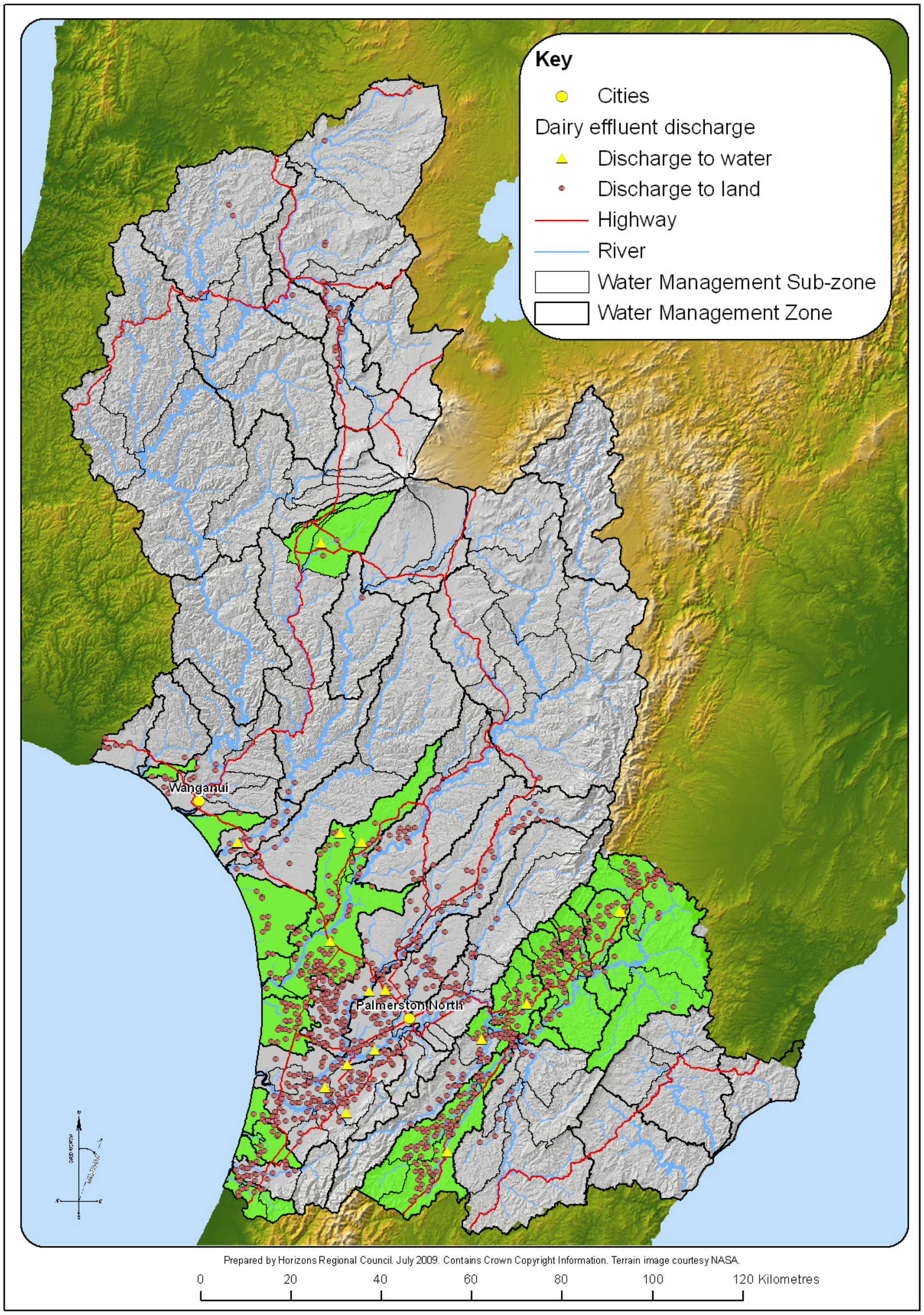
354. There are no numerical loss limits for phosphorus defined in the POP; however, phosphorus, faecal contamination and sediment are key considerations addressed in the FARM strategy. In conjunction with the FARM strategy, the sustainable land use initiative (SLUI) has a key goal of reducing erosion, thereby reducing particulate phosphorous inputs to waterways and the bed-deposited sediments that have the potential to remineralise DRP into the water column during low flow events (Parfitt *et al.,* 2007).

9.1 Target catchment data sources

355. The following sections of this evidence are a summary of the state of water quality and aquatic biodiversity in each target catchment including an overview of the catchment, receiving environment characteristics, water-body values and sources of the information and/or reports available. These sections should be read in conjunction with the reports of Dr Jon Roygard, Dr Alec Mackay and Dr Brent Clothier.

356. All land use and Land Use Capability (LUC) data is sourced from Clark and Roygard (2008) and tables of land use by LUC class (percentage) can be found for each target catchment in Appendix 3 of this evidence. Target catchments are described in the order they appear in Table 13.1 of the POP. All data on the number of dairy discharge consents in each target catchment is sourced from an analysis undertaken in January 2009 (Map 9) (also see the evidence of Dr Roygard). In some cases where farms span catchment boundaries there may be some inaccuracies between the recorded location of the discharge and the physical catchment for the effluent disposal. Therefore the number of discharge consents should be considered a best estimate of dairy farm numbers in the catchment.

357. Comparison of Year 20 output loss limits (calculated from the LUC classes in the tables below for each target catchment) with Standards load limits for nitrogen in water bodies are in most cases indicative only (with the exception of the Manawatū at Hopelands example). In some cases Standard load limits are unable to be calculated as the water bodies within the target catchments are not flowing rivers or streams, in these cases an alternate method is required.



Map 9. Consented dairy effluent discharges within target catchments for FARM strategy management as of January 2009.

9.2 Mangapapa Stream (Mana_9b)

358. The Mangapapa Stream is a small tributary flowing from the south-eastern Ruahine Ranges near the Manawatū Gorge. The catchment is approximately 26.6 km^2 and is located to the northwest of the township of Woodville. The Mangapapa flows into the Mangaatua Stream just before the Mangaatua Stream enters the Manawatū River.

359. The Mangapapa catchment supplies water to the township of Woodville. This water allocation places considerable pressure on the water resource and the ecology of the Mangapapa Stream as the water supply take is proportionately high at low stream flows. The use of an off-line storage dam reduces some of the pressure on the stream at very low flows by allowing the cessation of the water take.

360. The Mangapapa catchment was monitored as a Tier 2 Clean Streams Accord catchment and as a priority catchment for non-regulatory work by Horizons and the results of this monitoring, along with a substantial amount of other information on the catchment, is contained in the report of Clark *et al.* (2007). The following summary information is sourced largely from that report, except where otherwise stated.

361. The Mangapapa Water Management Sub-zone values are:
- Life-Supporting Capacity – Hill Country Mixed Geology
- Contact Recreation
- Mauri
- Stockwater
- Natural State
- Trout Spawning
- Capacity to Assimilate Pollution
- Water Supply, Irrigation and Industrial Abstraction.

362. SoE monitoring at the downstream point of the sub-zone (Mangapapa at Troup Rd) clearly reflected nutrient enrichment issues within the catchment area. Most of the sites monitored throughout the catchment (Map 10) breached the Proposed One Plan SIN standard on at least one of the two targeted sampling runs (Figure 20). The Proposed DRP standard (Figure 21) was not breached at as many sites as the SIN standard but still exceeded the standard at some locations. Nutrient enrichment is likely to cause periphyton proliferation. The standard for periphyton biomass was exceeded at two sites. Periphyton proliferation affects the Contact Recreation and Life-Supporting Capacity values of the Mangapapa Stream. Biotic indices were indicative of moderate

to severe nutrient pollution at a number of sites in the catchment, with reduced Life-Supporting Capacity and a breach of the MCI standard for the sub-zone.

363. *Escherichia coli* levels in the Mangapapa mainstem generally complied with the Proposed One Plan standard (Figure 22). However, the majority of the tributaries breached the standard on one occasion each. As there are no direct discharges to water in the catchment, elevated *E. coli* levels can be almost entirely attributed to direct faecal contamination from open grazing access and/or stock-crossings, negatively affecting Contact Recreation and Stockwater values in the stream.

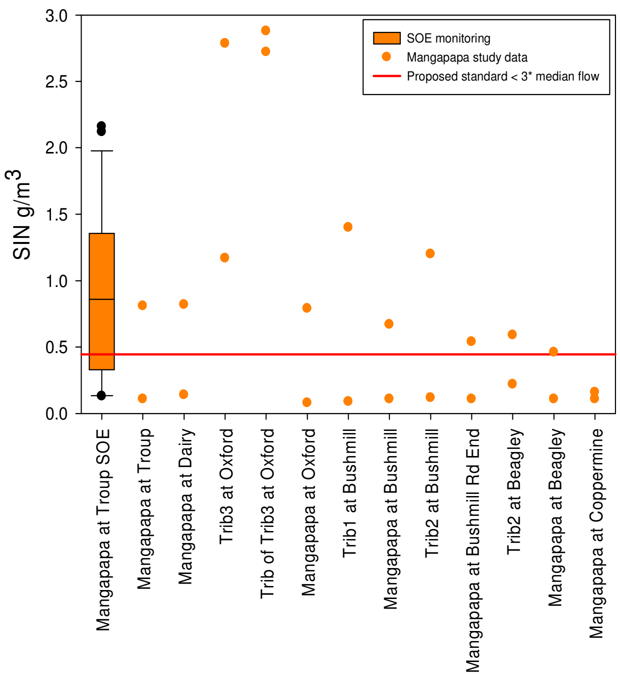


Figure 20. Soluble inorganic nitrogen (SIN) in the Mangapapa catchment measured on two sampling occasions in 2007 and on 27 sampling occasions at the SoE site Mangapapa at Troup Road between 2005 and 2007.

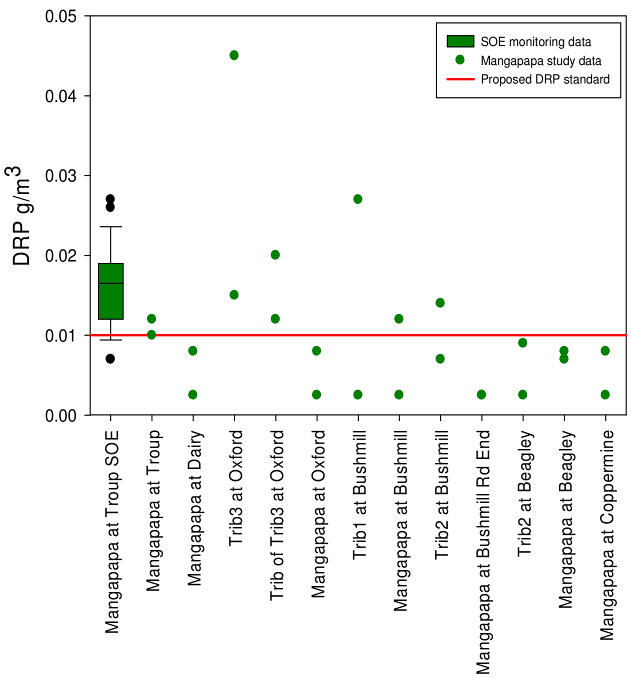


Figure 21. Dissolved reactive phosphorus (DRP) in the Mangapapa catchment on two sampling occasions in 2007 and on 27 sampling occasions at the SoE site Mangapapa at Troup Road between 2005 and 2007.

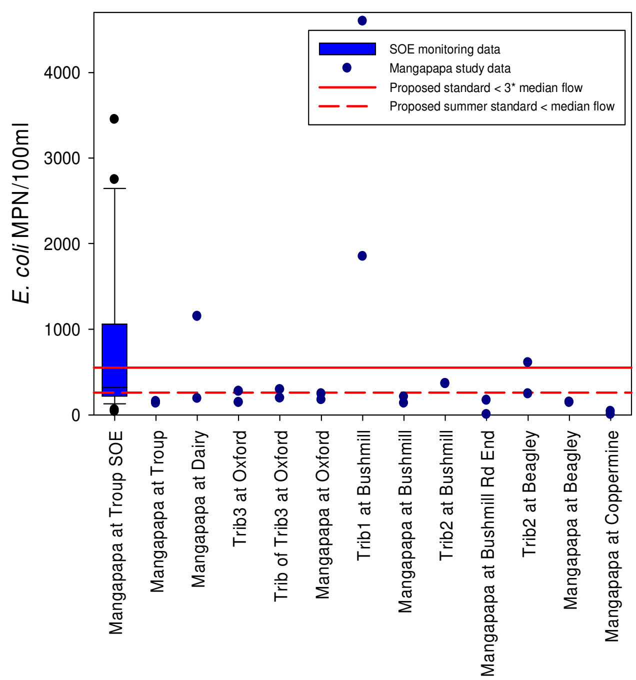
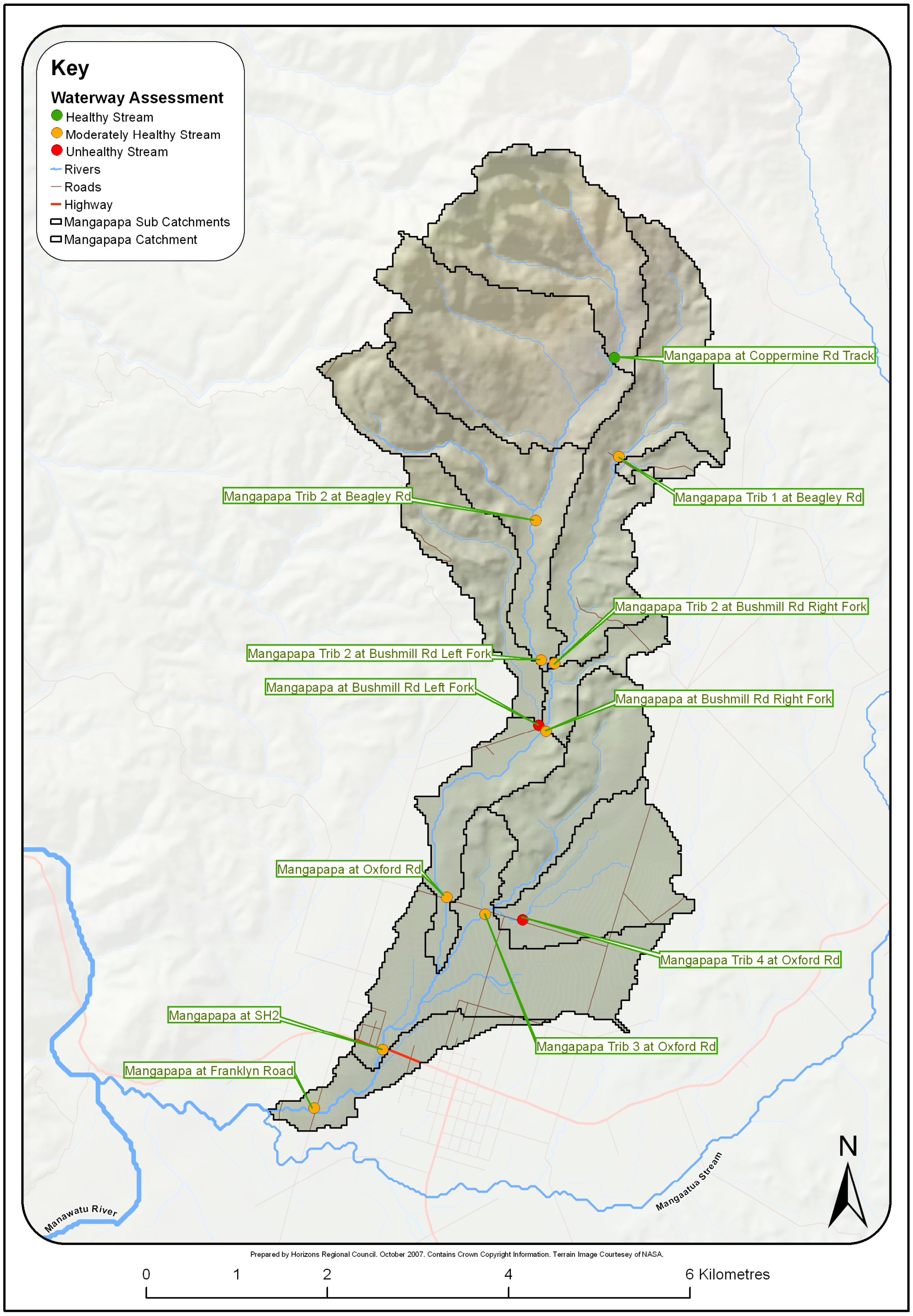


Figure 22. *Escherichia coli* in the Mangapapa catchment on two sampling occasions in 2007 and on 27 sampling occasions at the SoE site Mangapapa at Troup Road between 2005 and 2007.



Map 10. Survey sites in the Mangapapa catchment for Tier 2 Clean Streams Accord monitoring in 2007, reproduced from Clark *et al.* (2007).

364. Sheep and beef farming is the predominant land use in the Mangapapa catchment (approximately 50%; Table 17). An investigation of the sub-catchment scale land use found Sheep & Beef farming was dominant in eight of the 12 sub-catchments; Dairy was the major land use in only one sub-catchment, and the remaining three sub-catchments were dominated by a combination of Sheep & Beef and Native Cover. There are currently seven dairy discharges in the Mangapapa sub-zone and all are discharges to land. Discussions with landowners in the catchment have indicated that further conversions from Sheep & Beef to Dairy farming are being undertaken and more conversions are likely in the near future (Clark *et al.,* 2007).

365. Table 18 details the nitrogen loads per LUC class expected to enter the Mangapapa Stream as a result of the Rule 13-1 nitrogen output loss limits, assuming full intensification of all hectares within the catchment to the capability of the LUC class. The Standard load limit for the Mangapapa Stream is estimated to be 9.63 tonnes SIN/year (Table 18). Assuming full intensification, the total Year 20 annual loads are estimated to be 16.44 tonnes SIN/year, 171% of the Standard load limit for the sub-zone.

Table 17. Proportional Land use and Land Use Capability (LUC) information for the Mangapapa Stream catchment.

Land use type	Mangapapa	LUC class	Mangapapa
Built-up/Parks	1%	1	-
Cropping	-	2	13%
Dairy	18%	3	18%
Exotic Cover	1%	4	6%
Horticulture	2%	5	-
Native Cover	26%	6	46%
Other	1%	7	5%
Sheep & Beef	50%	8	11%
Water Body	-	Blank	1%

Table 18. Proposed nitrogen output limits resulting from the implementation of Rule 13-1 of the Proposed One Plan for the Mangapapa Water Management Sub-zone. *Note: Nitrogen attenuation of 50% between the land and river was assumed according to Clothier et al. (2007) and Mackay et al. (2008).*

Mangapapa		LUC I	LUC II	LUC III	LUC IV	LUC V	LUC VI	LUC VII	LUC VIII	Blank	Total
Output loss limit	**Year 1** (when rule comes into force) (kg of N/ ha/year)	32	29	22	16	13	10	6	2		
	Year 5 (kg N/ha/year)	27	25	21	16	13	10	6	2		
	Year 10 (kg N/ha/year)	26	22	19	14	13	10	6	2		
	Year 20 (kg N/ha/year)	25	21	18	13	12	10	6	2		
Area of LUC in Mangapapa (ha)		0	356	505	153	0	1287	146	291	33	2774
Measured load (in-river)	**Year 1** (Tonnes/year)	-	5.16	5.56	1.22	-	6.44	0.44	0.29		19.11
	Year 5 (Tonnes/year)	-	4.45	5.30	1.22	-	6.44	0.44	0.29		18.14
	Year 10 (Tonnes/year)	-	3.92	4.80	1.07	-	6.44	0.44	0.29		16.95
	Year 20 (Tonnes/year)	-	3.74	4.55	0.99	-	6.44	0.44	0.29		16.44
Standard load limit (Tonnes/year)											**9.63**[20]

Key points: Mangapapa target catchment

i. The Mangapapa is a small tributary catchment of the Mangaatua and Manawatū Rivers, covering 27 km^2.

ii. Soluble inorganic nitrogen, DRP and *E. coli* regularly exceed POP standards and degrade water quality in the Mangapapa, also contributing loads to the Manawatū above the Gorge.

iii. Periphyton biomass can be high and the aquatic macroinvertebrate health is low in some areas of the catchment.

iv. The predominant land uses are Sheep & Beef (50%), Native Cover (Ruahine Forest Park, 26%) and Dairy (16%). There are 7 dairy effluent consents.

v. Contact Recreation, Stockwater, Life-Supporting Capacity and Trout Spawning values are potentially compromised by water quality.

vi. The Year 20 output loss limits predicted from the application of Table 13.2 of the POP will be approximately 71% greater than the Standard load limit.

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[20] This annual load is based on a mean flow of 688 litres per second in the Mangapapa at Troup Rd, estimated from three years of continuous flow monitoring data. Given the limited dataset this load limit should be used with caution.

9.3 Mōwhānau Stream (West_3)

366. The Mōwhānau Stream is a small, slow-flowing coastal stream just north of the Whanganui River (Map 12). The catchment area is only 29 km^2 and the land cover is largely modified for pastoral agriculture throughout the catchment. Catchments such as the Mōwhānau Stream have been identified in the Proposed One Plan as requiring application of the FARM strategy approach largely due to microbial contamination of the stream and the local beach. Most of the Mōwhānau Stream catchment is in Sheep & Beef farming (73%), with a much smaller proportion of Dairy land use (< 20%) (Table 19).

367. In response to identifying the initial water quality problems in the Mōwhānau Stream an intensive monitoring survey was undertaken in 2008 (unpublished data; Map 11). The aims of that investigation were:

- to determine the degree of nutrient and faecal contamination of the stream spatially and at different stream flows; and
- to identify the sources of contaminants on a sub-catchment scale in relation to land use activities.

368. Water-body values of the Mōwhānau Water Management Zone include:

- Life-Supporting Capacity – lowland mixed (LM) geology
- Contact Recreation
- Amenity (Mōwhānau and Kai Iwi beach)
- Mauri
- Stockwater
- Site of Significance - Aquatic for redfin bully
- Inanga Spawning
- Whitebait Migration
- Capacity to Assimilate Pollution
- Shellfish Gathering
- Water Supply, Irrigation and Industrial Abstraction.

369. The highly sedimented nature of the Mōwhānau Stream bed (due to the soft-sedimentary geology of the catchment) means that there is the potential for faecal indicator bacteria (such as *E. coli*) to be attenuated within the stream bed sediments and remobilised during storm events, adding to the direct and indirect faecal inputs from the landscape. McArthur (unpublished data) found that *E. coli* concentrations at different sites in the catchment were not highly correlated with stream flow. Several sites with

elevated *E. coli* (Figure 23) during base flows were more likely to be contaminated by direct stock access or direct inputs from human sources such as septic tanks than by run-off from the landscape and would benefit from stock fencing as discussed in the evidence of Dr Davies-Colley. Significant concentrations of *E. coli* negatively impact on the Contact Recreation, Stockwater and Shellfish Gathering values of the Mōwhānau Stream, estuary and Kai Iwi Beach.

370. The concentration of DRP was consistently high at all sites and in almost all samples collected in the 2008 investigation (Figure 24). The uniformity in the results suggests that the source of phosphorus may be geological in origin. The substrate of the stream is covered with fine sediment sourced from the soft sedimentary lithology in the catchment. Other soft sedimentary catchments in the Region (and in other parts of the country) have high baseline DRP concentrations, often upstream of any apparent land use influence.

371. Because the Mōwhānau Stream catchment has little woody vegetative cover, particularly in the upper catchment, there is no riparian or headwater buffer to stop erosional and run-off processes from bringing high levels of DRP from geological and animal faecal sources into both the surface water and substrate sediments of the Mōwhānau Stream. Without vegetative buffers, these processes also bring high concentrations of faecal indicator bacteria to the stream.

372. The Mōwhānau water quality results showed extremely high SIN, particularly in the upper catchment (Figure 25). The soft-bottomed stream is unlikely to provide good habitat for the attachment of benthic periphyton. However, at a number of sites throughout the catchment the stream is choked by submerged macrophytes (dominated by exotic pest plant species; McArthur, Unpublished data). Any nutrients not utilised by submerged plants are likely to be exported from the stream catchment into the coastal marine environment. Concentrations of Total N and P were elevated above POP standards in seawater at Kai Iwi Beach, below the Mōwhānau and Kai Iwi Stream outflows (Figure 14 and Figure 15). Such coastal enrichment, in combination with high concentrations of faecal contaminants, has the potential to adversely affect Life-Supporting Capacity, Amenity, Contact Recreation and Shellfish Gathering (Figure 18) values in the CMA as well as in the stream.

373. Land use information for the Mōwhānau Stream catchment suggests that approximately 21% of the catchment is in intensive land use (eg. Dairy and Horticulture) (Table 19, Map 13, Map 14). However, only one dairy discharge consent is held for the Mōwhānau

catchment and anecdotal ground-truthing of the land use by Horizons staff suggests a number of the dairy farms are no longer operating in the catchment, though intensive beef farming (bull beef) and yearling heifer raising have replaced the Dairy farms at some locations.

374. The total SIN load after Year 20 of the FARM strategy implementation is estimated to be 23.85 tonnes SIN/year, based on intensification of all available land and LUC classes. This load is 2111% of the Standard load limit of 1.13 tonnes SIN/year. However, the Standard load limit is estimated from a very low mean flow of 81 litres/second from extremely limited flow information and the full utilisation of LUC classes to the maximum productive capacity would require a radical change in land use throughout the catchment, which at this stage seems unlikely.

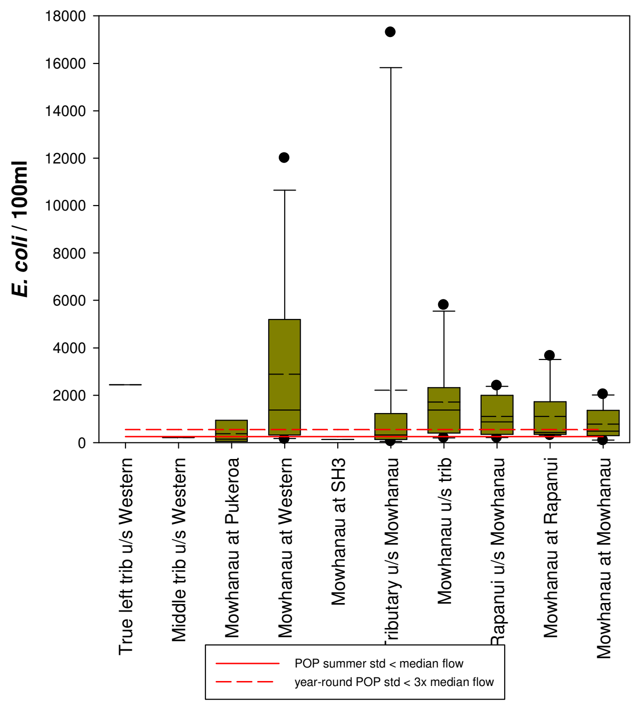


Figure 23. *Escherichia coli* per 100 ml from ten sites in the Mōwhānau Stream catchment sampled between January and November 2008.

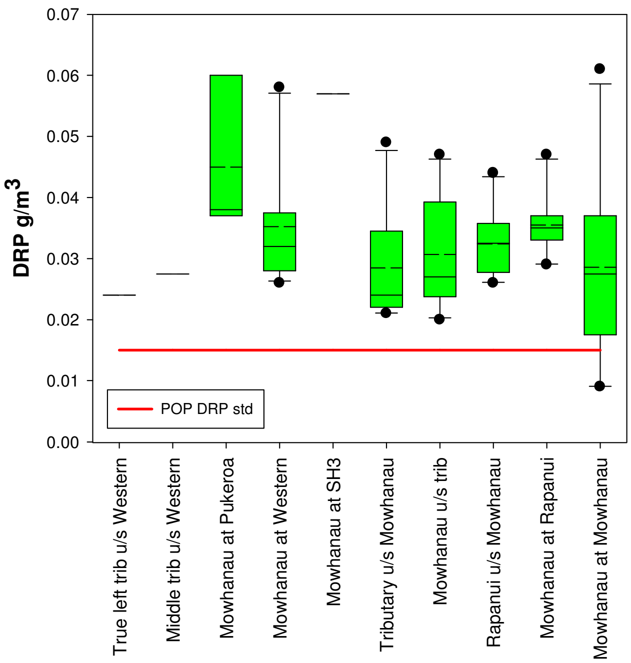


Figure 24. Dissolved reactive phosphorus (DRP) concentration from ten sites in the Mōwhānau Stream catchment measured between January and November 2008.

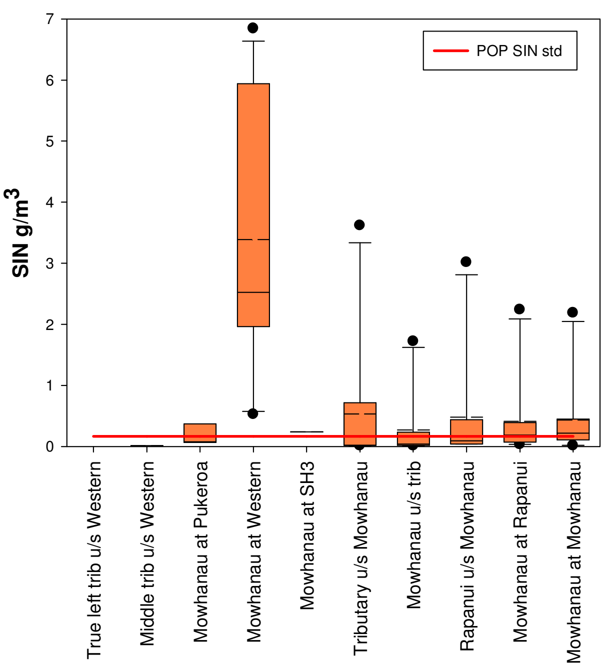
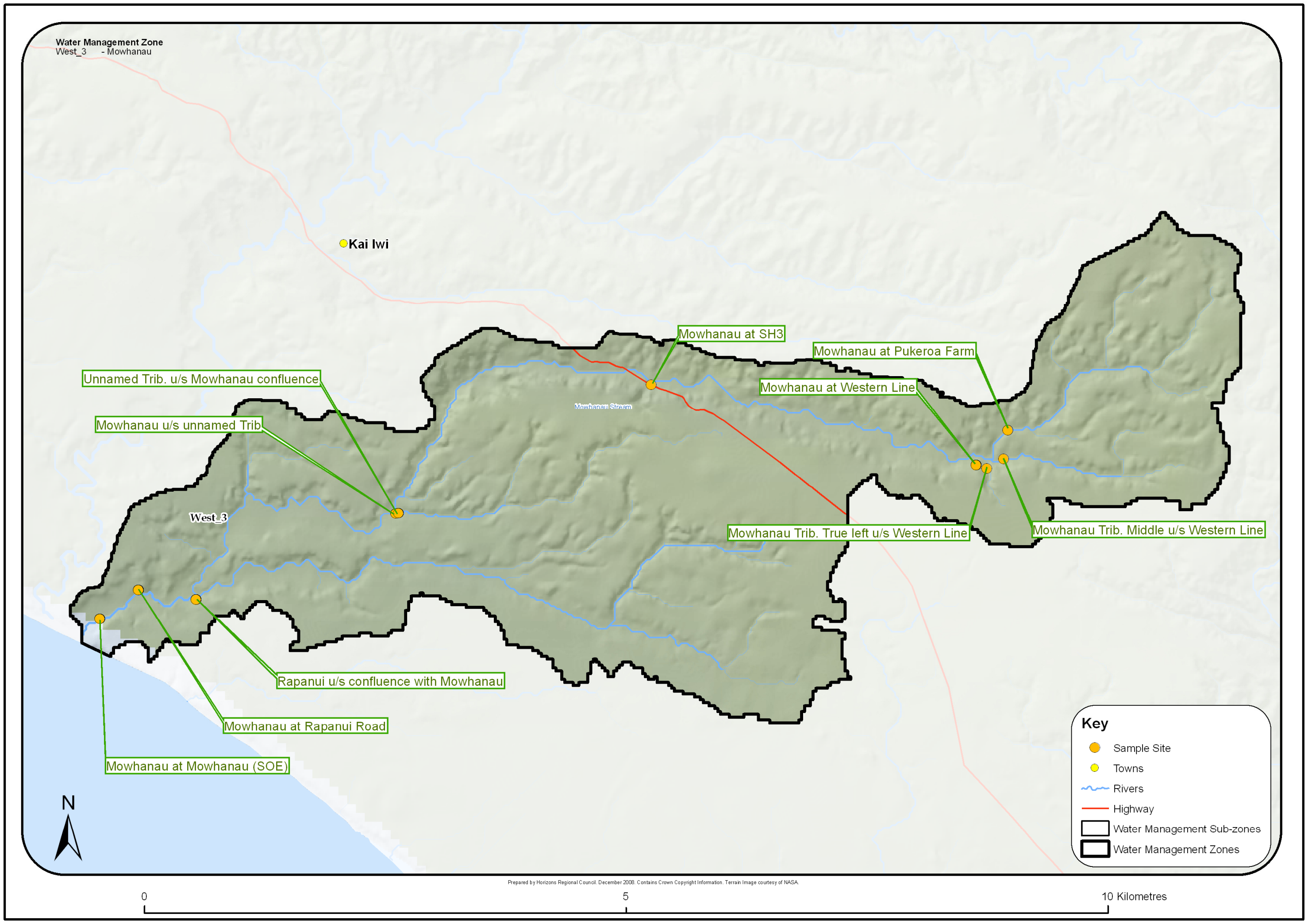
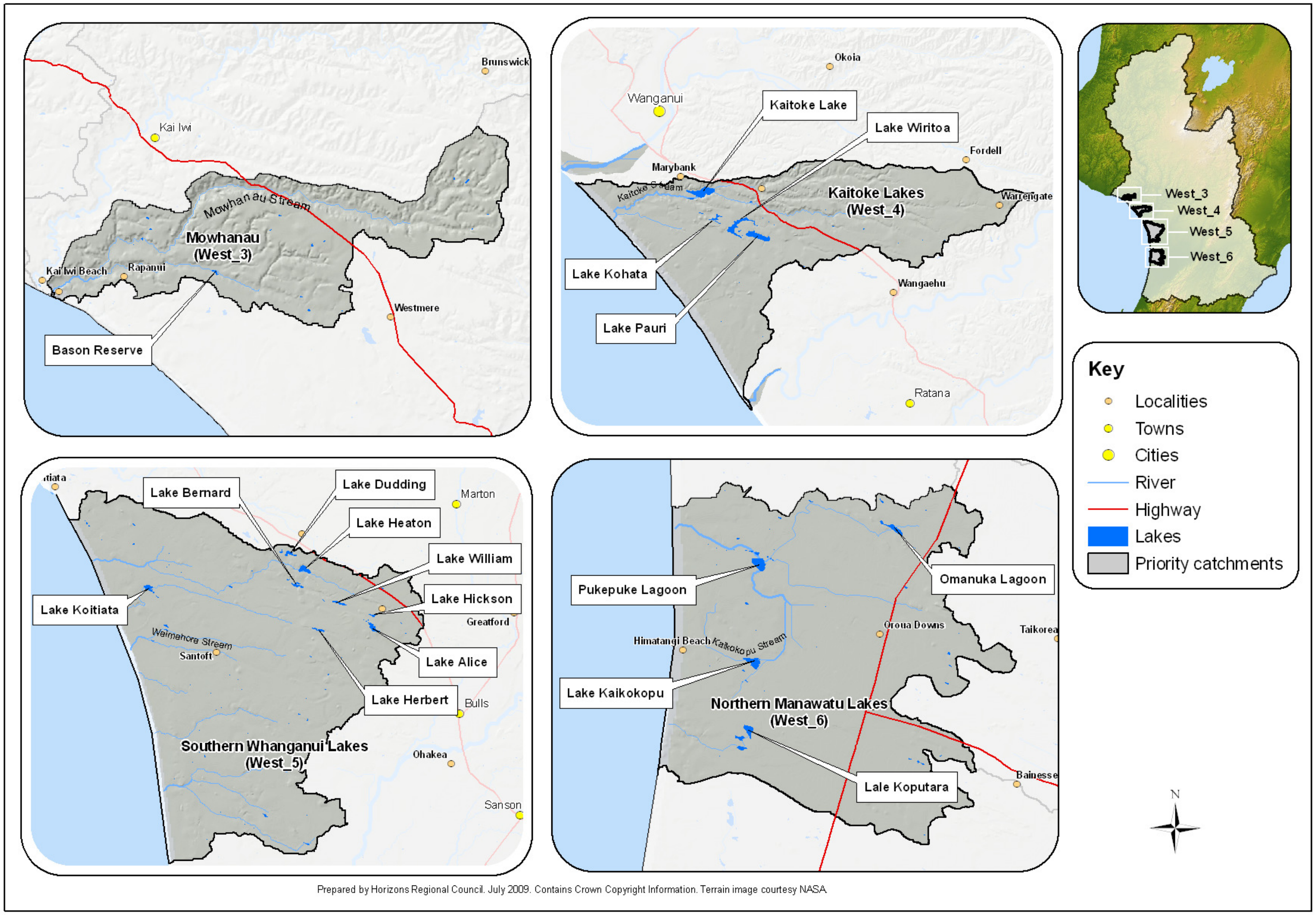


Figure 25. Soluble inorganic nitrogen (SIN) concentration from ten sites in the Mōwhānau Stream catchment measured between January and November 2008.



Map 11. Monitoring sites in the Mōwhānau Stream catchment for the water quality investigation undertaken in 2008 (McArthur, unpublished data).



Map 12. Target catchments in Mōwhānau and other coastal Water Management Zones.

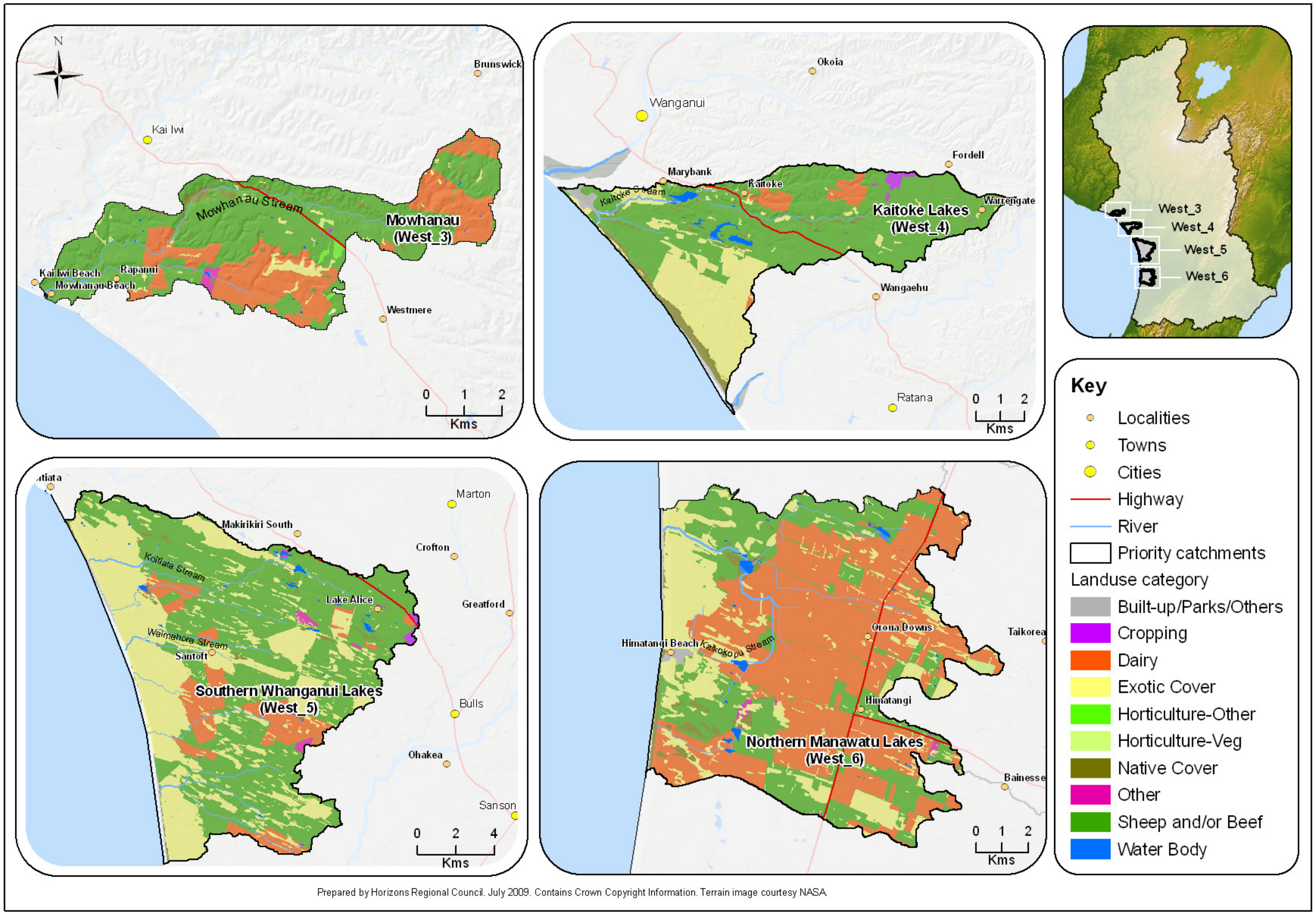
Table 19. Proportional land use and Land Use Capability (LUC) information for the Mōwhānau Stream catchment.

Land use type	Mōwhānau	LUC class	Mōwhānau
Built-up/Parks	-	1	30%
Cropping	-	2	10.5%
Dairy	20%	3	4.5%
Exotic Cover	3%	4	4%
Horticulture	1%	5	-
Native Cover	2.5%	6	51%
Other	1%	7	-
Sheep & Beef	73%	8	-
Water Body	-	Blank	-

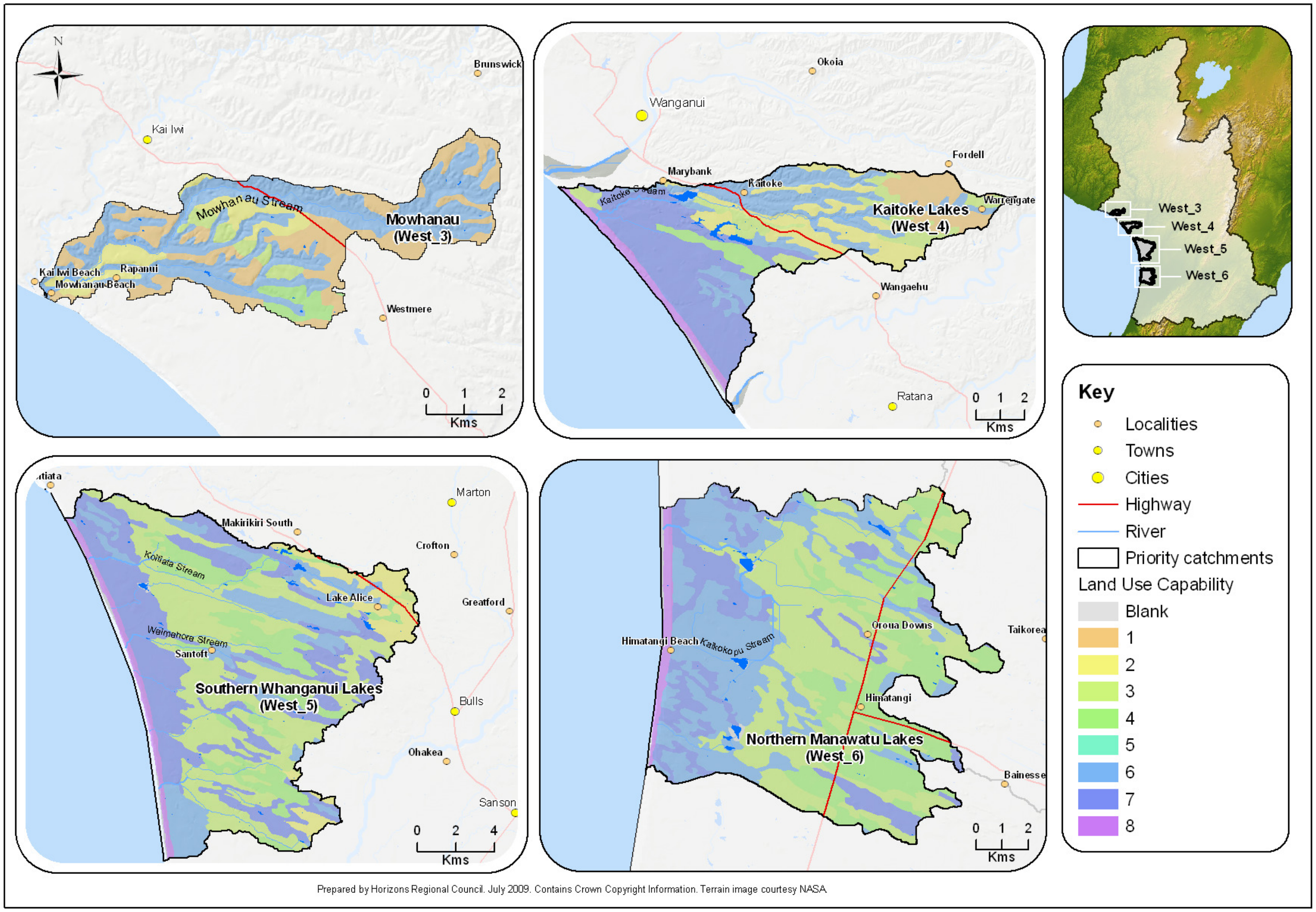
Table 20. Proposed nitrogen output limits resulting from the implementation of Rule 13-1 of the Proposed One Plan for the Mōwhānau Water Management Zone. *Note: Nitrogen attenuation of 50% between the land and river was assumed according to Clothier et al. (2007) and Mackay et al. (2008).*

Mōwhānau		LUC I	LUC II	LUC III	LUC IV	LUC V	LUC VI	LUC VII	LUC VIII	Total
Output loss limit	**Year 1** (when rule comes into force) (kg of N/ ha/year)	32	29	22	16	13	10	6	2	
	Year 5 (kg N/ha/year)	27	25	21	16	13	10	6	2	
	Year 10 (kg N/ha/year)	26	22	19	14	13	10	6	2	
	Year 20 (kg N/ha/year)	25	21	18	13	12	10	6	2	
Area of LUC in Mōwhānau (ha)		894	308	132	112	0	1504	0	0	2949
Measured load (in-river)	**Year 1** (Tonnes/year)	14.30	4.47	1.45	0.90	0.00	7.52	0.00	0.00	28.64
	Year 5 (Tonnes/year)	12.07	3.85	1.39	0.90	0.00	7.52	0.00	0.00	25.72
	Year 10 (Tonnes/year)	11.62	3.39	1.25	0.78	0.00	7.52	0.00	0.00	24.57
	Year 20 (Tonnes/year)	11.18	3.23	1.19	0.73	0.00	7.52	0.00	0.00	23.85
Standard load limit (Tonnes/year)										**1.12**[21]

[21] This annual load is based on a mean flow of 80 litres per second from the Mōwhanau at Hislops site in the lower catchment near Rapanui Road, estimated from four years of historic continuous flow monitoring data. Given the limited dataset this load limit should be used with caution.



Map 13. Land use in the Mōwhānau, Kaitoke Lakes, Southern Whanganui Lakes and Northern Manawatū Lakes Water Management Zones.



Map 14. Land Use Capability (LUC) in the Mōwhānau, Kaitoke Lakes, Southern Whanganui Lakes and Northern Manawatū Lakes Water Management Zones.

Key points: Mōwhānau target catchment

i. The Mōwhānau is a small (29 km^2), slow-flowing coastal stream north of the Whanganui River.

ii. Soluble inorganic nitrogen, DRP and *E. coli* regularly exceed POP standards, degrading water quality in the stream and contributing to loads in the estuary and Coastal Marine Area.

iii. The stream is affected by prolific aquatic weed growth and is heavily sedimented.

iv. The predominant land use is Sheep & Beef (73%) and there is little Native Cover in the catchment.

v. Dairy is estimated to be less than 20% of the catchment land use and there is only one dairy effluent discharge consent.

vi. Contact Recreation, Stockwater, Amenity, Life-Supporting Capacity, Shellfish Gathering and potentially the Site of Significance - Aquatic values are compromised by poor water quality.

vii. The year 20 output loss limits predicted from the application of Table 13.2 of the POP will be approximately 2000% greater than the Standard load limit.

9.4 Mangatainoka (Mana_8a, Mana_8b, Mana_8c, Mana_8d)

375. The Mangatainoka is a major tributary of the Manawatū River that drains the north-eastern Tararua Ranges with a catchment area of 492 km^2. The Mangatainoka enters the Tiraumea River a short distance from the confluence of the Tiraumea and Manawatū Rivers at Haukopua Reserve (Ngawapurua Road Bridge, State Highway 2). Most of the information comprising this section is taken from Roygard and McArthur (2008) with some additional information from a draft report on the low flow investigation of the Mangatainoka by Clark *et al.* (unpublished data).

376. The Mangatainoka is covered by a Local Water Conservation Notice for the quality of the trout fishery and spawning in the mainstem and tributaries. There are a range of water takes which include the town supplies for Eketahuna and Pahiatua, the Pleckville rural water supply, industrial abstractions for Fonterra Pahiatua and DB Breweries and two agricultural irrigation consents in the lower catchment.

377. Water-body values in the Mangatainoka Water Management Zone include:

- Natural State
- Life-Supporting Capacity – Upland Hard Sedimentary (UHS) and Hill Mixed (HM) geology

- Site of Significance – Aquatic for kōaro, shortjaw kōkopu and dwarf *Galaxias*
- Site of Significance – Riparian for dotterel
- Regionally Significant Trout Fishery
- Trout Spawning
- Contact Recreation
- Mauri
- Aesthetic
- Stockwater
- Capacity to Assimilate Pollution
- Water Supply, Industrial Abstraction and Irrigation.

378. Particularly in the lower catchment, water quality in the Mangatainoka exceeds nutrient standards at low flows (Map 15 and Map 16), as well as under other flow conditions (see sections on water quality state above). There is a marked reduction in aquatic ecosystem health as measured by MCI (Figure 26) between the upper catchment site Mangatainoka at Putara and the lower catchment site Mangatainoka at SH2. This shows an adverse effect is being had from upstream to downstream on values such as Life-Supporting Capacity and Trout Fishery and that the recommended MCI standard of 120 is not being met in the downstream catchment.

379. Although modelling predictions (see the evidence of Dr Biggs) and limited monitoring data on periphyton biomass suggest that the chlorophyll *a* standard is not often breached in the Mangatainoka at SH2, cover by potentially toxic benthic cyanobacteria can be a significant issue in this catchment. Over both the 2007/2008 (Nicholson, 2008) and 2008/2009 summers the Mangatainoka Reserve at State Highway 2 (among other sites in the catchment) was closed to Amenity and Contact Recreation use due to extensive cover by *Phormidium* sp. Cyanobacteria (Photo 1 and Photo 2). Blooms of this type can have significant effects on values such as Contact Recreation, Trout Fishery, Amenity, Aesthetics, Water Supply and Life-Supporting Capacity.

380. With regards to faecal contamination in the Mangatainoka, *E. coli* concentrations are usually within the standard for flows less than three times the median (Figure 30). However there is a measurable increase in *E. coli* concentration from upstream to downstream sites.

381. There are four significant point source discharges to water in the Mangatainoka catchment, of which two are municipal wastewater discharges (Eketahuna STP and Pahiatua STP) and two are industrial wastewater discharges (Fonterra Pahiatua

condensate and DB Breweries). Information on the contribution of each of these discharges can be found in Roygard and McArthur (2008) and with regard to low flows in McArthur and Clark (2007).

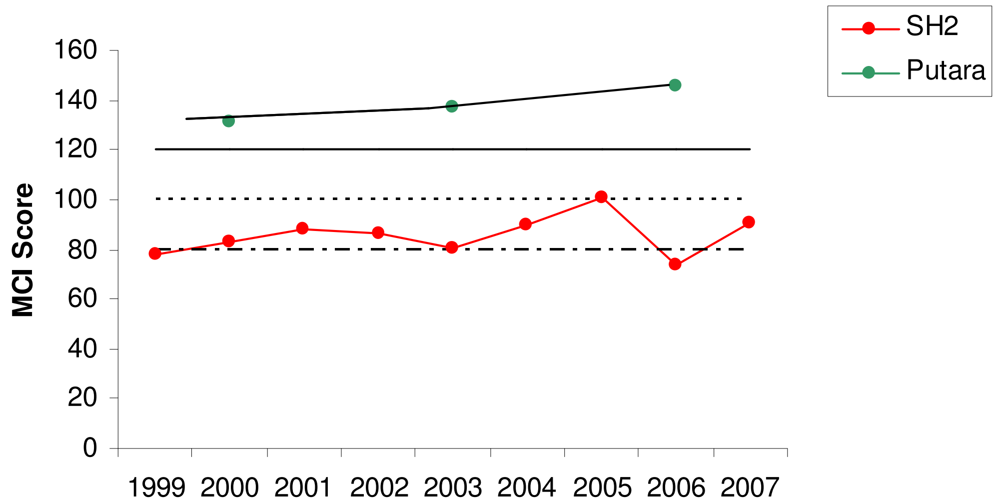


Figure 26. Changes in Macroinvertebrate Community Index (MCI) between 1999 and 2007 at two sites in the Mangatainoka River catchment. The upstream site is Mangatainoka at Putara and the downstream site is Mangatainoka at SH2. The solid line represents the lower limit for 'excellent' water quality, the dashed line the lower limit for 'good' water quality and the bottom broken line the lower limit for 'fair' water quality, below which water is classified as 'poor' (Stark and Maxted, 2007).

Photo 1. Photo of cyanobacterial bloom in a riffle of the Mangatainoka River immediately upstream of the State Highway 2 Reserve and swimming hole (photo: Kate McArthur, May 2008).

Photo 2. Cyanobacterial bloom in the Makakahi River at Konini Bridge looking upstream (photo: Kate McArthur, May 2008).

382. Roygard and McArthur (2008) concluded that loads of N (Figure 27) and P (Figure 28) in the Mangatainoka River (measured at SH2) exceeded the Standard load limits, depending on the flow decile. More than 99% of the annual average SIN load and approximately 84% of the DRP load was from non-point sources in the Mangatainoka (Figure 29).

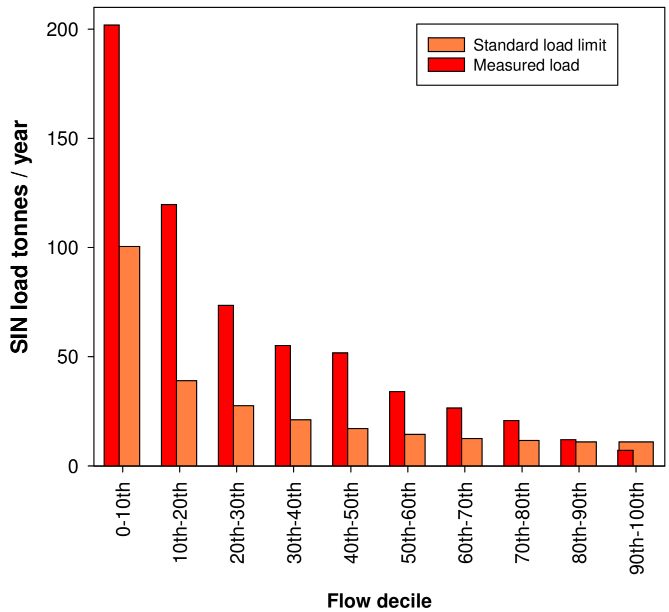


Figure 27. Comparison of Measured soluble inorganic nitrogen (SIN) load (red bar) to Standard load limit (orange bar) in tonnes/year by flow decile category for the Mangatainoka River at SH2 between 1993 and 2005.

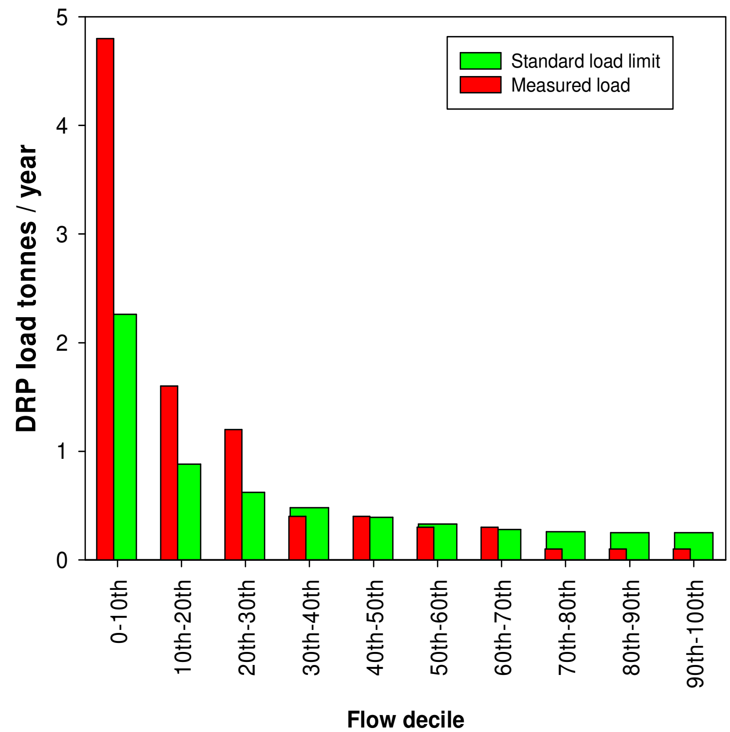


Figure 28. Comparison of Measured dissolved reactive phosphorus (dissolved reactive phosphorus) load (red bar) to Standard load limit (green bar) in tonnes/year by flow decile category for the Mangatainoka River at SH2 between 1993 and 2005.

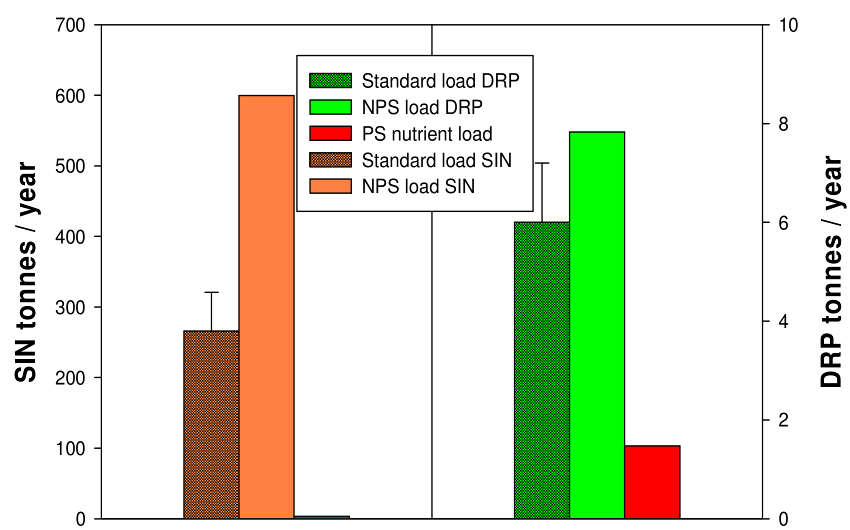
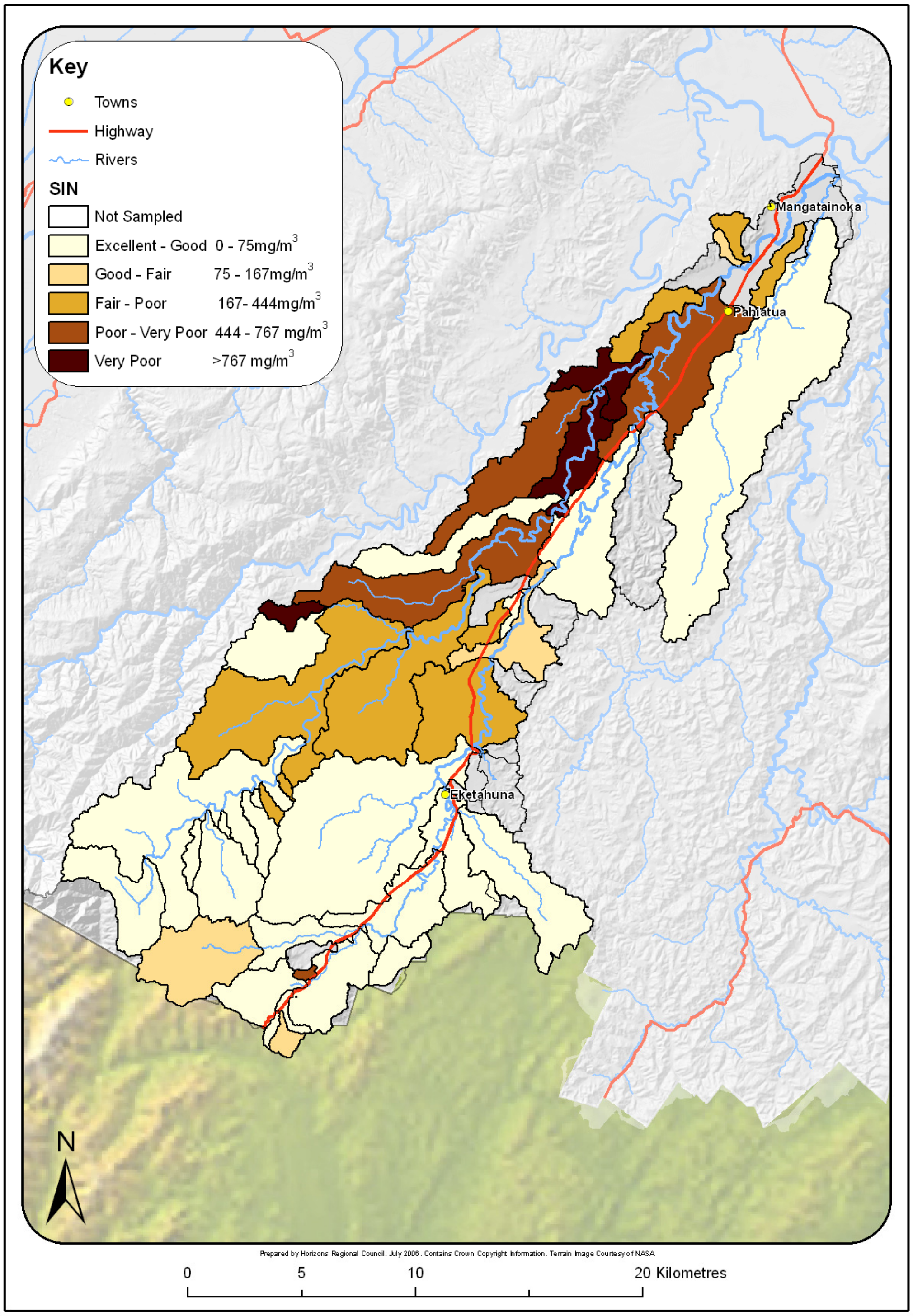
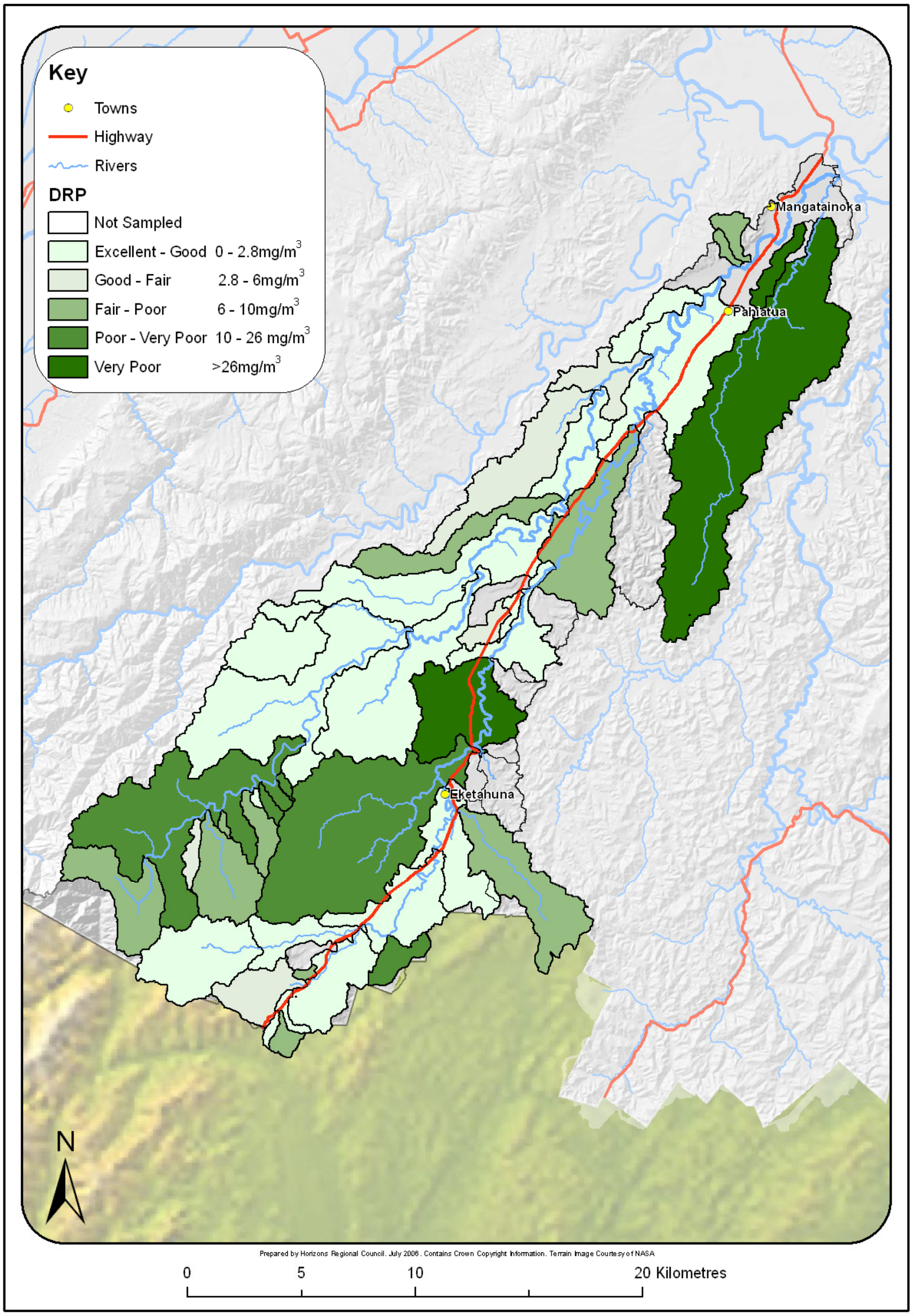


Figure 29. Annual soluble inorganic nitrogen (SIN) and dissolved reactive phosphorus (DRP) load (tonnes/year) attributable to point sources (PS, Pahiatua STP) and non-point sources (NPS) of nutrient in the Mangatainoka catchment upstream of the State Highway 2 monitoring site.



Map 15. Soluble inorganic nitrogen (SIN) concentrations in sub-catchments of the Mangatainoka Water Management Zone, sampled at low flows on 29th February 2008.



Map 16. Dissolved reactive phosphorus (DRP) concentrations in sub-catchments of the Mangatainoka Water Management Zone, sampled at low flows on 29th February 2008.

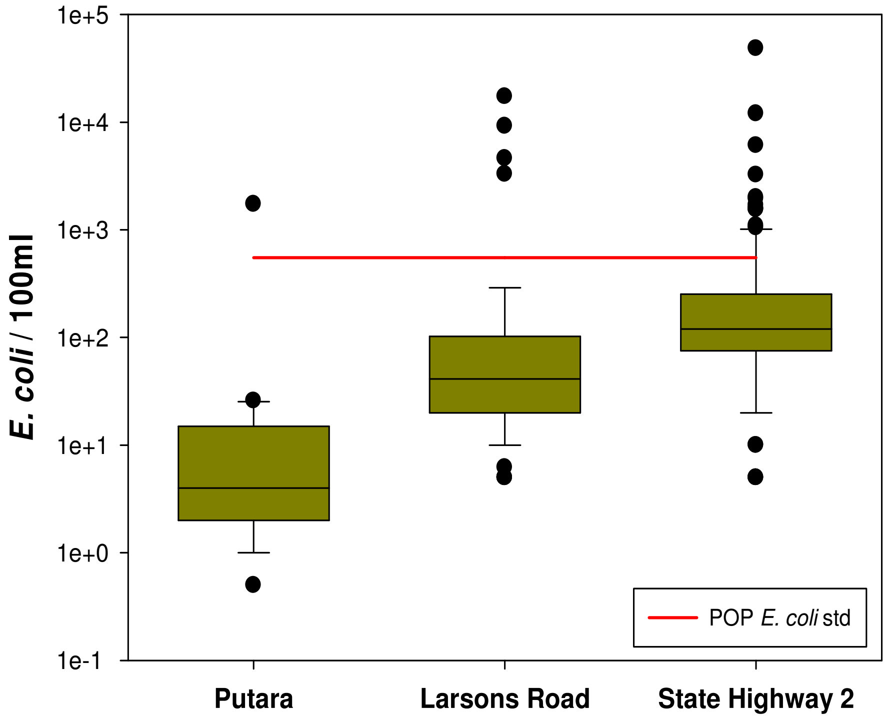


Figure 30. Log_{10} *Escherichia coli* concentrations from three sites in the Mangatainoka River from upstream (Putara) to downstream (SH 2). Red line equals year-round Proposed One Plan standard at flows less than three times the median.

383. There are 97 dairy discharge consents in the Water Management Sub-zones of the Mangatainoka catchment, 96 of which are discharges to land. Dairying comprises 28% of the catchment land use (Map 17 and Map 18), with Sheep & Beef making up the most dominant land use at 51% (Table 21). Table 22 shows that the nitrogen output loss limit after Year 20 of the FARM strategy is predicted to be 301 tonnes SIN/year. Successful implementation of the FARM strategy is predicted to result in an annual load that is 113% of the Standard load limit of 266 tonnes SIN/year.

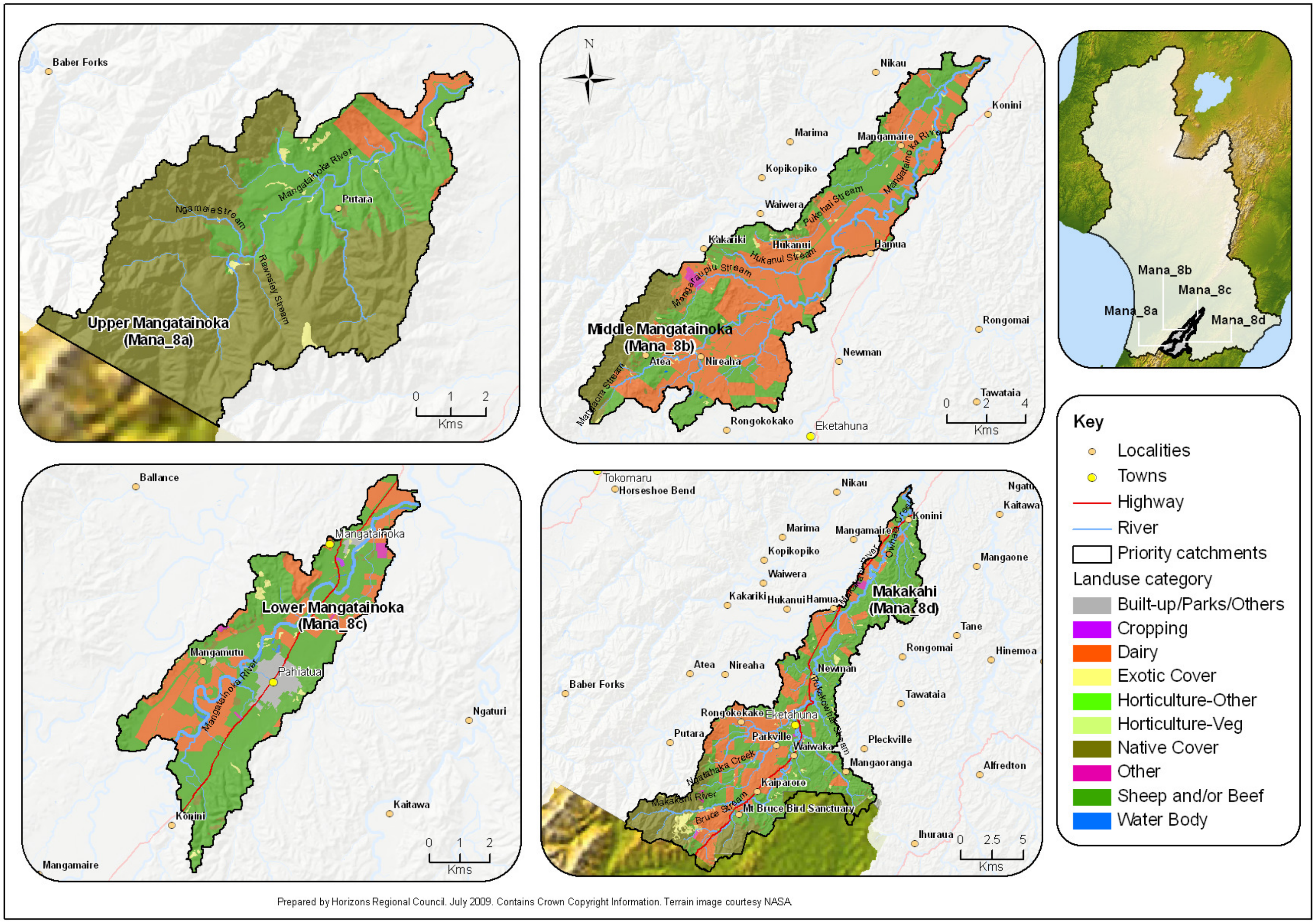
Table 21. Proportional land use and Land Use Capability (LUC) information for the Mangatainoka River catchment.

Land use type	Mangatainoka	LUC class	Mangatainoka
Built-up/Parks	1%	1	1%
Cropping	-	2	22%
Dairy	28%	3	13%
Exotic Cover	2%	4	3%
Horticulture	-	5	1%
Native Cover	18%	6	37%
Other	-	7	16%
Sheep & Beef	51%	8	8%
Water Body	-	Blank	1%

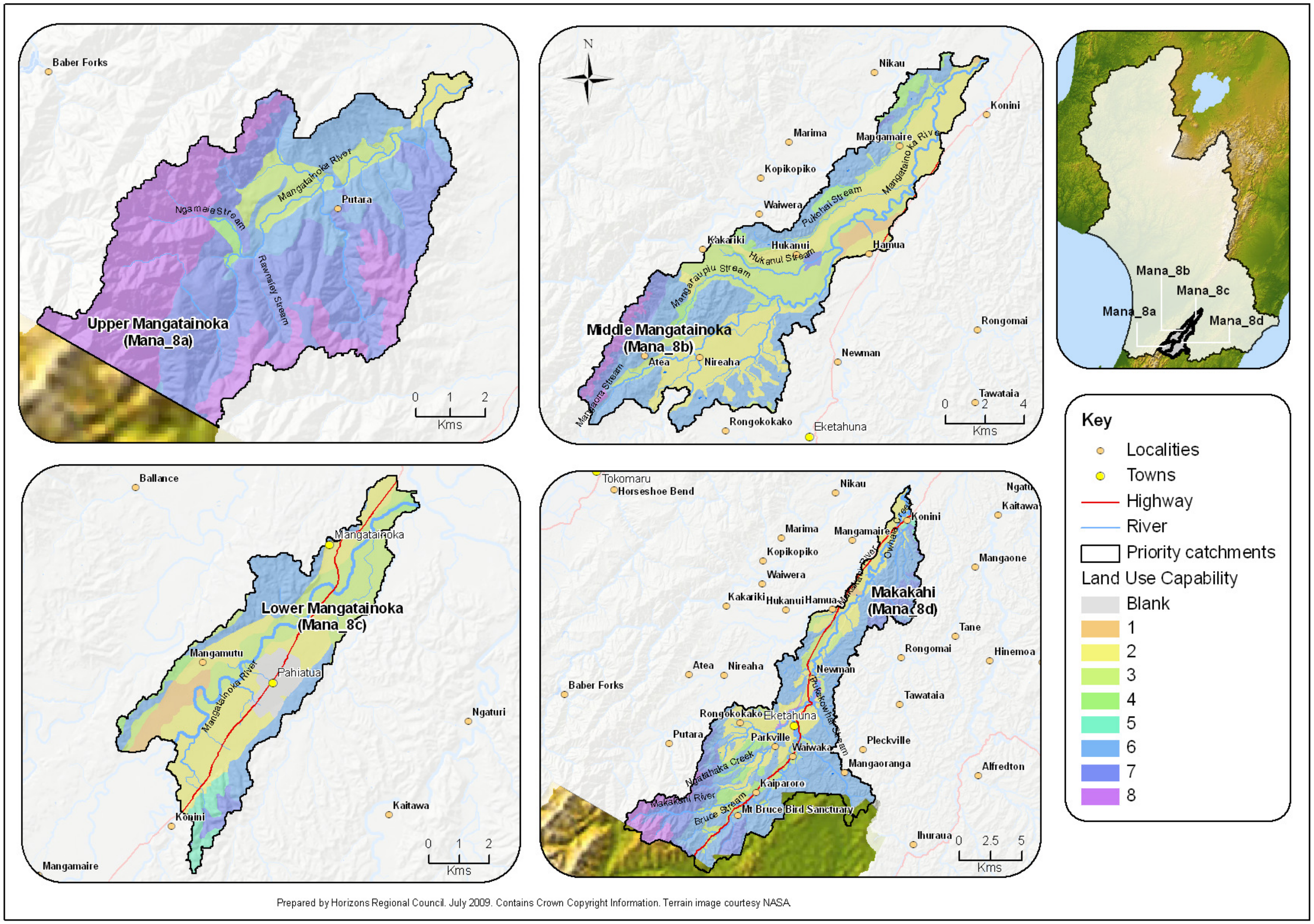
Table 22. Proposed nitrogen output limits and Measured loads resulting from the implementation of Rule 13-1 of the Proposed One Plan for the Water Management Sub-zones of the Mangatainoka River. *Note: Nitrogen attenuation of 50% between the land and river was assumed according to Clothier et al. (2007) and Mackay et al. (2008).*

Mangatainoka		LUC I	LUC II	LUC III	LUC IV	LUC V	LUC VI	LUC VII	LUC VIII	Total
Output loss limit	**Year 1** (when rule comes into force) (kg of N/ ha/year)	32	29	22	16	13	10	6	2	
	Year 5 (kg N/ha/year)	27	25	21	16	13	10	6	2	
	Year 10 (kg N/ha/year)	26	22	19	14	13	10	6	2	
	Year 20 (kg N/ha/year)	25	21	18	13	12	10	6	2	
Area of LUC in Mangatainoka (ha)		549	10394	6074	1498	409	18110	8057	3874	48965
Measured load (in-river)	**Year 1** (Tonnes/year)	8.8	150.7	66.8	12	2.7	90.6	24.2	3.9	360
	Year 5 (Tonnes/year)	7.4	129.9	63.8	12	2.7	90.6	24.2	3.9	334
	Year 10 (Tonnes/year)	7.1	114.3	57.7	10.5	2.7	90.6	24.2	3.9	311
	Year 20 (Tonnes/year)	6.9	109.1	54.7	9.7	2.5	90.6	24.2	3.9	301[22]
Standard load limit (Tonnes/year)										266
Measured load (Tonnes/year)										603
NPS load (Tonnes/year)										599.6

[22] Note: the nitrogen output limits are calculated from the whole catchment (including the Mangaramarama sub-zone which was formerly within the Mangatainoka Water Management Zone). Load limits, Measured loads and NPS load are calculated based on nutrients contributed from the catchment area upstream of the SH2 monitoring site only and do not include all of the hectares in the output loss limit calculation.



Map 17. Land use in the Water Management Sub-zones of the Mangatainoka River catchment.



Map 18. Land Use Capability in the Water Management Sub-zones of the Mangatainoka River catchment.

Key points: Mangatainoka target catchment

i. The Mangatainoka is a major tributary of the upper Manawatū River covering 492 km^2.

ii. Soluble inorganic nitrogen is extremely high (with > 99% from non-point sources), DRP is elevated at high flows and is largely non-point source derived (84%) and *E. coli* is generally within the standards but increases downstream.

iii. Periphyton occasionally exceeds the standards, aquatic macroinvertebrate health declines downstream and potentially toxic cyanobacterial blooms can be pervasive at a number of sites in the catchment when flows are low.

iv. Sheep & Beef is the predominant land use (51%), followed by Dairy (28%) and Native Cover (18%). There are 97 dairy discharge consents in the catchment.

v. Contact Recreation, Life-Supporting Capacity, Regionally Significant Trout Fishery, Water Supply, Stockwater, Amenity, Aesthetics and potentially Site of Significance – Aquatic values are compromised by poor water quality.

vi. The year 20 output loss limits predicted from the application of table 13.2 of the POP will be approximately 13% greater than the Standard load limit.

9.5 Upper Manawatū (Mana_1a, Mana_1b, Mana_1c, Mana_2a, Mana_2b, Mana_3, Mana_4, Mana_5a, Mana_5b, Mana_5c, Mana_5d, Mana_5e)

384. The Manawatū River drains an area of approximately 5895 km^2 from the east and west slopes of the Tararua and Ruahine Ranges and the western slopes of the Puketoi Ranges. Of this total land area, the upper Manawatū above the Hopelands SoE monitoring site drains approximately 1267 km^2, or 126,669 ha. The upper Manawatū encompasses five Water Management Zones, which are further split into 12 sub-zones (Map 22, Map 23 and Map 24). The upper Manawatu catchment is fully allocated with respect to water availability. Allocation has been addressed through a water resource assessment (Roygard *et al.,* 2006).

385. In this section the description of the upper Manawatū includes all of the catchment area upstream of the Manawatū at Hopelands monitoring site. Water quality issues in the upper Manawatū catchment have been described in the sections above and are well documented in a number of reports (Ballantine and Davies-Colley, 2009a and 2009b; Roygard and McArthur, 2008; McArthur and Clark, 2007; Ausseil and Clark, 2007c; Ledein *et al.,* 2007; Gibbard *et al.,* 2006; Roygard *et al.,* 2006; Scarsbrook, 2006; Horizons, 2005). This section provides a brief summary of water quality issues, land

use and LUC in the upper Manawatū and the changes to nitrogen loads that can be predicted from implementation of the FARM strategy scenarios.

386. The values which apply to the upper Manawatū Water Management Sub-zones (above Hopelands) are:

- Life-Supporting Capacity – Hill Mixed (HM), Hill Soft Sedimentary (HSS), Upland Hard Sedimentary (UHS) geologies
- Contact Recreation
- Mauri
- Amenity
- Trout Fishery – Regionally Significant
- Stockwater
- Natural State
- Site of Significance - Aquatic for kōaro and dwarf *Galaxias*
- Site of Significance – Riparian for dotterel
- Trout Spawning
- Capacity to Assimilate Pollution
- Water Supply, Industrial Abstraction and Irrigation.

387. Both nitrogen (Figure 31) and phosphorus (Figure 32) are problematic at a range of flows in the upper Manawatū catchment. At low flows, concentrations exceed the standards at a number of sub-catchment locations (Map 19 and Map 20). The loads of nitrogen and phosphorus are largely sourced from non-point inputs (Figure 33) and the key significant point source contributor in the catchment is Dannevirke STP. Information on the contribution of each of these sources can be found in Roygard and McArthur (2008) and with regard to low flows in McArthur and Clark (2007). In brief, non-point sources contribute nearly 98% of the SIN and 80% of the DRP at all flows.

388. *Escherichia coli* contamination during the Manawatū low flow investigation (Map 21) showed that several tributaries of the upper Manawatū were unsuitable for contact recreation at the time of the survey (Clark *et al.,* 2009). Elevated *E. coli* concentrations at low flows indicate these tributary streams were subject to direct faecal inputs from either stock crossings or stock access to the waterways, adversely affecting the Contact Recreation and Stockwater values in these tributaries.

389. Aquatic ecosystem health in the upper Manawatū catchment has not been measured over the same timescale at the Manawatū at Hopelands and Weber Road sites. However, the results that are available indicate a reduction in macroinvertebrate

community quality between the upstream Weber Rd site and the downstream Hopelands site (Figure 34) and show that neither of these sites are meeting the recommended MCI standard of 120 or greater. Native fish communities in the upper Manawatū are generally depauperate and most migratory species are absent from the communities surveyed (see Appendix 4 McArthur *et al.,* 2007b for summary of native fish surveys). However, the tributaries of the upper Manawatū still hold important populations of non-migratory dwarf Galaxias.

390. As noted above in the section on the state of periphyton communities, Death (2009) reported that the Manawatū at Hopelands site exceeded the aesthetic guideline of 120 mg/m^2 chlorophyll *a* 56% of the time. The recommendation from Dr Barry Biggs for the addition of a provision for percent cover by diatoms and cyanobacteria > 3 mm thick to the water quality standards is especially relevant to the upper Manawatū catchment (and others such as the Mangatainoka). During the 2008/2009 summer all public swimming spots upstream of Palmerston North were closed to contact recreation and Amenity use including swimming and dog walking due to extensive cover of the bed of the river by the smelly and potentially toxic cyanobacteria (*Phormidium sp.;* see the evidence of Barry Gilliland; Photo 3). The Manawatū at Hopelands was also affected during the 2007/2008 summer season (Nicholson, 2008). Blooms of this type can have significant effects on values such as Contact Recreation, Trout Fishery, Amenity, Water Supply, Life-Supporting Capacity and Stockwater.

391. The draft national guideline for managing cyanobacteria in recreational waters (MfE/MoH, 2009) advocates the assessment of percent cover by benthic cyanobacteria as the most appropriate method for determining risk to humans (and stock), rather than simply by toxin testing. The draft guideline suggests moving to an amber alert when there is 20-50% coverage of potentially toxic cyanobacterial species and a red alert at greater than 50% cover or at less than 50% where there is material detaching from mats. The recommendation to remove the cyanobacterial toxin standard from Schedule D of the POP reflects the shift in risk assessment of benthic cyanobacterial blooms from toxin testing to percent cover visual assessment. Draft national guidelines (MfE/MoH, 2009) are still in their infancy and percent cover standards developed through this process could provide useful standards for the management of benthic cyanobacteria in the future.

392. The effects of periphyton proliferation on Life-Supporting Capacity, Trout Fishery, Amenity and Contact Recreation values in the upper Manawatū cannot easily be captured simply by assessing periphyton biomass (chlorophyll *a*) as discussed above;

cover by filamentous algae and cyanobacterial mats must also be considered. The periphyton monitoring programme (Kilroy *et al.,* 2009) has been designed with these multiple considerations in mind.

Photo 3. Cyanobacterial bloom looking downstream from the Manawatū at Hopelands Bridge State of the Environment monitoring site (photo: Kate McArthur, January 2009).

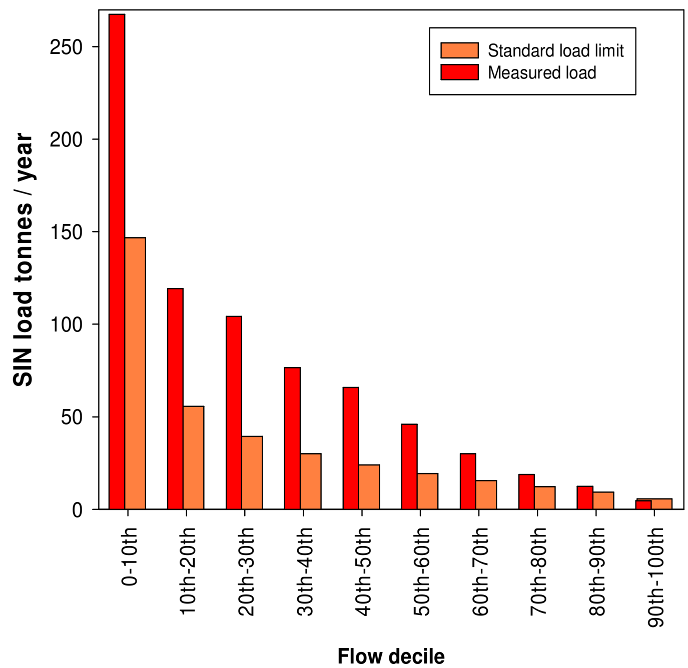


Figure 31. Comparison of Measured soluble inorganic nitrogen (SIN) load (red bar) to Standard load limit (orange bar) in tonnes/year by flow decile category for the upper Manawatū River at Hopelands between 1989 and 2005.

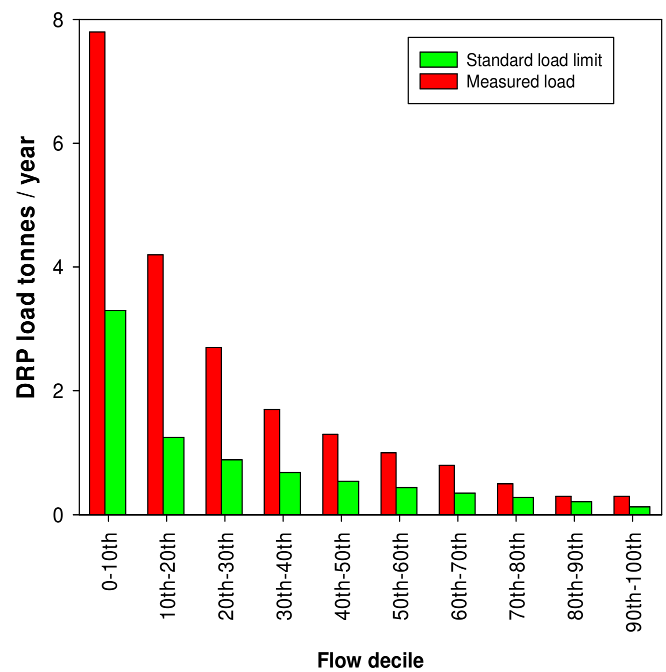


Figure 32. Comparison of Measured dissolved reactive phosphorus (DRP) load (red bar) to Standard load limit (green bar) in tonnes/year by flow decile category for the upper Manawatū River at Hopelands between 1989 and 2005.

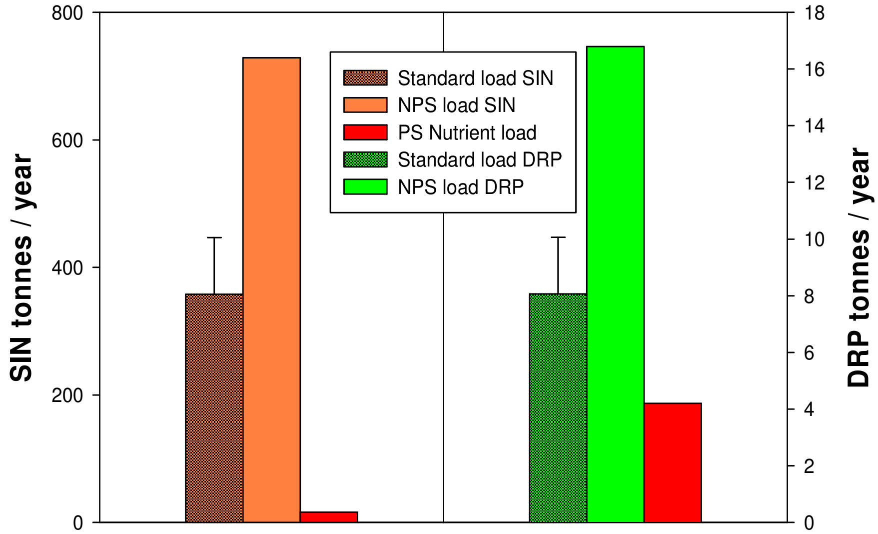
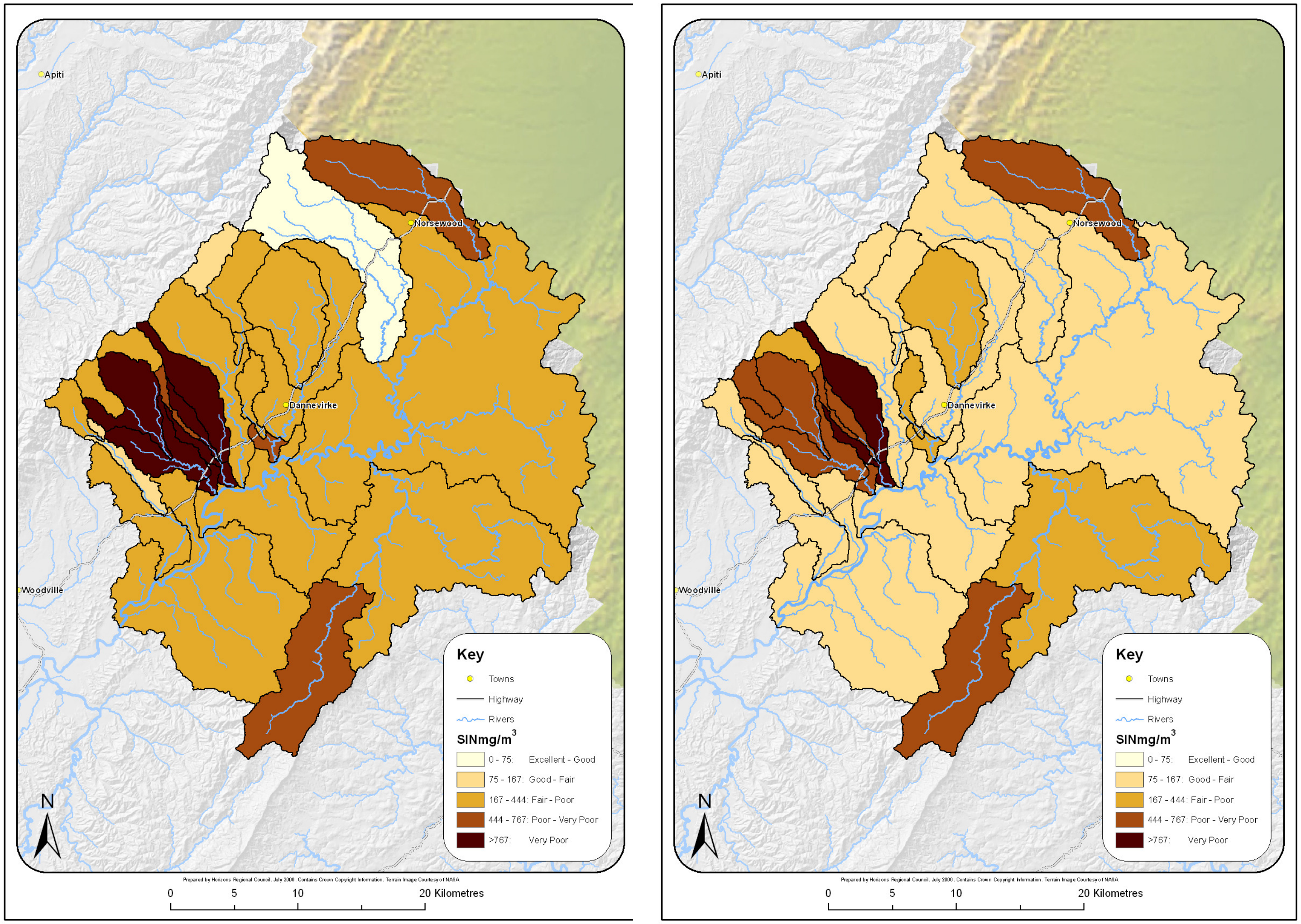
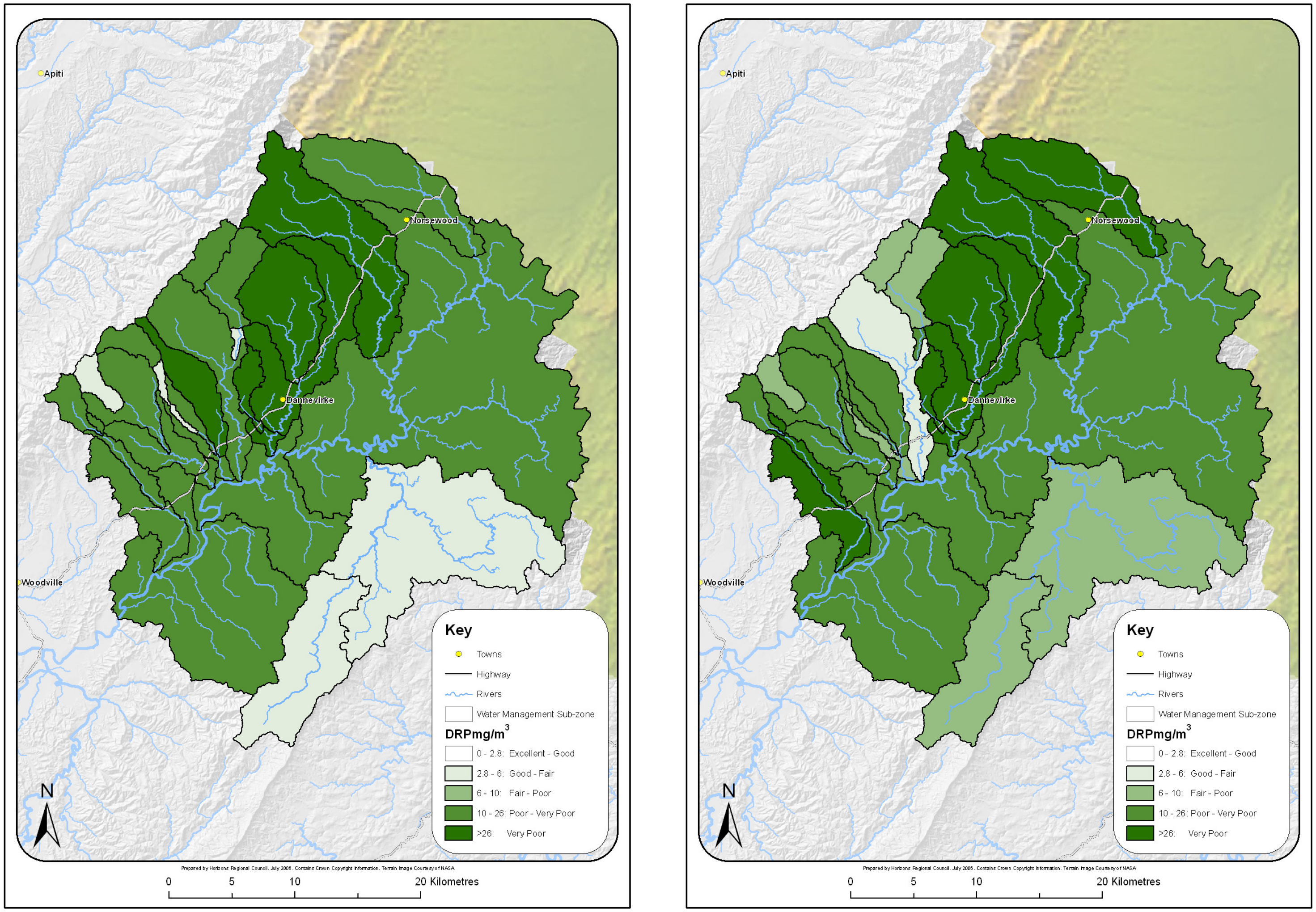


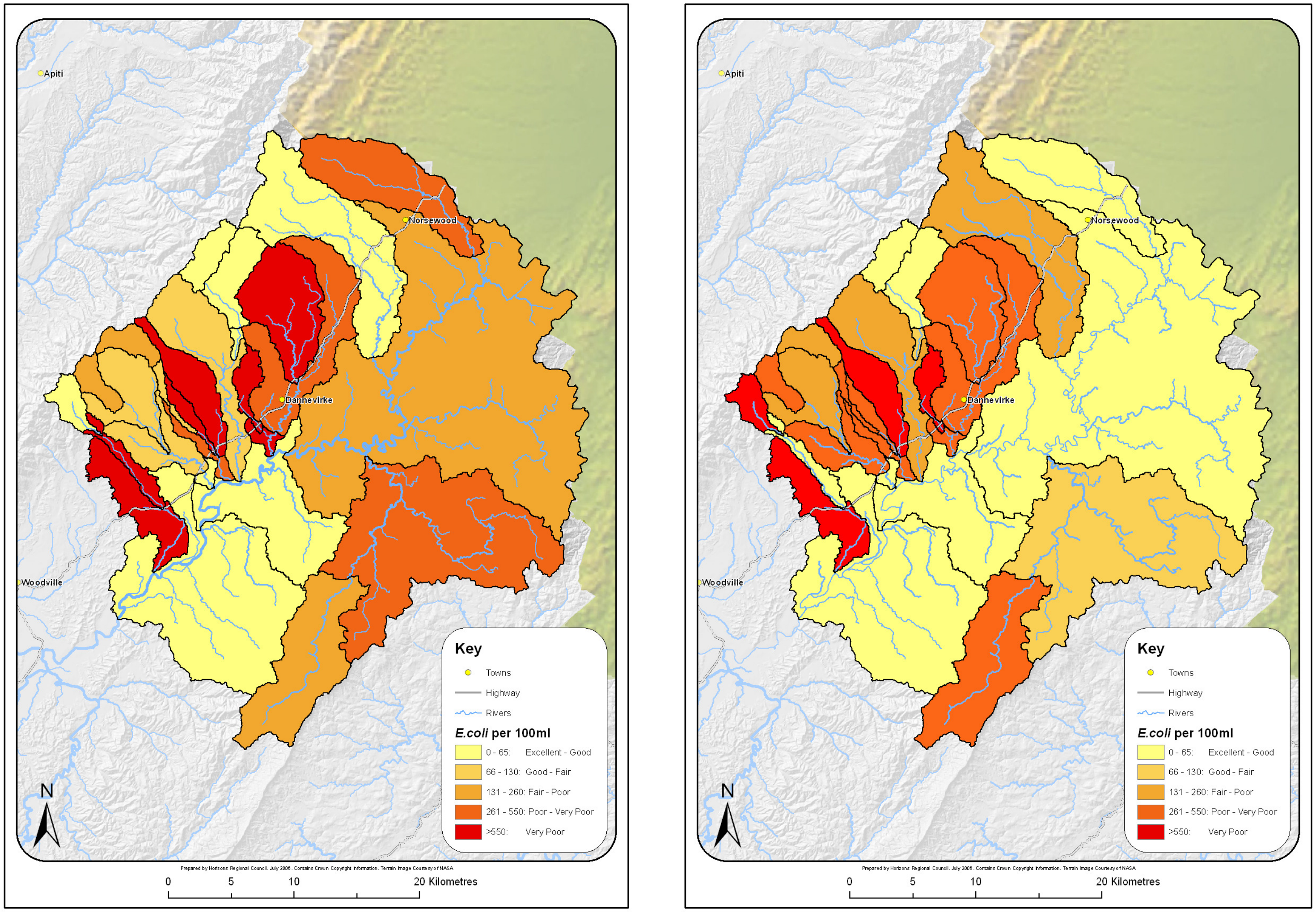
Figure 33. Annual soluble inorganic nitrogen (SIN) load (tonnes/year) attributable to point sources (PS, Dannevirke STP) and non-point sources (NPS) of nutrient in the upper Manawatū catchment upstream of the Hopelands monitoring site.



Map 19. Soluble inorganic nitrogen (SIN) concentration at sub-catchment locations in the upper Manawatū catchment under low flow conditions in January (left) and February (right) 2007.



Map 20. Dissolved reactive phosphorus (DRP) concentration at sub-catchment locations in the upper Manawatū catchment under low flow conditions in January (left) and February (right) 2007.



Map 21. *Escherichia coli* concentration at sub-catchment locations in the upper Manawatū catchment under low flow conditions in January (left) and February (right) 2007. *Note: all areas with the darkest two shades were unsuitable for contact recreation at the time of sampling.*

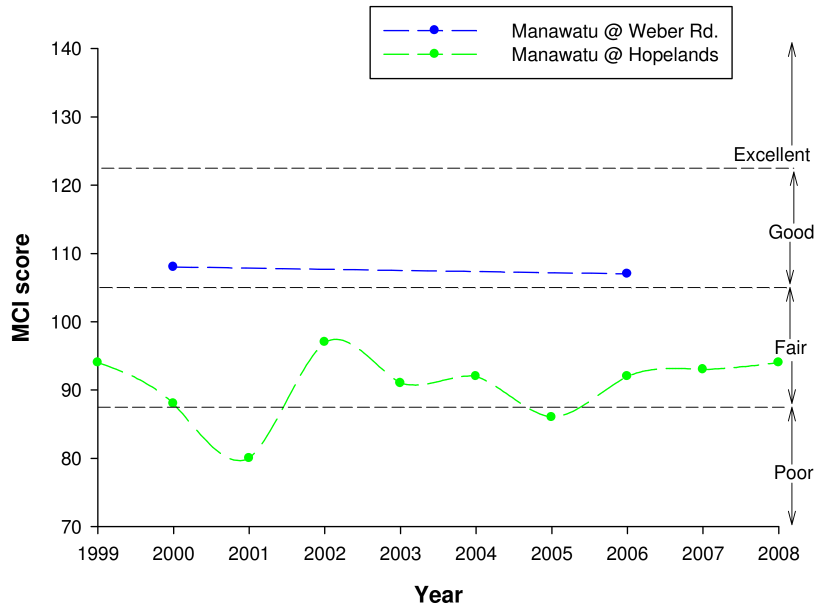
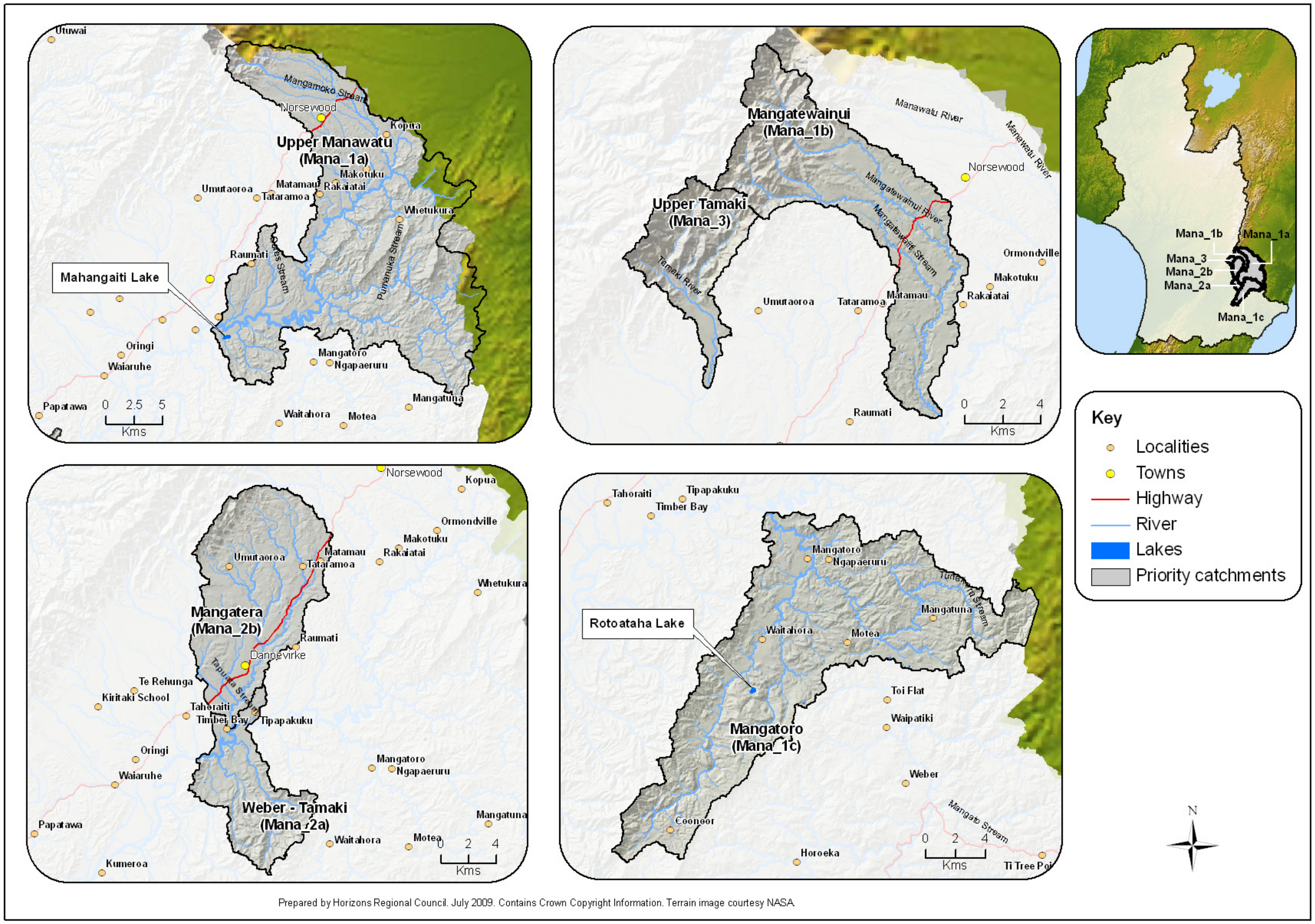


Figure 34. Changes in Macroinvertebrate Community Index (MCI) scores between 1999 and 2008 at two sites on the upper Manawatū River. From upstream to downstream the sites are Manawatū at Weber Rd and Manawatū at Hopelands. The water quality classes shown on the graph are according to Stark and Maxted (2007).

393. Land use in the upper Manawatū is dominated by Sheep & Beef (69%; Table 23) and Dairy, which is the second highest land use in the catchment at 16%. Most of the Dairy land use is concentrated in the lower catchment of the upper Manawatū, between the Weber Rd and Hopelands monitoring sites (see the evidence of Dr Brent Clothier, Dr Jon Roygard and Dr Alec Mackay). There are 148 dairy discharge consents to the upper Manawatū catchment. Of these only one consent is for a discharge to water.

394. The effects of FARM strategy scenarios on nitrogen loads in relation to Standard load limits are detailed in Roygard and McArthur (2008). Table 24 shows nitrogen output loss limits after Year 20 of the FARM strategy are predicted to total 751 tonnes SIN/year. Successful implementation of the FARMS strategy is predicted to result in an annual load that is 210% of the Standard load limit of 358 tonnes SIN/year. The increase from the current non-point source Measured load of 729 tonnes SIN/year to the 20 year load of 751 tonnes SIN/year reflects the possibility of land use intensifying to the maximum capacity for the LUC classes in the catchment. For further information on this point see the evidence of Dr Jon Roygard, Dr Alec Mackay and Dr Brent Clothier.



Map 22. Target catchments in the Upper Manawatū Water Management Zones and Sub-zones.

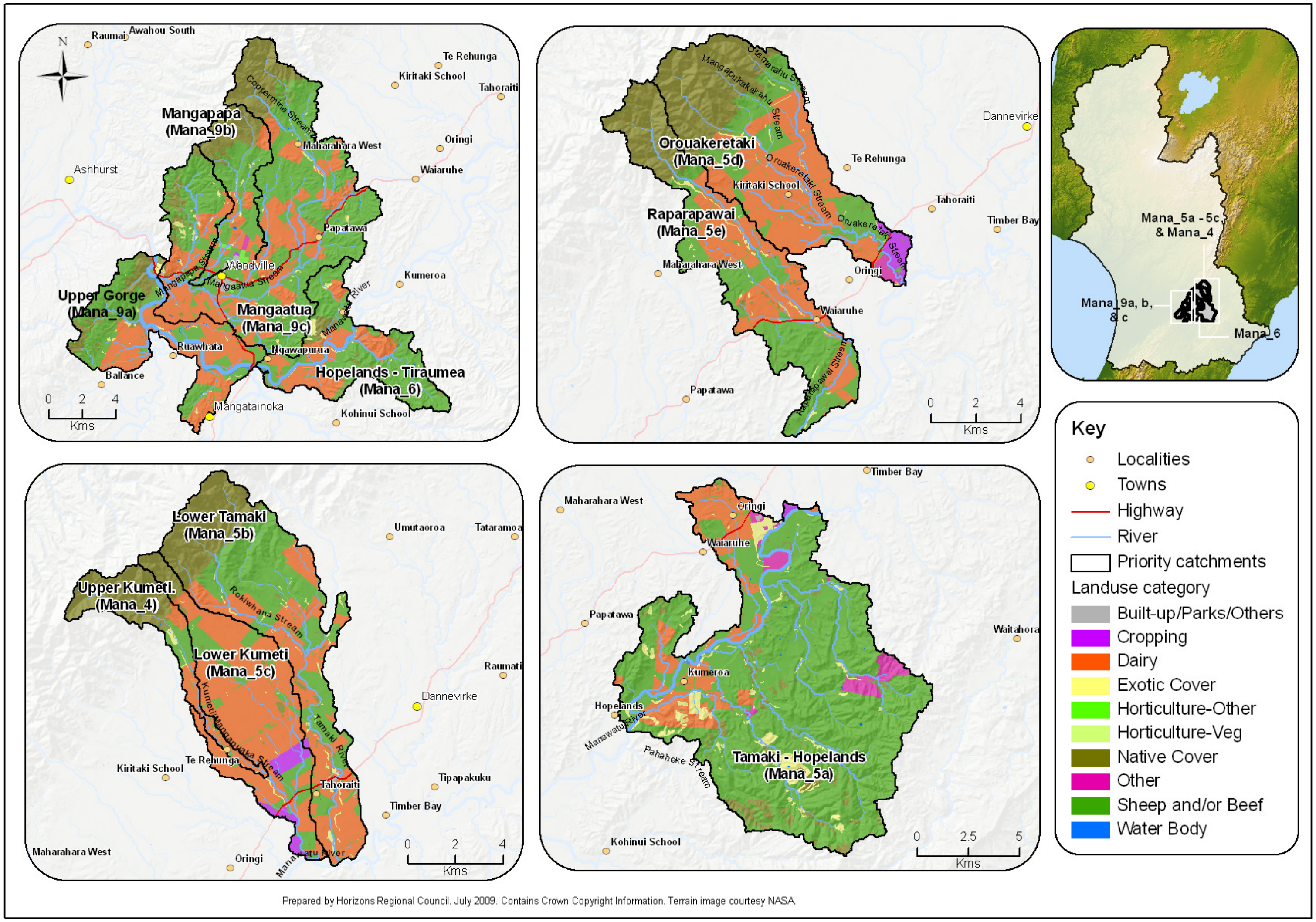
Table 23. Proportional land use type and Land Use Capability (LUC) class in the upper Manawatū (catchment upstream of Hopelands).

Land use type	Upper Manawatū	LUC class	Upper Manawatū
Built-up/Parks	-	1	-
Cropping	-	2	10%
Dairy	16%	3	16%
Exotic Cover	3%	4	9%
Horticulture	-	5	1%
Native Cover	10%	6	13%
Other	1%	7	8%
Sheep & Beef	69%	8	5%
Water Body	-	Blank	-

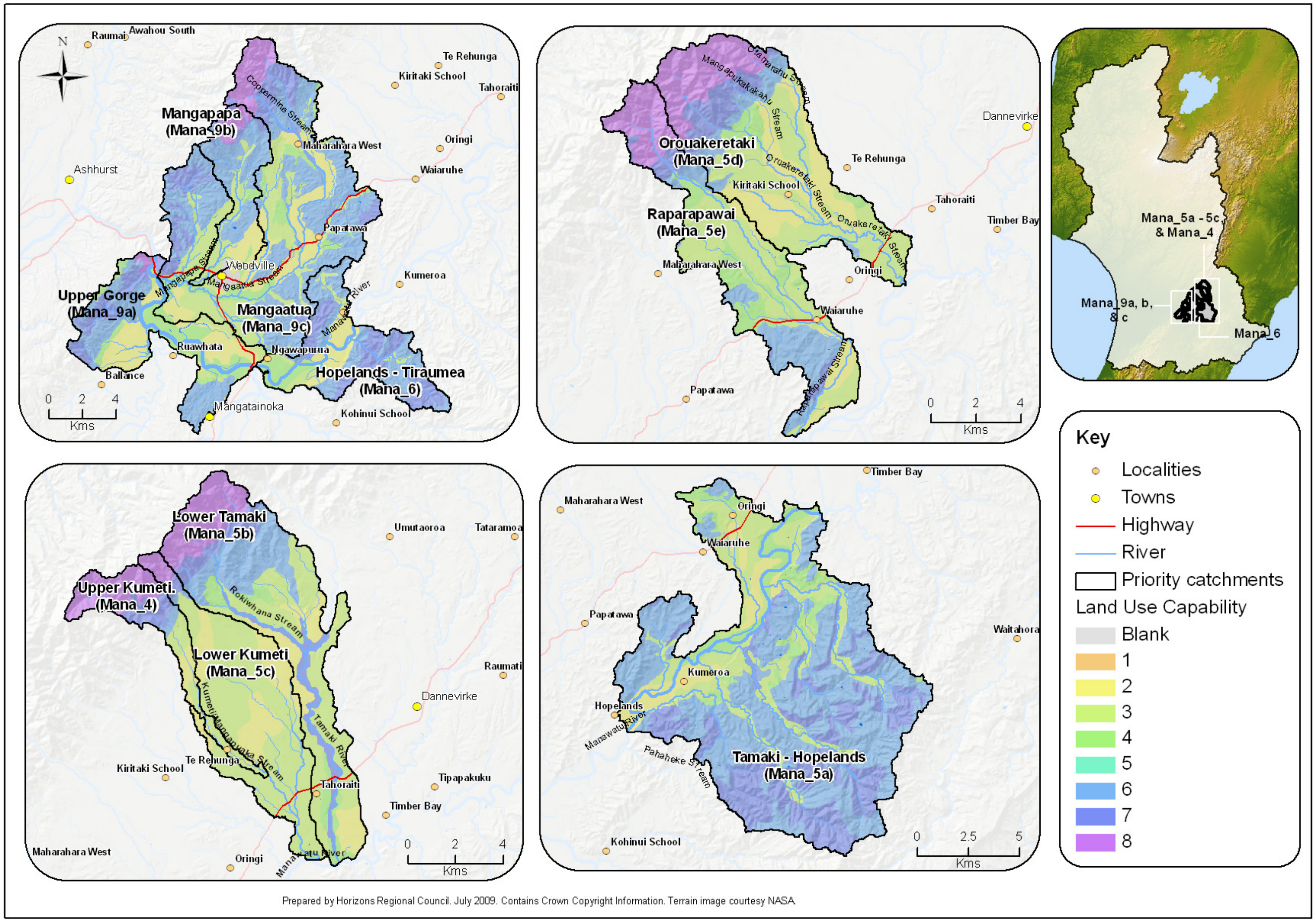
Table 24. Proposed nitrogen output limits and Measured loads resulting from the implementation of Rule 13-1 of the Proposed One Plan for the Water Management Zones of the upper Manawatū River above the Hopelands monitoring site. *Note: Nitrogen attenuation of 50% between the land and river was assumed according to Clothier et al. (2007) and Mackay et al. (2008).*

upper Manawatū		LUC I	LUC II	LUC III	LUC IV	LUC V	LUC VI	LUC VII	LUC VIII	Total
Output loss limit	**Year 1** (when rule comes into force) (kg of N/ ha/year)	32	29	22	16	13	10	6	2	
	Year 5 (kg N/ha/year)	27	25	21	16	13	10	6	2	
	Year 10 (kg N/ha/year)	26	22	19	14	13	10	6	2	
	Year 20 (kg N/ha/year)	25	21	18	13	12	10	6	2	
Area of LUC in upper Manawatū (ha)		0	12424	20257	11508	907	57254	22108	5180	129638
Measured load (in-river)	**Year 1** (Tonnes/year)	0	180	223	92	6	286	66	5	859
	Year 5 (Tonnes/year)	0	155	213	92	6	286	66	5	824
	Year 10 (Tonnes/year)	0	137	192	81	6	286	66	5	773
	Year 20 (Tonnes/year)	0	130	182	75	5	286	66	5	751
Standard load limit (Tonnes/year)										358
Measured load (Tonnes/year)										745
NPS load (Tonnes/year)										729[23]

[23] Note: the Measured load figure differs from the 'current state' figure published by Clothier *et al.* (2007) and Mackay *et al.* (2008) due to differences in the calculation of PS nitrogen loads for the upper Manawatu catchment.



Map 23. Upper Manawatū and upper Gorge Water Management Sub-zone land use.



Map 24. Upper Manawatū and upper Gorge Water Management Sub-zone Land Use Capability (LUC) class.

Key points: Upper Manawatū target catchment

i. The upper Manawatū target area is part of a large catchment draining 1267 km^2 from the Ruahine and Puketoi Ranges to the Hopelands SoE site.

ii. Soluble inorganic nitrogen and DRP significantly exceed the POP standards and are generally non-point sourced (98% and 80% respectively), *E. coli* exceeds safe swimming standards in some tributaries at low flows and in all waterways including the mainstem when flows are elevated.

iii. Periphyton proliferation and potentially toxic cyanobacterial blooms are common, the aquatic macroinvertebrate health is low and declines with distance downstream, and migratory native fish are almost absent from the catchment.

iv. Non-migratory dwarf *Galaxias* populations are isolated in Ruahine tributaries and are vulnerable to habitat and water quality degradation.

v. Land use is predominantly Sheep & Beef (69%) with Dairy (16%) and Native Cover (10%) following. There are 148 dairy discharge consents within the target area.

vi. Contact Recreation, Life-Supporting Capacity, Stockwater, Regionally Significant Trout Fishery, Amenity, and potentially Sites of Significance – Aquatic values are compromised by poor water quality and sediment transport and deposition.

vii. The year 20 output loss limits predicted from the application of Table 13.2 of the POP will be approximately 110% greater than the Standard load limit and may exceed the current Measured load if land use intensifies to the maximum potential.

9.6 Lake Horowhenua (Hoki_1a, Hoki_1b)

395. Lake Horowhenua is the largest of a series of shallow coastal dune lakes extending along the west coast of the lower North Island. The surface water catchment area of the lake and outflowing Hokio Stream is approximately 70 km^2 (Map 25). As the largest wetland in the Region, Lake Horowhenua has significant biodiversity value (both terrestrial and aquatic) and it is also a site of substantial cultural importance to local iwi. The lake level is set by Government legislation.

396. The water-body values which apply to the Lake Horowhenua Water Management Zone are:

- Life-Supporting Capacity – Lowland Mixed (LM) geology
- Contact Recreation
- Mauri

- Amenity
- Stockwater
- Site of Significance – Aquatic for giant kōkopu
- Inanga Spawning
- Whitebait Migration
- Capacity to Assimilate Pollution
- Shellfish Gathering
- Water Supply, Irrigation and Industrial Abstraction.

397. Water quality issues are detailed in the sections above on lake water quality. In brief, Lake Horowhenua is subject to extremely elevated total and dissolved nitrogen and phosphorus concentrations. Ammoniacal nitrogen is also occasionally elevated to levels that are toxic to aquatic life. Considering the often high pH in Lake Horowhenua, the risk of toxic effects from unionised ammonia is substantial.

398. High nutrient enrichment from nitrogen and phosphorus is exhibited in the chlorophyll *a* concentrations measured in the lake (Figure 7 see lake water quality sections above). Chlorophyll *a* from suspended algal and cyanobacterial production, in conjunction with nutrient concentrations, suggests that Lake Horowhenua is hypertrophic (see the evidence of Max Gibbs). Turbidity is also often elevated in Lake Horowhenua as a result of algal blooms. Cyanobacterial blooms are frequently toxic in the lake, greatly affecting Amenity and Contact Recreation values. For further information on cyanobacterial blooms in Lake Horowhenua see the evidence of Barry Gilliland.

399. Although faecal contaminants (*E. coli*) do not appear to exceed levels that would reduce the ability for Lake Horowhenua to be utilised for contact recreation, planktonic cyanobacteria cause closure of the lake to recreational users on a regular basis. Rather than applying a standard for cyanotoxins as proposed in Schedule D, the draft national guideline on managing cyanobacteria in recreational waters (MfE/MoH, 2009) recommends setting alert levels consistent with cell biovolumes or cell counts.

400. Aquatic biodiversity has potentially been affected by the poor water quality in the lake, particularly with respect to ammonia toxicity and fluctuations in pH and dissolved oxygen that result from the 'boom and bust' cycle of algal blooms. Two of the main inflowing tributary streams of Lake Horowhenua (Patiki and Arawhata Streams) hold remnant populations of regionally rare and threatened native fish species such as banded (Photo 4) and giant kōkopu (Photo 5), found at only a handful of sites in the Region. The lake once provided significant habitat for resident and spawning fish of many species, but

poor water quality and habitat degradation may have resulted in native fish needing to seek refuge in tributary streams, causing contracted populations and reductions in fish community diversity.

Photo 4. Banded kōkopu (photo: Natural Sciences Image Library of New Zealand).

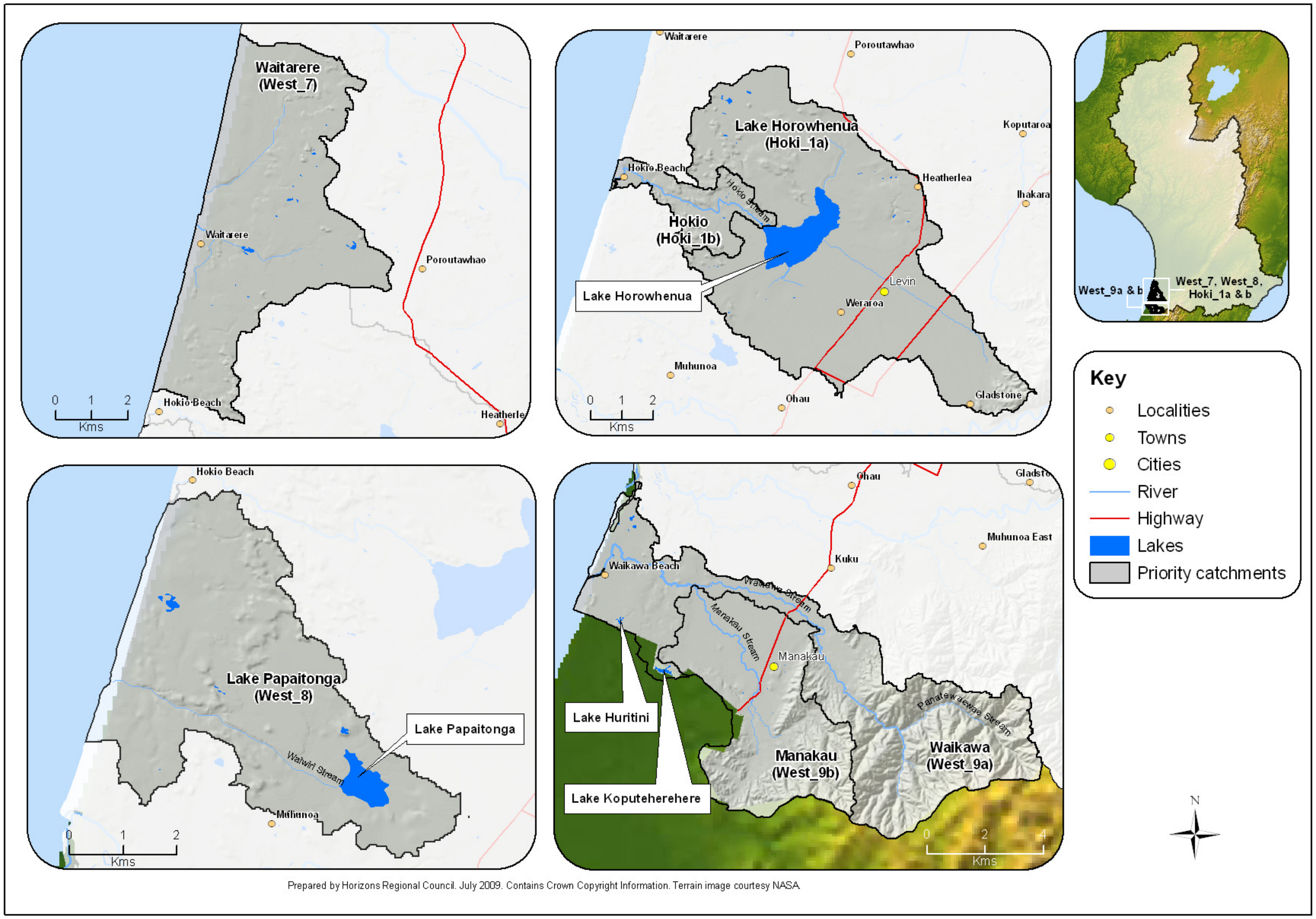
Photo 5. Giant kōkopu (photo: Natural Sciences Image Library of New Zealand).

401. Historically sewage from the town of Levin was discharged into the lake until the mid 1980's (see the evidence of Barry Gilliland). Stormwater from Levin is also discharged to the Lake via the Queen Street Drain. However, the sources of contamination of Lake Horowhenua are now largely non-point sourced. Land use in the catchment is dominated by Sheep & Beef (51%) with 18% of the catchment in Dairy, approximately 7% in Cropping or Horticulture and half of the catchment is in LUC classes 1 to 3 and there are ten dairy effluent discharge consents in the catchment. Twelve percent of the catchment is in Built up land use, covered by the township of Levin.

402. The elevated nutrients and low faecal contaminants in Lake Horowhenua suggest that either nutrient enrichment is not sourced from animal-based intensive land uses or that faecal contaminants are being removed via attenuation processes or die-off between the land and the lake (eg. via slow travel times and/or reduced conditions in the groundwater).

403. Determining the catchment land use contributing to water quality issues in the lake is not a simple issue for any of the Region's coastal dune lakes. Groundwater inputs to Lake Horowhenua may be considerable (see the evidence of Hisham Zarour and Max Gibbs). The extent of the catchment contributing to the nutrient-laden groundwater may reach beyond the surface water boundaries applied to the Water Management Zone of Lake Horowhenua. In the catchment area west of the lake (towards the coast) the land use contributes to water quality issues in the Hokio Stream and coastal marine waters, which are also both nutrient enriched and faecally contaminated.

404. Work is underway to better characterise the water balance and groundwater catchments for Lake Horowhenua and neighbouring Lake Papaitonga to better understand both the hydrological (see the evidence of Hisham Zarour) and water quality resources. Until this work is completed a Standard load limit or Measured load cannot be calculated for the lake to compare with the output loss limits (Table 26).



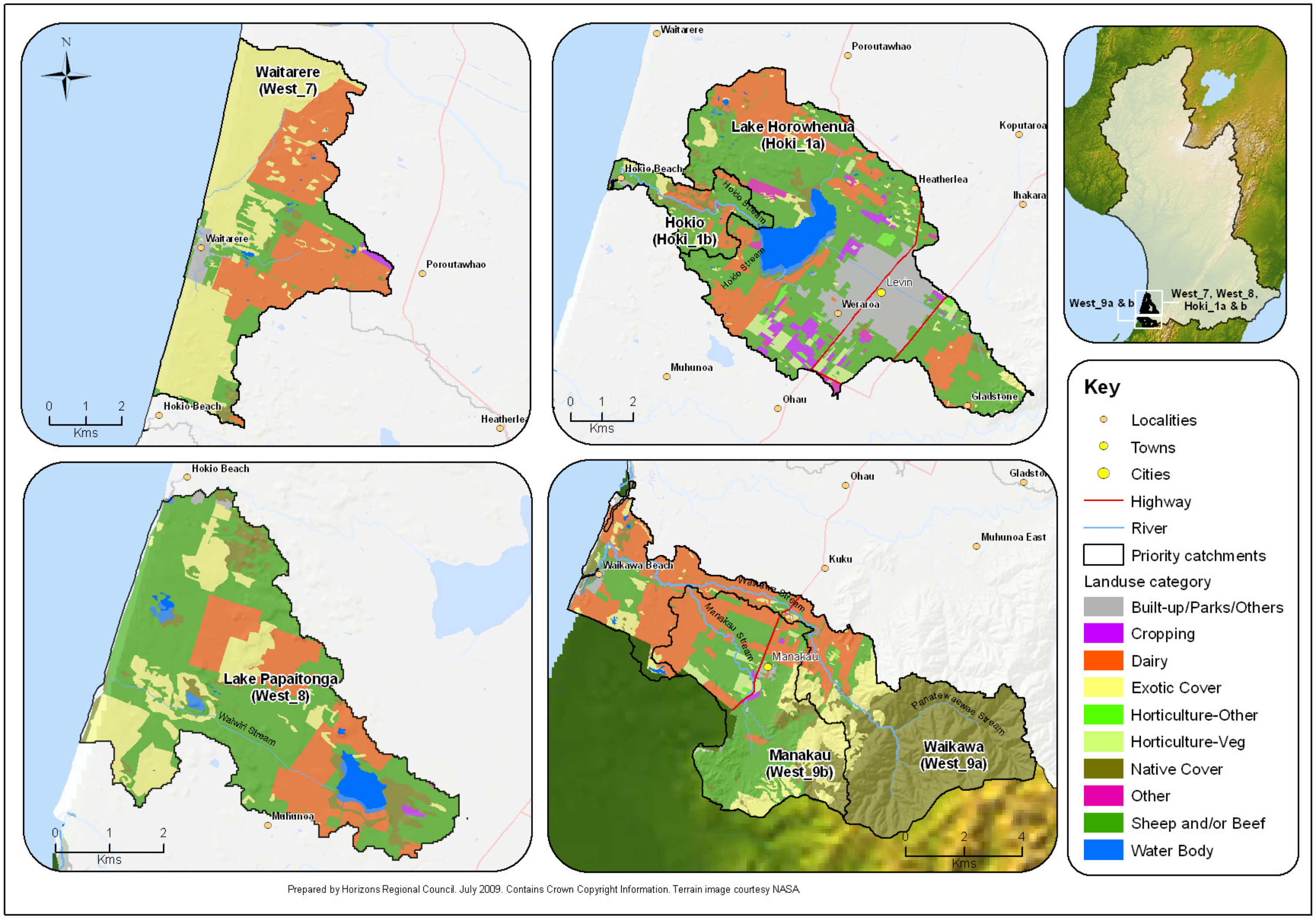
Map 25. Target catchments in Waitarere, Lake Horowhenua, Lake Papaitonga and Waikawa Water Management Zones.

Table 25. Proportional land use and Land Use Capability (LUC) class in the Lake Horowhenua Water Management Sub-zones.

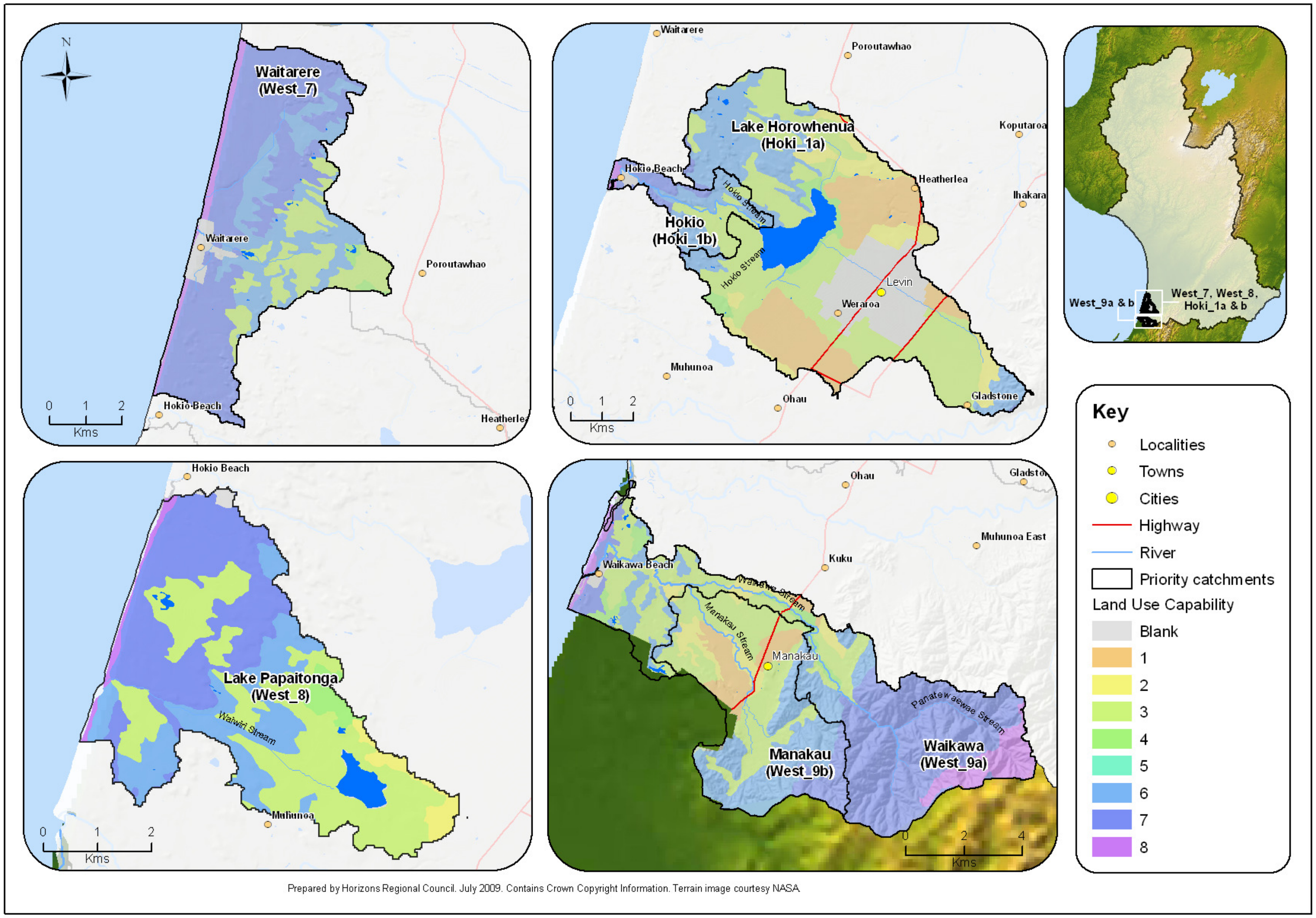
Land use type	Lake Horowhenua	LUC class	Lake Horowhenua
Built-up/Parks	12%	1	17%
Cropping	3%	2	8%
Dairy	18%	3	35%
Exotic Cover	3.5%	4	2%
Horticulture	3.5%	5	-
Native Cover	3.5%	6	18.4%
Other	1.4%	7	2.5%
Sheep & Beef	51%	8	0
Water Body	4.4%	Blank	16.5%

Table 26. Proposed nitrogen output limits resulting from the implementation of Rule 13-1 of the Proposed One Plan for the Lake Horowhenua Water Management Zone. *Note: Nitrogen attenuation of 50% between the land and lake was assumed according to Clothier et al. (2007) and Mackay et al. (2008).*

Lake Horowhenua		LUC I	LUC II	LUC III	LUC IV	LUC V	LUC VI	LUC VII	LUC VIII	Total
Output loss limit	**Year 1** (when rule comes into force) (kg of N/ ha/year)	32	29	22	16	13	10	6	2	
	Year 5 (kg N/ha/year)	27	25	21	16	13	10	6	2	
	Year 10 (kg N/ha/year)	26	22	19	14	13	10	6	2	
	Year 20 (kg N/ha/year)	25	21	18	13	12	10	6	2	
Area of LUC in Lake Horowhenua (ha)		1202	575	2527	154	0	1315	181	21	2949
Measured load (to lake)	**Year 1** (Tonnes/year)	19.23	8.34	27.80	1.23	8.55	0.91	0.06	0.02	66.14
	Year 5 (Tonnes/year)	16.23	7.19	26.53	1.23	8.55	0.91	0.06	0.02	60.72
	Year 10 (Tonnes/year)	15.63	6.33	24.01	1.08	8.55	0.91	0.06	0.02	56.57
	Year 20 (Tonnes/year)	15.03	6.04	22.74	1.00	7.89	0.91	0.06	0.02	53.69
Standard load limit (Tonnes/year)										-



Map 26. Land use in the Waitarere, Lake Horowhenua, Lake Papaitonga and Waikawa target Water Management Zones.



Map 27. Land Use Capability (LUC) in the Waitarere, Lake Horowhenua, Lake Papaitonga and Waikawa target Water Management Zones.

Key points: Lake Horowhenua target catchment

i. Horowhenua is the largest coastal dune lake and, in combination with the outflowing stream (Hokio), the catchment covers a land area of 70 km^2.

ii. Biodiversity (both terrestrial and aquatic) and cultural values associated with the lake are significant.

iii. Total and soluble nitrogen and phosphorus regularly exceed POP standards, ammoniacal-N is also high at times and nutrient contamination is non-point sourced, although historic point sources have contributed significantly to the nutrient sink in the lake.

iv. *Escherichia coli* is generally within safe swimming levels, indicating contamination may not be sourced from animal-based intensive land uses.

v. The lake is hypertrophic. Algal and cyanobacterial blooms occur regularly and are frequently toxic.

vi. Land use in the catchment is dominated by Sheep & Beef (51%), Dairy (18%), Built up (Levin 12%) and Cropping/Horticulture (7%). There are ten dairy discharge consents in the target area.

vii. Contact Recreation, Life-Supporting Capacity, Amenity, potentially Site of Significance – Aquatic and coastal Shellfish Gathering values are compromised by the effects of poor water quality and the hypertrophic state of the lake.

viii. Calculating a Standard load limit to compare with the Year 20 output loss limits from Table 13.2 of the POP cannot be undertaken until the water balance for the lake is better understood.

9.7 Waikawa (West_9a, West_9b)

405. The Waikawa Stream catchment and its main tributary the Manakau Stream have a catchment area of approximately 80 km^2. The Waikawa captures the southern-most area of the Region from the western slopes of the Tararua Ranges to the coast (Map 25). Water allocation in the Waikawa and Manakau has reduced from historic levels due to less water being used from water races in the catchment and lower demand for horticultural purposes.

406. The values of the Waikawa Water Management Zone are:

- Life-Supporting Capacity – Lowland Mixed (LM) geology
- Contact Recreation
- Mauri
- Amenity

- Natural State
- Site of Significance – Aquatic for kōaro, shortjaw kōkopu and redfin bully
- Site of Significance – Riparian for dotterel
- Capacity to Assimilate Pollution
- Shellfish Gathering
- Water Supply, Irrigation and Industrial Abstraction.

407. Aquatic ecosystem health appears to be in reasonable condition in the upper Waikawa catchment. The whole mainstem of the Waikawa Stream is valued as a Site of Significance – Aquatic due to the diversity of native fish communities found there (Photo 6). The large number of fish monitoring survey sites on the mainstem indicate relatively contiguous native fish habitat. Aquatic macroinvertebrates at the Waikawa at Manakau site also show that the stream is only mildly degraded at that site (see Appendix 2). However, over the 2008/2009 summer the Waikawa Stream was subject to significant cyanobacterial cover, which affected Contact Recreation, Amenity, Stockwater and Life-Supporting Capacity values.

408. The main water quality issues in the Waikawa as identified in the 2005 State of the Environment report were nutrient enrichment (Figure 35 and Figure 36) and lack of suitability for contact recreation from faecal contamination (Figure 37).

409. As there are no known point sources of contamination in the Waikawa Stream, the significant increases in soluble nitrogen, phosphorus and *E. coli* between upstream and downstream sites (Map 28) are directly attributable to non-point source contamination in these reaches. The high *E. coli* concentrations recorded in the Manakau Stream at State Highway 1 are also of some concern. The effects of this contamination adversely impacts Life-Supporting Capacity, Amenity, Stockwater and Contact Recreation values, with potential effects on the Site of Significance – Aquatic value if life-supporting capacity is compromised to the point that migration and recruitment of native fish is affected.

410. The Waikawa Stream at Huritini (in the lower catchment) is somewhat soft-bottomed and less likely to provide ideal substrate for the attachment of benthic periphyton. Nutrients and faecal contaminants in the lower stream catchment will be directly exported into the Waikawa Estuary and Coastal Marine Area, affecting Contact Recreation, Life-Supporting Capacity and Shellfish Gathering values in those areas. However, the catchment upstream of Huritini is cobble-bottomed and provides suitable substrate for the attachment and proliferation of periphyton, which is a concern.

411. Land cover in the Waikawa is dominated by Native Cover of the Tararua Forest Park in the upper catchment (35%; Table 27, Map 26 and Map 27). The proportion of Native Cover, in combination with the distance of this forested habitat from the sea, contributes to the high aquatic biodiversity value of the catchment because native fish only have to migrate a short distance between the sea and unimpacted stream habitat.

412. Dairy (24%) and Sheep & Beef farming (26%) comprise the other two most dominant land uses in the Waikawa catchment (Table 27). There are eight dairy effluent discharge consents in the catchments and all of these are discharges to land. A comparison of the predicted nitrogen loss limits by LUC class (assuming full intensification to the productive capacity of all land area) with the Standard load limit for nitrogen, shows that Year 20 losses may be 603% of the Standard load limit (Table 28).

Photo 6. Kōaro (photo: Natural Sciences Image Library of New Zealand).

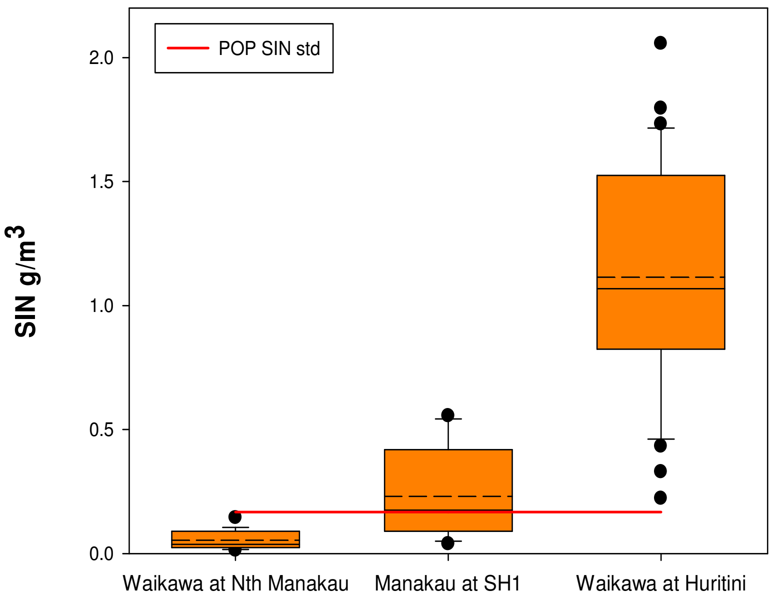


Figure 35. Soluble inorganic nitrogen (SIN) concentration at three sites in the Waikawa catchment from upstream (left) to downstream (right) collected monthly between July 2006 and July 2009.

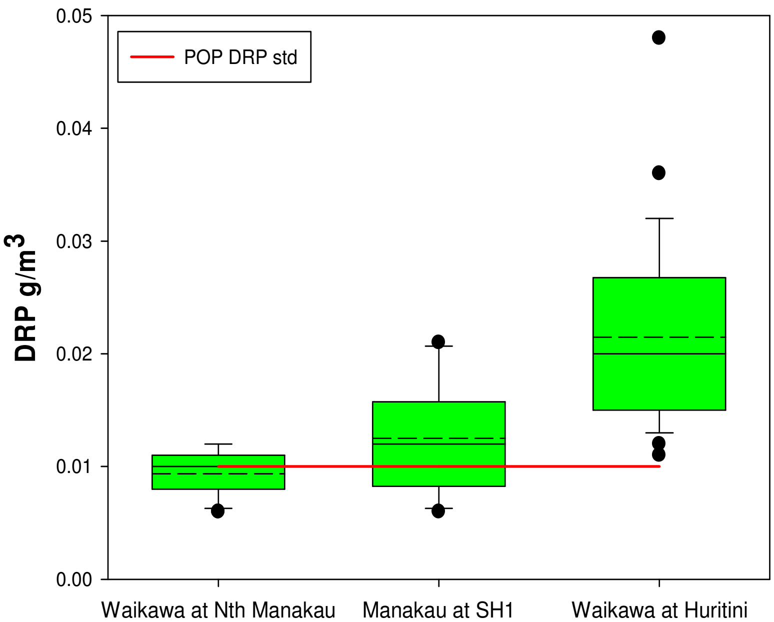


Figure 36. Dissolved reactive phosphorus (DRP) concentration at three sites in the Waikawa catchment from upstream (left) to downstream (right) collected monthly between July 2006 and July 2009.

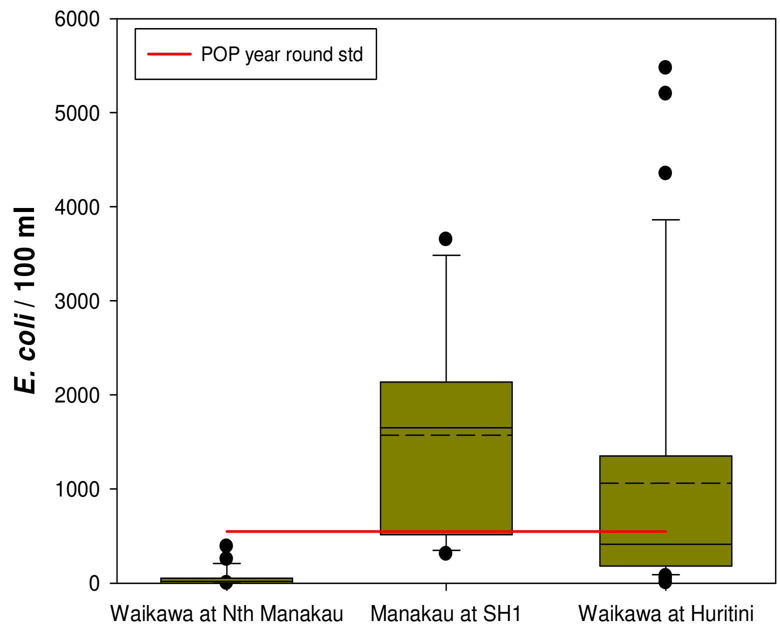
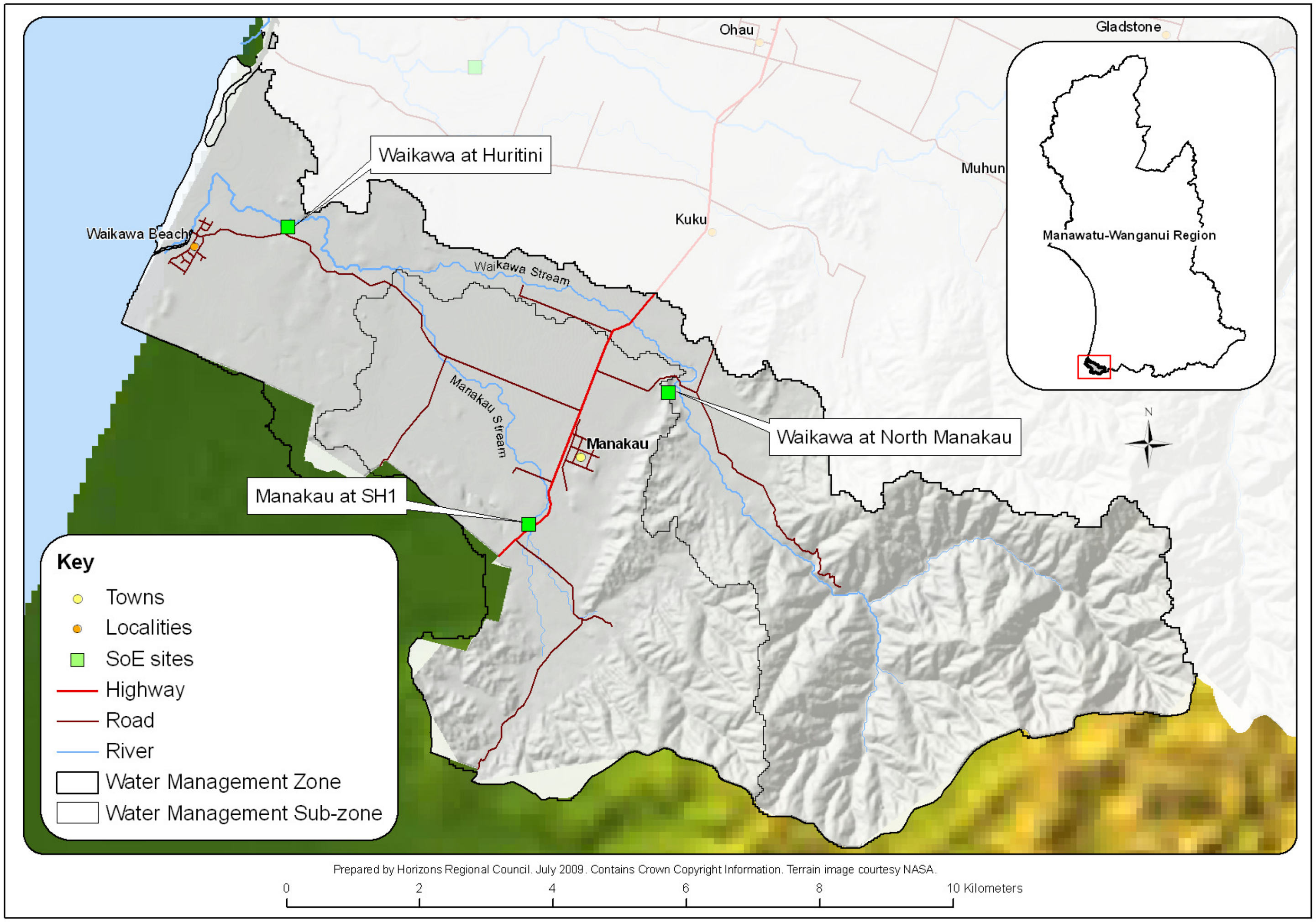


Figure 37. *Escherichia coli* concentration at three sites in the Waikawa catchment from upstream (left) to downstream (right) collected monthly between July 2006 and July 2009.



Map 28. State of the Environment monitoring sites in the Waikawa Water Management Zone. *Note: biomonitoring is also undertaken at the Waikawa at North Manakau site.*

Table 27. Proportional land use and Land Use Capability (LUC) class in the Waikawa Water Management Zone.

Land use type	Waikawa	LUC class	Waikawa
Built-up/Parks	1%	1	5.5%
Cropping	-	2	6%
Dairy	24%	3	27%
Exotic Cover	13%	4	3%
Horticulture	-	5	-
Native Cover	35%	6	20%
Other	-	7	33%
Sheep & Beef	26%	8	6%
Water Body	-	Blank	1%

Table 28. Proposed nitrogen output limits resulting from the implementation of Rule 13-1 of the Proposed One Plan for the Waikawa Water Management Zone. *Note: Nitrogen attenuation of 50% between the land and river was assumed according to Clothier et al. (2007) and Mackay et al. (2008).*

Waikawa		LUC I	LUC II	LUC III	LUC IV	LUC V	LUC VI	LUC VII	LUC VIII	Total
Output loss limit	**Year 1** (when rule comes into force) (kg of N/ ha/year)	32	29	22	16	13	10	6	2	
	Year 5 (kg N/ha/year)	27	25	21	16	13	10	6	2	
	Year 10 (kg N/ha/year)	26	22	19	14	13	10	6	2	
	Year 20 (kg N/ha/year)	25	21	18	13	12	10	6	2	
Area of LUC in Waikawa (ha)		434	453	2137	230	0	1567	2640	489	7988
Measured load (in-river)	**Year 1** (Tonnes/year)	6.94	6.57	23.51	1.84	10.19	13.20	1.47	0.49	64.20
	Year 5 (Tonnes/year)	5.86	5.66	22.44	1.84	10.19	13.20	1.47	0.49	61.14
	Year 10 (Tonnes/year)	5.64	4.98	20.30	1.61	10.19	13.20	1.47	0.49	57.88
	Year 20 (Tonnes/year)	5.43	4.76	19.23	1.50	9.40	13.20	1.47	0.49	55.47
Standard load limit (Tonnes/year)										9.2[24]

[24] This figure is calculated from mean flow data from a short period of record and should be used with caution, also this is calculated from only the catchment area upstream of the flow recorder site.

Key points: Waikawa target catchment

i. The Waikawa is a small west coast catchment draining 80 km^2 at the southern border of the Region.

ii. Soluble inorganic nitrogen, DRP and *E. coli* all increase significantly between the upper and lower catchment State of the Environment sites and exceed the POP standards, contamination is from non-point sources.

iii. The Waikawa has high aquatic biodiversity value because of the forested habitat in close proximity to the sea, allowing easy migration into the forest park for native fish. However periphyton proliferation and cyanobacterial blooms are common.

iv. Land use is dominated by Native Cover (35%), Sheep & Beef (26%) and Dairy (24%) with 8 dairy effluent discharge consents occurring in the catchment.

v. Contact Recreation, Stockwater, Amenity, Life-Supporting Capacity, coastal Shellfish Gathering and potentially Sites of Significance – Aquatic values are compromised by poor water quality.

vi. The year 20 output loss limits predicted from the application of Table 13.2 of the POP will be approximately 500% greater than the Standard load limit.

9.8 Manawatū above Gorge (Mana_6, Mana_9a, Mana_9c)

413. The Manawatū above Gorge target catchment takes in the Manawatū River at the upper end of the Gorge to the Hopelands monitoring site and includes the tributary catchment of the Mangaatua Stream, a total catchment area of approximately 212 km^2. The Mangapapa catchment is also in this management zone, although the Mangapapa is the first catchment programmed for FARM strategy implementation in Table 13.1 of the POP and is described in previous sections.

414. The Manawatū above Gorge zone receives major inflows from the Manawatū upstream of Hopelands, Tiraumea (including the Mangatainoka) and Mangahao Rivers between Hopelands and the upper Gorge. Cumulative contaminant loads from the Manawatū at Hopelands and inflowing tributary catchments contribute to the nutrient and faecal contaminants measured at the upper Gorge site.

415. The water-body values in the target catchments of the Manawatū above Gorge area are:

- Life-Supporting Capacity – Hill Mixed (HM) geology
- Contact Recreation
- Mauri
- Amenity

- Trout Fishery – Regionally and Locally Significant
- Stockwater
- Natural State
- Site of Significance – Aquatic for redfin bully and shortjaw kōkopu
- Site of Significance – Riparian for dotterel
- Aesthetics
- Capacity to Assimilate Pollution
- Water Supply, Industrial Abstraction and Irrigation.

416. The Manawatū at Upper Gorge is the monitoring site at the downstream end of this target zone. The only point source discharge that occurs within the zone is the Woodville STP discharge to the Mangaatua Stream. However, the zone is subject to the cumulative point source and non-point source inputs from the Mangatainoka and upper Manawatū Rivers.

417. Woodville STP makes a small contribution of nutrients and *E. coli* to the Mangaatua Stream when the upstream and downstream concentrations are compared. Rather, the upstream water quality of the Mangaatua is significantly affected by non-point source contaminants from the Mangaatua and Mangapapa catchment inflows.

418. Water quality at the Manawatū at Upper Gorge site is marginally better than at Hopelands with regard to soluble nitrogen (Figure 38) and phosphorus (Figure 39). There are three reasons that may contribute to these reduced concentrations of nutrients: 1) dilution of contaminants from cleaner inflowing tributaries; 2) reduced relative nutrient loads from land use in the catchment area; or 3) a combination of both factors. Without calculation of the cumulative loads and inputs of nitrogen and phosphorus from each contributing catchment the relative contribution of nitrogen and phosphorus from the land use in the Manawatū above Gorge target area cannot be clearly quantified. However, with respect to *E. coli* concentration the Upper Gorge site is similar to or slightly higher than the Hopelands site (Figure 40).

419. Plotting the Upper Gorge MCI results over the graph of Weber Road and Hopelands shows that the upper Gorge MCI is highly variable (largely due to the influence of the 2004 flood event) but indicative of aquatic ecosystem health similar to Weber Road in 2006 and Hopelands in 2007 and 2008 (Figure 41) with Life-Supporting Capacity somewhat impaired and not meeting the recommended MCI standard of 100 or greater.

420. In the summers of 2007/2008 and 2008/2009 the Upper Gorge site was significantly affected by extensive growths of *Phormidium sp*. cyanobacteria causing the closure of the Woodville Ferry Reserve to swimming and dog walking and affecting the Contact Recreation and Amenity values of the river.

421. Land use in the Manawatū above Gorge target catchment is predominantly Sheep & Beef (48%) and Dairy (41%; Table 29, Map 29). There are 24 dairy effluent discharges within the target catchment and all are to land. The Standard load limit of 1174 tonnes SIN/year (Table 30) is significantly higher than the predicted Year 20 nitrogen loss loads calculated from the target zone land area (176 tonnes SIN/year). This is because the loss limits do not account for the cumulative nitrogen loads from the remainder of the catchment area contributing to the Upper Gorge zone, which includes the inputs from the Manawatū upstream of Hopelands, Mangapapa, Tiraumea (encompassing the Mangatainoka and Mākurī contributions) and Mangahao Rivers. Cumulative contaminant loads will need to be calculated to appropriately partition land use inputs to the zone from the upstream loads.

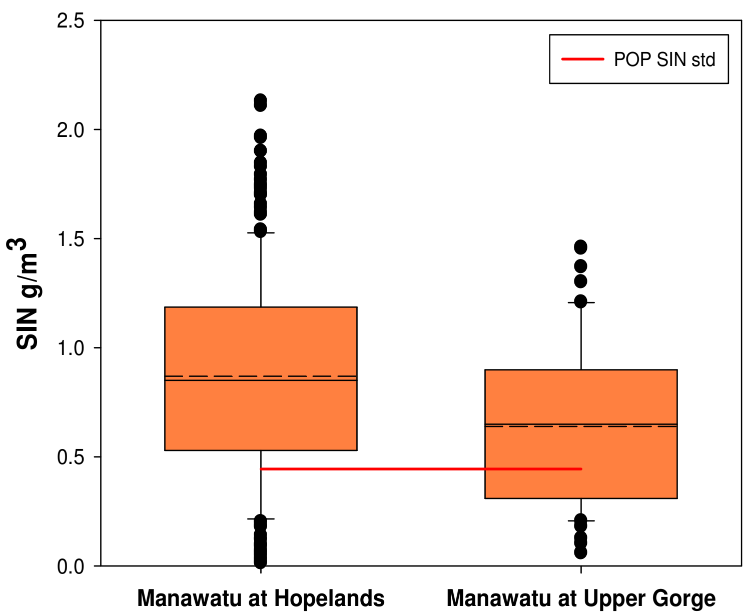


Figure 38. Soluble inorganic nitrogen (SIN) concentration at two sites in the Manawatū catchment from Manawatū at Hopelands upstream (left) to the Manawatū at Upper Gorge site downstream (right) collected over variable time periods between August 1989 and March 2009.

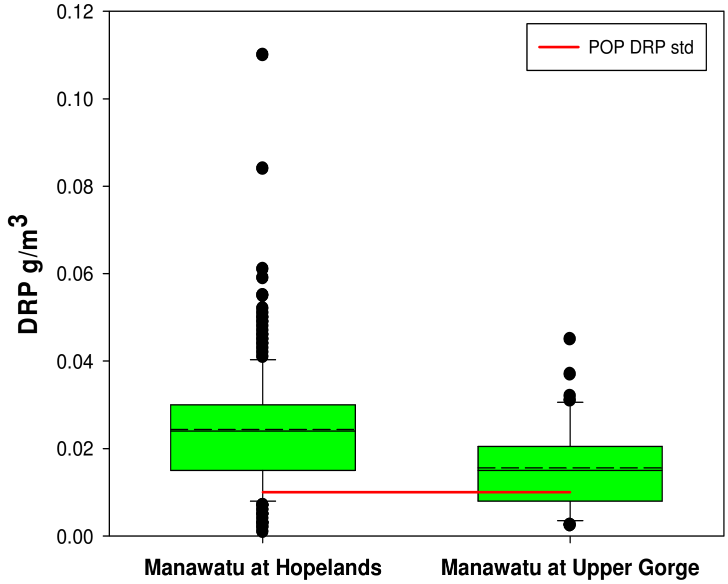


Figure 39. Dissolved reactive phosphorus (DRP) concentration at two sites in the Manawatū catchment from Manawatū at Hopelands upstream (left) to the Manawatū at Upper Gorge site downstream (right) collected over variable time periods between August 1989 and March 2009.

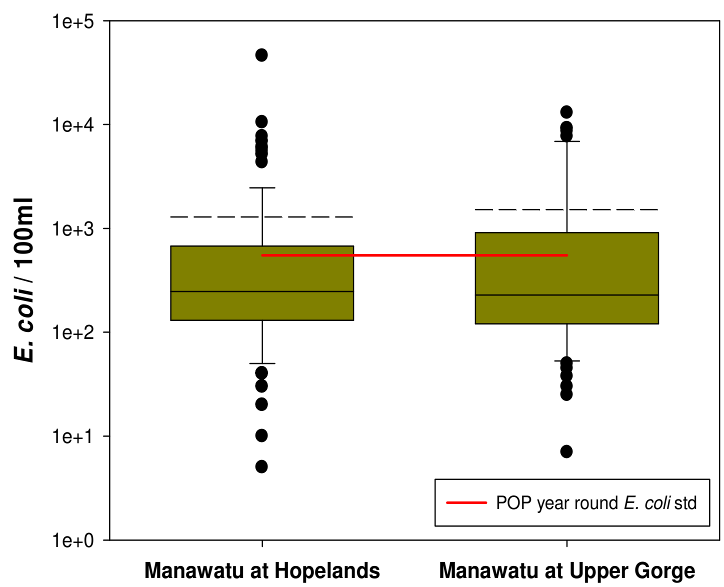


Figure 40. *Escherichia coli* concentration at two sites in the Manawatū catchment from Manawatū at Hopelands upstream (left) to the Manawatū at Upper Gorge site downstream (right) collected over variable time periods between August 1989 and March 2009.

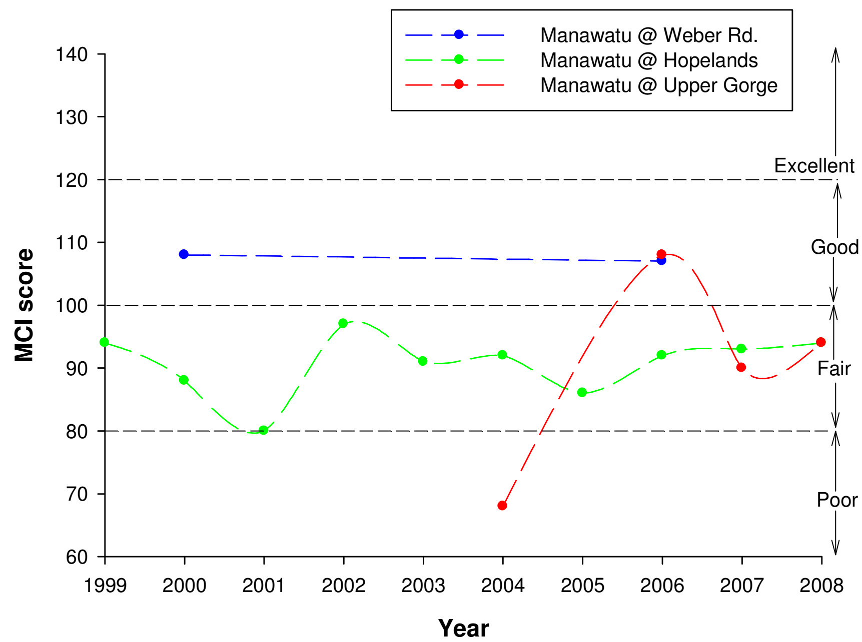
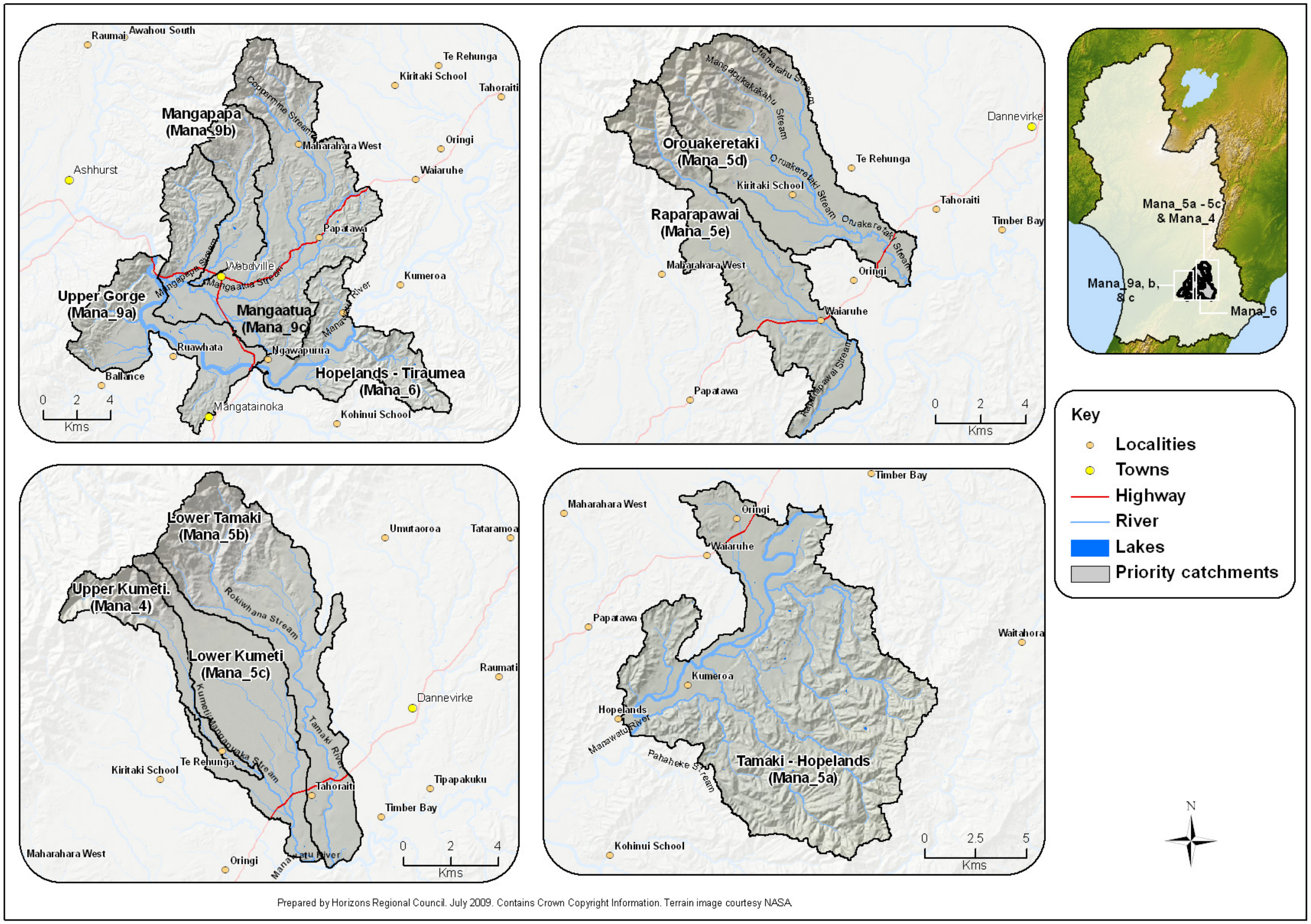


Figure 41. Changes in Macroinvertebrate Community Index (MCI) score between 1999 and 2008 at three sites on the upper Manawatū River. From upstream to downstream the sites are Manawatū at Weber Road, Manawatū at Hopelands and Manawatū at Upper Gorge. The water quality classes shown on the graph are according to Stark and Maxted (2007).



Map 29. Selection of Water Management Zones in the Upper Gorge and Upper Manawatū target catchments.

Table 29. Proportional land use type and Land Use Capability (LUC) class in the Manawatū at Upper Gorge and Hopelands to Tiraumea Water Management Zones.

Land use type	Manawatū Upper Gorge	LUC class	Manawatū Upper Gorge
Built-up/Parks	1%	1	-
Cropping	-	2	16%
Dairy	41%	3	17%
Exotic Cover	2%	4	11%
Horticulture	-	5	-
Native Cover	9%	6	39%
Other	-	7	13%
Sheep & Beef	48%	8	3%
Water Body	-	Blank	1%

Table 30. Proposed nitrogen output limits and Measured loads resulting from the implementation of Rule 13-1 of the Proposed One Plan for the Manawatū above Gorge Water Management Zone. *Note: Nitrogen attenuation of 50% between the land and river was assumed according to Clothier et al. (2007) and Mackay et al. (2008).*

Manawatū Upper Gorge		LUC I	LUC II	LUC III	LUC IV	LUC V	LUC VI	LUC VII	LUC VIII	Total
Output loss limit	**Year 1** (when rule comes into force) (kg of N/ ha/year)	32	29	22	16	13	10	6	2	
	Year 5 (kg N/ha/year)	27	25	21	16	13	10	6	2	
	Year 10 (kg N/ha/year)	26	22	19	14	13	10	6	2	
	Year 20 (kg N/ha/year)	25	21	18	13	12	10	6	2	
Area of LUC Manawatū Upper Gorge (ha)		0	4002	4153	2813	0	9791	3288	810	25003
Measured load (in-river)[25]	**Year 1** (Tonnes/year)	0.00	58.03	45.68	22.50	63.64	16.44	2.43	0.81	209.54
	Year 5 (Tonnes/year)	0.00	50.03	43.61	22.50	63.64	16.44	2.43	0.81	199.46
	Year 10 (Tonnes/year)	0.00	44.02	39.45	19.69	63.64	16.44	2.43	0.81	186.49
	Year 20 (Tonnes/year)	0.00	42.02	37.38	18.28	58.75	16.44	2.43	0.81	176.11
Standard load limit (Tonnes/year)										1174

25 Note: these predicted Measured loads do not account for cumulative nitrogen loads from upstream zones but only allow for the loads generated from the land area of the target zone in isolation. Comparison with the Standard load limit is therefore erroneous.

Key points: Manawatū above Gorge target catchment

i. The Manawatū target catchment between the upper Gorge site and Hopelands SoE sites (including the tributary Mangaatua Stream) drains approximately 212 km^2.

ii. Soluble inorganic nitrogen and DRP exceed POP standards most of the time, although concentrations are lower than the Manawatū at Hopelands. Median *E. coli* is similar to the Manawatū at Hopelands and is elevated at high flows. The vast majority of the contaminants are non-point sourced with a minor contribution from the Woodville STP.

iii. The upper Gorge site has been subject to severe cyanobacterial blooms over the 2008/2009 summer and MCI is often below the recommended standard, indicating impacted aquatic ecosystem health.

iv. Land use in the catchment is predominantly Sheep & Beef (48%) and Dairy (41%). There are 24 dairy effluent discharge consents, all of which are to land.

v. Contact Recreation, Amenity, Aesthetic, Stockwater, Regionally Significant Trout Fishery, Life-Supporting Capacity and potentially Sites of Significance – Aquatic values are compromised by poor water quality and cyanobacterial blooms.

vi. The year 20 output loss limits predicted from the application of Table 13.2 of the POP cannot be compared to the Standard load limit until the cumulative loads from upstream inflows are accurately accounted for.

9.9 Waitarere (West_7)

422. The Waitarere Water Management Zone is comprised of coastal land south of the Manawatū River Estuary with a catchment area of approximately 34 km^2. Surface water bodies in the Waitarere zone are largely associated with coastal lagoons and wetlands and their related drainage systems (both natural and modified; Map 25).

423. The water-body values in the Waitarere Water Management Zone are:

- Life-Supporting Capacity – Lowland Sand (LS) geology
- Contact Recreation
- Mauri
- Amenity
- Stockwater
- Capacity to Assimilate Pollution
- Shellfish Gathering
- Water Supply, Irrigation and Industrial Abstraction.

424. The wetlands listed in the Waitarere zone include Wai-rarawa Lagoon, Lake Tangimate, Otaneko Lagoon, Kai kai Lagoon, Oporou Lagoon, Mangawhati Lagoon and the Waitarere Forest Wetlands. Little is known about the water quality of these lagoons and wetlands and there is no monitoring data available for them. All are significant in terms of their biodiversity value regionally and nationally, and in terms of their classification as threatened habitats (see the evidence of Fleur Maseyk on Biodiversity).

425. Like Lake Horowhenua, it is difficult to quantify the catchment land area which contributes to contaminant loads flowing into individual lagoons and wetlands because the dominant inflows are most likely to come from groundwater. Winter *et al.* (2003) detail the complexities of understanding the groundwater system in small catchments with wetlands and lakes and advise that groundwater flows do not underlie surface water divides in many cases. Other than the wetlands and lagoons within the zone, the other receiving environment of concern is the Coastal Marine Area.

426. Water quality results for coastal beaches show that the Waitarere Beach site had the highest median total N concentration over the 2007/2008 summer monitoring period (Figure 15) and that total P was also elevated (Figure 14). Enterococci and faecal coliforms were at times above safe Contact Recreation (Figure 17) and Shellfish Gathering (Figure 18) standards, adversely affecting these values. However, it is likely that the predominant source of contaminants in the coastal environment adjacent to the Waitarere zone is the Manawatu River. Further monitoring data is required to verify this (see the evidence of Dr John Zeldis).

427. Land use in the Waitarere Management Zone is predominantly comprised of Exotic Cover (48%) and Dairy (34%; Table 31, Map 26). There are three dairy effluent discharges, in the Waitarere zone, all to land. Predicted nitrogen loss loads from Year 20 implementation are 16.99 tonnes SIN/year (Table 32). A Standard load limit for the Waitarere zone is difficult to quantify due to the interaction and complexity of the surface, ground and coastal hydrological systems in this area.

Table 31. Proportional land use type and Land Use Capability (LUC) class in the Waitarere Water Management Zone.

Land use type	Waitarere	LUC class	Waitarere
Built-up/Parks	2%	1	-
Cropping	1%	2	-
Dairy	34%	3	17%
Exotic Cover	48%	4	1%
Horticulture	-	5	-
Native Cover	2%	6	23%
Other	-	7	53%
Sheep & Beef	14%	8	3%
Water Body	-	Blank	3%

Table 32. Proposed nitrogen output limits resulting from the implementation of Rule 13-1 of the Proposed One Plan for the Waitarere Water Management Zone. *Note: Nitrogen attenuation of 50% between the land and water was assumed according to Clothier et al. (2007) and Mackay et al. (2008).*

Waitarere		LUC I	LUC II	LUC III	LUC IV	LUC V	LUC VI	LUC VII	LUC VIII	Total
Output loss limit	**Year 1** (when rule comes into force) (kg of N/ ha/year)	32	29	22	16	13	10	6	2	
	Year 5 (kg N/ha/year)	27	25	21	16	13	10	6	2	
	Year 10 (kg N/ha/year)	26	22	19	14	13	10	6	2	
	Year 20 (kg N/ha/year)	25	21	18	13	12	10	6	2	
Area of LUC in Waitarere (ha)		0	0	566	34	778	1791	113	92	3375
Measured load (to water)	**Year 1** (Tonnes/year)	0.00	0.00	6.23	0.27	11.64	0.57	0.28	0.09	19.07
	Year 5 (Tonnes/year)	0.00	0.00	5.94	0.27	11.64	0.57	0.28	0.09	18.79
	Year 10 (Tonnes/year)	0.00	0.00	5.38	0.24	11.64	0.57	0.28	0.09	18.19
	Year 20 (Tonnes/year)	0.00	0.00	5.09	0.22	10.75	0.57	0.28	0.09	16.99
Standard load limit (Tonnes/year)										-

Key points: Waitarere target catchment

i. The Waitarere Water Management Zone is comprised of coastal sand country to the south of the Manawatū estuary, with wetlands, lagoons and drainage systems covering approximately 34 km^2.

ii. No monitoring data exists for the wetlands or drainage systems of the Waitarere Management Zone so water quality can only be assumed to be similar in nutrient status to other coastal dune lakes.

iii. Because of the complexity of contributing contaminants sources and inflowing ground and surface water catchments, the contribution of a particular area of land use to the water quality of a particular water body is not easily quantifiable.

iv. The large number of wetlands means there are significant biodiversity values associated with this Water Management Zone. Water-body values potentially compromised by land use influences on water quality are Contact Recreation, coastal Shellfish Gathering, Amenity, Stockwater and Life-Supporting Capacity.

v. Land use is predominantly Exotic Cover (48%) and Dairy (34%) and there are three dairy effluent discharges to land in the zone.

9.10 Papaitonga (West_8)

428. The Lake Papaitonga Water Management Zone comprises the surface catchment of Lake Papaitonga and the lake outflow Waiwiri Stream. There are also two significant wetlands within the zone (Muhunoa Coastal Swamp and Rakau Hamama Lagoon). The catchment area is approximately 22 km^2 and covers low lying coastal sand country south of Levin and Lake Horowhenua.

429. The water-body values for the Lake Papaitonga Water Management Zone are:

- Life-Supporting Capacity – Lowland Sand (LS) geology
- Contact Recreation
- Mauri
- Stockwater
- Site of Significance – Aquatic for brown mudfish and banded kōkopu;
- Inanga Spawning
- Whitebait Migration
- Capacity to Assimilate Pollution
- Shellfish Gathering
- Water Supply, Irrigation and Industrial Abstraction.

430. Lake Papaitonga is partially surrounded by remnant lowland forest on the east and north shores and as such has very high terrestrial and aquatic biodiversity values. Rare and threatened native fish that have been surveyed in the lake catchment and tributaries include brown mudfish and banded kōkopu and the Waiwiri Stream margins are utilised by spawning inanga. However, from monitoring undertaken since late 2007, water quality issues appear to be significant.

431. Total and soluble nitrogen are the highest of any monitored lake in the Region (Figure 5 and Figure 9). The median ammoniacal nitrogen concentration (Figure 6) would be above the limit proposed for the protection of aquatic organisms under elevated pH, although pH values were largely inside the ranges proposed as water quality standards in the POP (Figure 10).

432. Phosphorus concentrations (both total and dissolved) were elevated but less so than a number of other lakes in the Region (Figure 4 and Figure 8). However, *E. coli* was elevated to levels that would adversely affect Contact Recreation and Stockwater values (Figure 13). Elevated *E. coli* indicates there is contamination from stock, either Sheep & Beef or Dairy, in the vicinity of the lake or inflowing tributaries.

433. Land use in the Lake Papaitonga catchment is predominantly Sheep & Beef (54%, Table 33). Dairy comprises 19% of the catchment (Map 26), concentrated largely on the southern and western shores of the lake or in the surface catchment area of the Waiwiri Stream. There is one dairy effluent discharge consent in the zone, which is to land.

434. As with Lake Horowhenua and the other coastal lakes, the hydrology of the inflows is not well described and the groundwater catchment contributing to the lake may not conform to the surface Water Management Zone boundary (Winter *et al*., 2003). Considerable work is underway to identify the linkages between surface water bodies and groundwater flows in this area.

435. Until the hydrological regime of the Lake is better understood, predicted nitrogen losses from implementation of the FARM strategy (Table 34) cannot be compared with a Standard load limit or Measured load for the lake, stream, wetlands or coastal waters.

Table 33. Proportional land use type and Land Use Capability (LUC) class in the Lake Papaitonga Water Management Zone.

Land use type	Lake Papaitonga	LUC class	Lake Papaitonga
Built-up/Parks	-	1	-
Cropping	-	2	4%
Dairy	19%	3	39%
Exotic Cover	17%	4	3%
Horticulture	-	5	-
Native Cover	7%	6	20%
Other	-	7	31%
Sheep & Beef	54%	8	2%
Water Body	3%	Blank	3%

Table 34. Proposed nitrogen output limits resulting from the implementation of Rule 13-1 of the Proposed One Plan for the Lake Papaitonga Water Management Zone. *Note: Nitrogen attenuation of 50% between the land and water bodies was assumed according to Clothier et al. (2007) and Mackay et al. (2008).*

Lake Papaitonga		LUC I	LUC II	LUC III	LUC IV	LUC V	LUC VI	LUC VII	LUC VIII	Total
Output loss limit	**Year 1** (when rule comes into force) (kg of N/ ha/year)	32	29	22	16	13	10	6	2	
	Year 5 (kg N/ha/year)	27	25	21	16	13	10	6	2	
	Year 10 (kg N/ha/year)	26	22	19	14	13	10	6	2	
	Year 20 (kg N/ha/year)	25	21	18	13	12	10	6	2	
Area of LUC in Lake Papaitonga (ha)		0	81	875	64	0	450	697	35	2265
Measured load (to lake)	**Year 1** (Tonnes/year)	0.00	1.17	9.63	0.51	2.93	3.49	0.11	0.04	17.86
	Year 5 (Tonnes/year)	0.00	1.01	9.19	0.51	2.93	3.49	0.11	0.04	17.26
	Year 10 (Tonnes/year)	0.00	0.89	8.31	0.45	2.93	3.49	0.11	0.04	16.20
	Year 20 (Tonnes/year)	0.00	0.85	7.88	0.42	2.70	3.49	0.11	0.04	15.47
Standard load limit (Tonnes/year)										-

Key Points: Lake Papaitonga target catchment

i. The Lake Papaitonga Water Management Zone encompasses the surface water catchment surrounding the lake, the Waiwiri Stream and the coastal sand country and wetlands to the west of the lake (roughly 22 km^2).

ii. Total and soluble nitrogen are extremely elevated, as is ammoniacal nitrogen. Total and soluble phosphorus and *E. coli* are also high.

iii. Aquatic and terrestrial biodiversity values are high for the lake, wetlands and outflow stream because of the habitat provided by the forested remnant on the margin of the lake.

iv. Land use in the Water Management Zone is predominantly Sheep & Beef (54%) and Dairy (19%), although there is only one dairy effluent consent in the zone.

v. Contact Recreation, Amenity, Stockwater, coastal Shellfish Gathering and potentially Sites of Significance – Aquatic values are compromised by poor water quality.

vi. Calculating a Standard load limit to compare with the Year 20 output loss limits from Table 13.2 of the POP cannot be undertaken until the water balance for the lake is better understood.

9.11 Other coastal lakes (West_4, West_5, West_6)

9.11.1 Kaitoke Lakes (West_4)

436. The Kaitoke Lakes Water Management Zone comprises the catchments of Lakes Kaitoke, Wiritoa, Kohata, Pauri and the Marangai Bush wetland, a series of coastal lakes and wetlands just south of the Whanganui River (Map 12). The catchment area is 69 km^2 and the land cover is largely modified for pastoral agriculture throughout the catchment, with a large forestry block to the south-east of the catchment boundary. Most of the Kaitoke Lakes catchment is in Sheep & Beef (65%) and Exotic Cover (25%), with only a small proportion of Dairy (4%).

437. Water-body values for the Kaitoke Lakes Water Management Zone include:

- Life-Supporting Capacity – Lowland Mixed (LM) geology
- Contact Recreation
- Mauri
- Stockwater
- Amenity
- Inanga Spawning

- Whitebait Migration
- Capacity to Assimilate Pollution
- Shellfish Gathering
- Water Supply, Irrigation and Industrial Abstraction.

438. Water quality monitoring data is limited to Lakes Pauri and Wiritoa and is detailed in the lakes section above. The concentration of total phosphorus in Lake Pauri is significantly higher than in Lake Wiritoa (Figure 4), with some samples highly elevated as a result of the release of phosphorus from lake bed sediments (see evidence of Max Gibbs).

439. Pauri also had significantly higher total nitrogen than Lake Wiritoa on almost all sampling occasions, although both lakes exceeded the standard (Figure 5). Low concentrations of soluble inorganic nitrogen in both Lakes Pauri and Wiritoa suggest that the majority of nitrogen within the lakes is organic and therefore not immediately bioavailable. Faecal contaminants were often low; however, high nutrient concentrations in these lakes regularly leads to algal and cyanobacterial blooms (see the evidence of Barry Gilliland) negatively impacting on the Contact Recreation, Amenity, Stockwater and Life- Supporting Capacity values of the lakes.

440. Land use information for the Kaitoke Lakes catchment suggests that approximately 5% of the catchment is in intensive land use (eg. Dairy and Cropping) (Table 35, Map 13). There is only one dairy discharge consent for the Kaitoke Lakes catchment and this is to land.

441. Like other coastal lakes in the Region, the hydrological regime and source of contaminant inputs is complex. Until the capture zones of the catchment's lakes and wetlands are better understood, predicted nitrogen losses from implementation of the FARM strategy (Table 36) cannot be compared with a Standard load limit or Measured load.

Table 35. Proportional land use type and Land Use Capability (LUC) class in the Kaitoke Lakes Water Management Zone.

Land use type	Kaitoke Lakes	LUC class	Kaitoke Lakes
Built-up/Parks	1%	1	9%
Cropping	1%	2	16%
Dairy	4%	3	10%
Exotic Cover	25%	4	4%
Horticulture	-	5	-
Native Cover	5%	6	24%
Other	-	7	32%
Sheep & Beef	65%	8	5%
Water Body	-	Blank	-

Table 36. Proposed nitrogen output limits resulting from the implementation of Rule 13-1 of the Proposed One Plan for the Kaitoke Lakes Water Management Zone. *Note: Nitrogen attenuation of 50% between the land and water was assumed according to Clothier et al. (2007) and Mackay et al. (2008).*

Kaitoke Lakes		LUC I	LUC II	LUC III	LUC IV	LUC V	LUC VI	LUC VII	LUC VIII	Total
Output loss limit	**Year 1** (when rule comes into force) (kg of N/ ha/year)	32	29	22	16	13	10	6	2	
	Year 5 (kg N/ha/year)	27	25	21	16	13	10	6	2	
	Year 10 (kg N/ha/year)	26	22	19	14	13	10	6	2	
	Year 20 (kg N/ha/year)	25	21	18	13	12	10	6	2	
Area of LUC in Kaitoke Lakes (ha)		608	1125	713	246	0	1657	2234	306	6914
Measured load (to water)	**Year 1** (Tonnes/year)	9.73	16.31	7.84	1.97	10.77	11.17	0.92	0.31	59.02
	Year 5 (Tonnes/year)	8.21	14.06	7.49	1.97	10.77	11.17	0.92	0.31	54.89
	Year 10 (Tonnes/year)	7.90	12.38	6.77	1.72	10.77	11.17	0.92	0.31	51.94
	Year 20 (Tonnes/year)	7.60	11.81	6.42	1.60	9.94	11.17	0.92	0.31	49.76
Standard load limit (Tonnes/year)										-

9.11.2 Southern Whanganui Lakes (West_5)

442. The Southern Whanganui Lakes Water Management Zone comprises the catchments of Lakes Bernard, Koitiata, Dudding, Heaton, William, Hickson, Alice, Rhodes and Herbert, a series of coastal lakes and small outflow streams just north of the Rangitīkei River (Map 12). The catchment comprises approximately 195 km^2 and has a large number of

significant wetlands. The land cover is largely modified for pastoral agriculture with a large forestry block to the south-east of the catchment.

443. Water-body values of the Southern Whanganui Lakes are:

- Life-Supporting Capacity – Lowland Mixed (LM) geology
- Contact Recreation
- Mauri
- Stockwater
- Amenity
- Inanga Spawning
- Whitebait Migration
- Site of Significance – Aquatic for banded kōkopu
- Capacity to Assimilate Pollution
- Shellfish Gathering
- Water Supply, Irrigation and Industrial Abstraction.

444. Water quality monitoring data for the Southern Whanganui Lakes is relatively sparse, however Lake Dudding has been monitored under the swimming spots programme for a number of years (see the evidence of Barry Gilliland). Although total phosphorus at Lake Dudding exceeds the POP Standard on all sampling occasions, it is still low relative to other lakes monitored in the Region (Figure 4).

445. Total nitrogen in Lake Dudding also exceeds the POP Standard on all sampling occasions (Figure 5). Like Lakes Wiritoa and Pauri, the low concentrations of SIN suggests that the majority of nitrogen is organic. Ammoniacal nitrogen in Lake Dudding was relatively low, being below the standard on all but one sampling occasion. The 90th percentile for *E. coli* was below the POP summer standard.

446. Although contact recreation is not compromised by faecal contaminants, the elevated concentrations of nutrients mean Lake Dudding is susceptible to algal and cyanobacterial blooms which affect Amenity, Contact Recreation and Stockwater values.

447. Land use information for the Southern Whanganui Lakes catchment suggests that approximately 9% of the catchment is in intensive land use (eg. Dairy and Cropping) (Table 37, Map 13) with most of the catchment dominated by Sheep & Beef (54%). Ten dairy discharge consents are held for the Southern Whanganui catchment; all are to land.

448. Like other coastal lakes in the Region the hydrological regime and contaminant sources are complex. Until the hydrological regime of the catchment lakes and wetlands is better understood, predicted nitrogen losses from implementation of the FARM strategy (Table 38) cannot be compared with a Standard load limit or Measured load for the lakes, streams, wetlands or coastal waters.

Table 37. Proportional land use and Land Use Capability (LUC) class in the Southern Whanganui Lakes Water Management Zone.

Land use type	Southern Whanganui Lakes	LUC class	Southern Whanganui Lakes
Built-up/Parks	-	1	-
Cropping	-	2	7%
Dairy	9%	3	35%
Exotic Cover	36%	4	13%
Horticulture	-	5	-
Native Cover	1%	6	14%
Other	1%	7	30%
Sheep & Beef	54%	8	3%
Water Body	-	Blank	-

Table 38. Proposed nitrogen output limits resulting from the implementation of Rule 13-1 of the Proposed One Plan for the Southern Whanganui Lakes Water Management Zone. *Note: Nitrogen attenuation of 50% between the land and water bodies was assumed according to Clothier et al. (2007) and Mackay et al. (2008).*

Southern Whanganui Lakes		LUC I	LUC II	LUC III	LUC IV	LUC V	LUC VI	LUC VII	LUC VIII	Total
Output loss limit	**Year 1** (when rule comes into force) (kg of N/ ha/year)	32	29	22	16	13	10	6	2	
	Year 5 (kg N/ha/year)	27	25	21	16	13	10	6	2	
	Year 10 (kg N/ha/year)	26	22	19	14	13	10	6	2	
	Year 20 (kg N/ha/year)	25	21	18	13	12	10	6	2	
Area of LUC in Southern Whanganui Lakes (ha)		2	1283	6710	2541	0	2622	5758	520	19457
Measured load (to water)	**Year 1** (Tonnes/year)	0.03	18.60	73.81	20.33	17.04	28.79	1.56	0.52	160.69
	Year 5 (Tonnes/year)	0.03	16.04	70.46	20.33	17.04	28.79	1.56	0.52	154.76
	Year 10 (Tonnes/year)	0.03	14.11	63.75	17.79	17.04	28.79	1.56	0.52	143.58
	Year 20 (Tonnes/year)	0.03	13.47	60.39	16.52	15.73	28.79	1.56	0.52	137.01
Standard load limit (Tonnes/year)										-

9.11.3 Northern Manawatū Lakes (West_6)

449. The Northern Manawatū Lakes Water Management Zone comprises the catchments of Pukepuke and Omanuka Lagoons and Lakes Kaikōkopu and Koputara a series of coastal lakes and wetlands just north of the Rangitīkei River (Map 12). The catchment area is 125 km^2 and the land cover is largely modified for pastoral agriculture throughout the catchment with a large forestry block to the south-east of the catchment boundary (Map 13).

450. Water-body values for the Northern Manawatū Lakes Water Management Zone include:

- Life-Supporting Capacity – Lowland Mixed (LM) geology
- Contact Recreation
- Mauri
- Stockwater
- Amenity
- Site of Significance – Aquatic for redfin bully
- Inanga Spawning
- Whitebait Migration
- Capacity to Assimilate Pollution.

451. There has been no water quality monitoring of coastal lakes within the Northern Manawatū Lakes Water Management Zone but the Lake Kaikōkopu outflow Stream (Kaikokōpu Stream) has been monitored where it reaches the coast at Himatangi Beach as part of the swimming spots monitoring programme (see the evidence of Barry Gilliland). Given the monitoring results from other coastal dune lakes and the biodiversity values of the lakes and wetlands in the zone, it can be assumed that the state of these lakes is similar to those that have been monitored nearby and that the risk of adverse effects on biodiversity and water-body values such as Life-Supporting Capacity, Contact Recreation, Amenity, Stockwater and potential Sites of Significance – Aquatic are also similar.

452. Faecal contaminants in the Kaikōkopu Stream adversely affect Contact Recreation values in the stream and at Himatangi Beach. Coastal water quality adjacent to the zone at Himatangi Beach is impacted by elevated nutrient concentrations and faecal contaminants that adversely affect Contact Recreation, Shellfish Gathering and potentially Life-Supporting Capacity in the coastal environment. One-off monitoring of Kaikōkopu Stream upstream of the Himatangi Beach Township showed extremely elevated DRP (0.13 g/m^3), ammoniacal nitrogen (1.35 g/m^3), total phosphorus (0.453

g/m^3), total nitrogen (2.27 g/m^3) and particulate organic matter (8 g/m^3). This suggests the presence of an algal bloom in Lake Kaikōkopu. Such blooms have been observed during aerial photography runs from time to time; this supports the assertion that the coastal dune lakes in this zone are likely to be nutrient enriched.

453. Land use information for the Northern Manawatū Lakes catchment suggests that approximately 50% of the catchment is in intensive land use (eg. Dairy; Table 39, Map 13). The remaining land use is in Sheep & Beef (28%) and Exotic Cover (19%). There are twenty-nine dairy effluent discharge consents for the Northern Manawatū Lakes Zone; all of these discharges are to land.

454. Like other coastal lakes in the Region the hydrological regime and contaminant sources are complex. Until the capture zones of the catchment lakes and wetlands is better understood, predicted nitrogen losses from implementation of the FARM strategy (Table 40) cannot be compared with a Standard load limit or Measured load for the lakes, streams, wetlands or coastal waters.

Table 39. Proportional land use and Land Use Capability (LUC) class in the Northern Manawatū Lakes Water Management Zone.

Land use type	Northern Manawatū Lakes	LUC class	Northern Manawatū Lakes
Built-up/Parks	-	1	-
Cropping	-	2	-
Dairy	50%	3	34%
Exotic Cover	19%	4	22%
Horticulture	-	5	-
Native Cover	2%	6	29%
Other	-	7	13%
Sheep & Beef	28%	8	2%
Water Body	-	Blank	1%

Table 40. Proposed nitrogen output limits resulting from the implementation of Rule 13-1 of the Proposed One Plan for the Northern Manawatū Lakes Water Management Zone. *Note: Nitrogen attenuation of 50% between the land and water bodies was assumed according to Clothier et al. (2007) and Mackay et al. (2008).*

Northern Manawatū Lakes		LUC I	LUC II	LUC III	LUC IV	LUC V	LUC VI	LUC VII	LUC VIII	Total
Output loss limit	**Year 1** (when rule comes into force) (kg of N/ ha/year)	32	29	22	16	13	10	6	2	
	Year 5 (kg N/ha/year)	27	25	21	16	13	10	6	2	
	Year 10 (kg N/ha/year)	26	22	19	14	13	10	6	2	
	Year 20 (kg N/ha/year)	25	21	18	13	12	10	6	2	
Area of LUC in Northern Manawatū Lakes (ha)		0	0	4249	2745	0	3696	1649	289	12684
Measured load (to water)	**Year 1** (Tonnes/year)	0.00	0.00	46.74	21.96	24.02	8.25	0.87	0.29	102.12
	Year 5 (Tonnes/year)	0.00	0.00	44.61	21.96	24.02	8.25	0.87	0.29	100.00
	Year 10 (Tonnes/year)	0.00	0.00	40.37	19.22	24.02	8.25	0.87	0.29	93.01
	Year 20 (Tonnes/year)	0.00	0.00	38.24	17.84	22.18	8.25	0.87	0.29	87.66
Standard load limit (Tonnes/year)										-

Key points: Coastal Lakes target catchments

For all coastal lake catchments the monitoring data is limited and the interacting groundwater and surface water inputs (both hydrological and contaminant inputs) are complex. Standard load limits, Measured loads and output loss limits from Table 13.2 of the POP are unable to be compared or calculated for these zones and the influence of land use and hydrologic regime on the coastal environment adjacent to these zones is not well described.

Kaitoke Lakes

i. This zone comprises the catchments of lakes, wetlands and drainage systems towards the coast south of the Whanganui River and drains 69 km^2.

ii. Nutrient concentrations are elevated and are higher in Lake Pauri than in Lake Wiritoa. *Escherichia coli* is generally within standards although cyanobacterial blooms often occur and these are frequently toxic.

iii. Land use is predominantly Sheep & Beef (65%) and Exotic Cover (25%) with only 4% of the catchment land use in Dairy and one dairy effluent discharge consent.

iv. Contact Recreation, Amenity, Stockwater and coastal Shellfish Gathering values are affected by poor water quality and cyanobacterial blooms.

Southern Whanganui Lakes

v. This zone comprises the lakes, wetlands and drainage systems between the Kaitoke Lakes Zone and the Rangitīkei River (195 km^2);

vi. Nitrogen concentrations in Lake Dudding are elevated, but *E. coli* is generally within standards. Cyanobacterial blooms occur which are toxic at times;

vii. Land use is predominantly Sheep & Beef (54%) and Exotic Cover (36%) with 9% of the zone in Dairy. There are ten dairy effluent discharge consents.

Northern Manawatū Lakes

viii. This zone comprises lakes, wetlands and drainage systems in the Himatangi sand country north of the Manawatū River (125 km^2);

ix. Limited water quality monitoring suggests the Kaikōkopu outflow stream contains elevated nutrient concentrations flowing from the lake; this lake is subject to algal blooms, affecting water quality in the stream and at Himatangi Beach.

x. Land use is predominantly Dairy (50%), with Sheep & Beef (28%) and Exotic Cover (19%) making up the remainder. There are 29 dairy effluent consents.

9.11.4 Coastal Rangitīkei (Rang_4a, Rang_4b, Rang_4c, Rang_4d)

455. The Coastal Rangitīkei Water Management Zone encompasses the catchment of the Rangitīkei mainstem and tributaries from Onepuhi to the mouth of the river at Tangimoana and includes the sub-zone catchments of the Porewa and Tūtaenui Streams (Map 31), a total catchment area of 661 km^2. Water allocation in the Rangitikei was determined by a Water Resource Assessment (Roygard and Carlyon, 2006). Water is still available for allocation in the catchment (see the evidence of Raelene Hurndell for more information).

456. Values in the Coastal Rangitīkei Water Management Zone are:

- Life-Supporting Capacity – Hill Mixed (HM), Lowland Mixed (LM), Hill Soft Sedimentary (HSS) geology
- Contact Recreation
- Amenity
- Mauri
- Trout Fishery - other
- Stockwater
- Natural State
- Site of Significance – Aquatic for brown mudfish, redfin bully and giant kōkopu
- Site of Significance – Riparian for dotterel
- Inanga Spawning
- Whitebait Migration
- Trout Spawning
- Capacity to Assimilate Pollution
- Shellfish Gathering
- Water Supply, Industrial Abstraction and Irrigation.

457. Water quality issues in the Rangitīkei catchment are generally isolated to the lower mainstem and tributaries in the Coastal Rangitīkei Water Management Zone; some of the pertinent issues are documented in Roygard and Carlyon (2006) and McArthur and Clark (2007). However there are some areas of the catchment upstream of the coastal zone that have varying water quality issues with respect to nutrient load or faecal contaminants (see Appendix 2), for example the lower Hautapu River (Ballantine and Davies-Colley, 2009b) and the Rangitīkei mainstem from Mangaweka downstream, which has experienced significant periphyton blooms in recent years (Photo 7).

458. River health (as measured by MCI score) declines from upstream to downstream (Figure 42); as would be expected. The Rangitīkei at Kākāriki (just 6.8 km downstream of the upper boundary of the zone at Onepuhi) and the Rangitīkei at Scott's Ferry often have MCI scores that vary between fair and poor. The recommended MCI standard for the Coastal Rangitīkei is 100; this has not often been met.

459. The Coastal Rangitīkei Water Management Zone is subject to a number of significant point source discharges in the mainstem and tributaries (see Table 16 in previous sections on point source contributions to water quality). These have an influence on the SIN (Figure 43), DRP (Figure 44) and *E. coli* (Figure 45) in the tributaries themselves and on the nitrogen loads to the wider catchment (Map 30).

460. The Tūtaenui, Porewa, Pikatu and Rangitawa streams are all subject to point sources from the Marton, Hunterville, Sanson and Halcombe STP discharges respectively. Just below the Bulls Bridge (SH1), the Bulls STP and Riverlands meatworks discharges enter the mainstem of the river. Ohakea STP flows into the Rangitīkei after discharge into a drainage system some 4.4 km downstream of the Bulls Bridge and the Flockhouse STP system discharges into the Parewanui drainage system which also enters the river near Scott's Ferry. The only significant discharges to the Rangitīkei catchment outside of the coastal zone are the Taihape STP discharge to the Hautapu River and a small discharge from the Mangaweka STP.

461. With regard to nutrient enrichment in the lower Rangitīkei, the water quality standards have been set to maintain the Rangitīkei River in a generally 'good state' so as to maintain values such as Life-Supporting Capacity, Contact Recreation and Trout Fishery, and to prevent any further degradation as a result of land use intensification in the coastal zone.

462. Figure 46 shows the SIN concentrations at SoE sites in the mainstem of the Rangitīkei from upstream to downstream. Soluble inorganic nitrogen increases from upstream to downstream. The mean concentration is generally within the proposed standards until the river reach between the McKelvies and Scott's Ferry sites. The 25^{th} percentile for SIN concentration is elevated at Scott's Ferry.

463. Figure 47 shows the DRP concentrations at the same SoE sites. The mean DRP exceeds the POP standards from Onepuhi downstream. Some of the elevated dissolved reactive phosphorus in the upper catchment can be attributed to natural

sources from the volcanic acidic geology. Again the 25th percentile for dissolved reactive phosphorus at the Scott's Ferry site is elevated.

464. Figure 48 shows the *E. coli* concentrations from SoE sites upstream to downstream in the Rangitīkei mainstem. Generally concentrations are within the standards but the McKelvies and Scott's Ferry 75th percentiles start to exceed the summer and year-round standards respectively.

465. Few data points for the McKelvies site were available for the investigation of comparative contributions of N and P at low flows by McArthur and Clark (2007). Further investigation of contributions from point and non-point sources suggests that nitrogen, phosphorus and *E. coli* loads exceed the standards at higher flows. The Riverlands meatworks discharge contributes significantly to nutrient and faecal loads at McKelvies (regardless of flow) in addition to some non-point sourced *E. coli* contributions. The implementation of the FARM strategy in the Coastal Rangitīkei zone is largely driven by the need to ensure land use intensification does not degrade the river any further. For further information on the potential for expansion of intensive land uses in the Coastal Rangitikei zone refer to the evidence of Dr Roygard.

466. It should be noted that localised impacts from point and non-point sources are significant in the tributaries of the Rangitīkei and may adversely affect values such as Contact Recreation, Life-Supporting Capacity, Trout Fishery and Stockwater at the sub-zone level. Elevated nutrient concentrations at Scott's Ferry suggest there are non-point source inputs of both nutrients and faecal contaminants originating from the catchment land use between McKelvies and Scott's Ferry. This contamination is likely to adversely impact on values such as contact recreation, Stockwater, Amenity, Shellfish Gathering and Life-Supporting Capacity in the lower river, estuary and the coastal environment.

Photo 7. Periphyton bloom in the Rangitīkei River near Ohingaiti March 2009 (Photo: Peter Taylor).

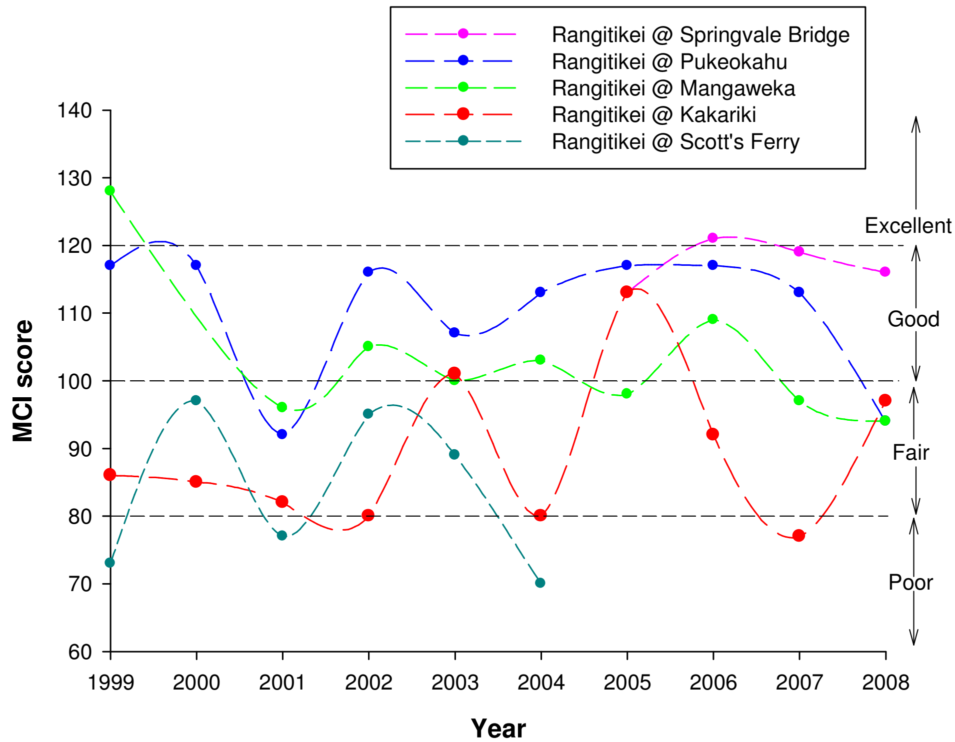
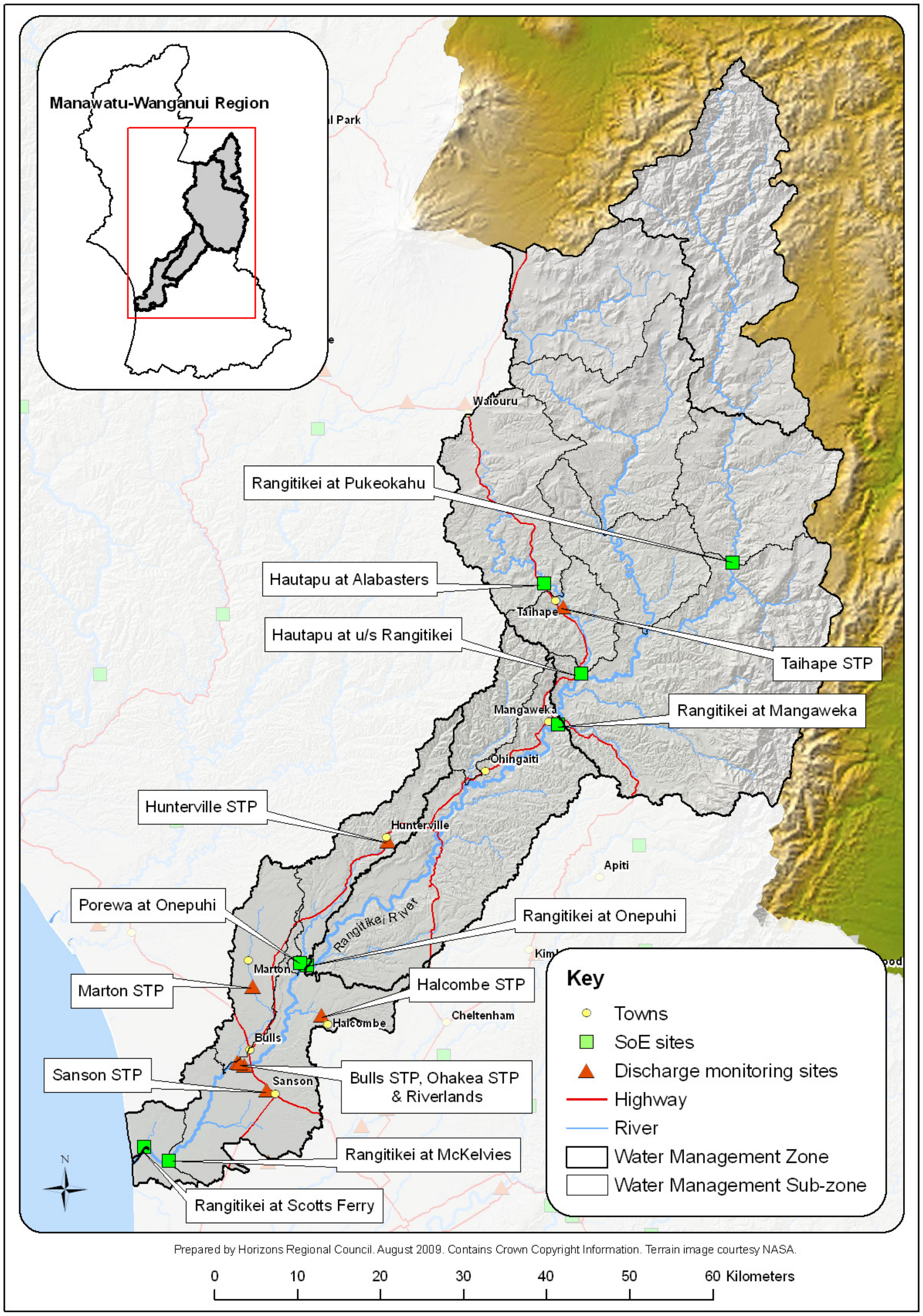


Figure 42. Changes in Macroinvertebrate Community Index (MCI) scores between 1999 and 2008 at five sites on the Rangitīkei River. From upstream to downstream the sites are Rangitīkei at Springvale Bridge, Rangitīkei at Pukeokahu, Rangitīkei at Mangaweka, Rangitīkei at Kākāriki, and Rangitīkei at Scott's Ferry. The water quality classes shown on the graph are according to Stark and Maxted (2007).



Map 30. State of the Environment and discharge monitoring sites in the Rangitīkei River catchment.

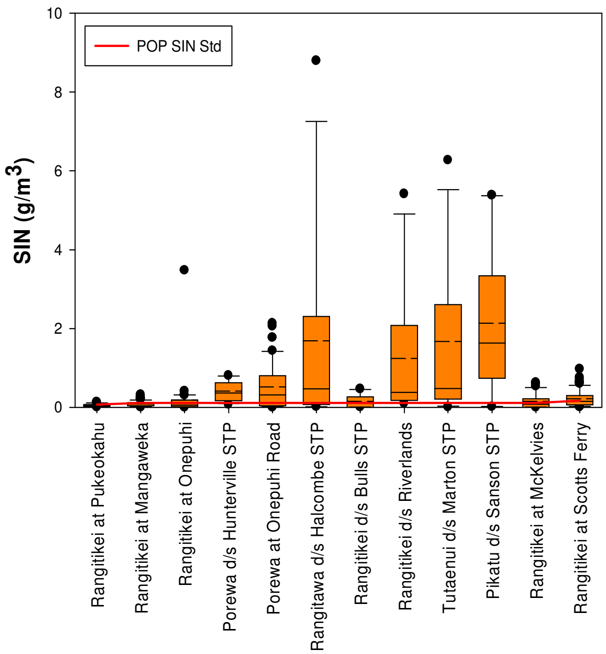


Figure 43. Soluble inorganic nitrogen (SIN) concentration at sites within the Coastal Rangitīkei Water Management Zone collected over various timeframes since 1993. Sites are in order from upstream to downstream from left to right.

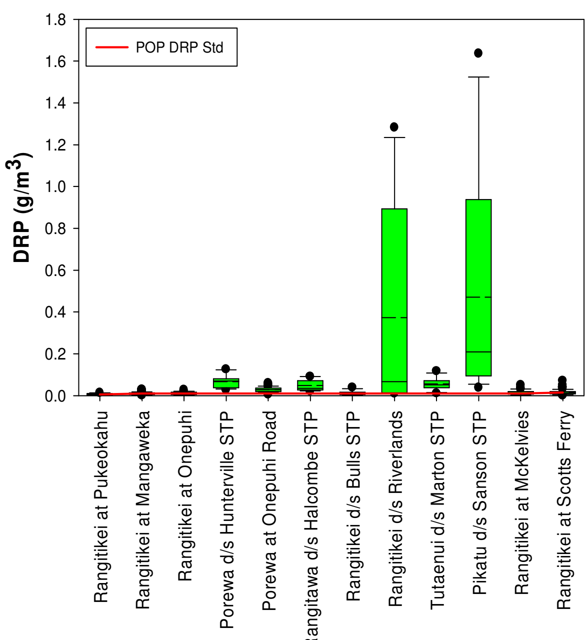


Figure 44. Dissolved reactive phosphorus (DRP) concentration at sites within the Coastal Rangitīkei Water Management Zone collected over various timeframes since 1993. Sites are in order from upstream to downstream from left to right.

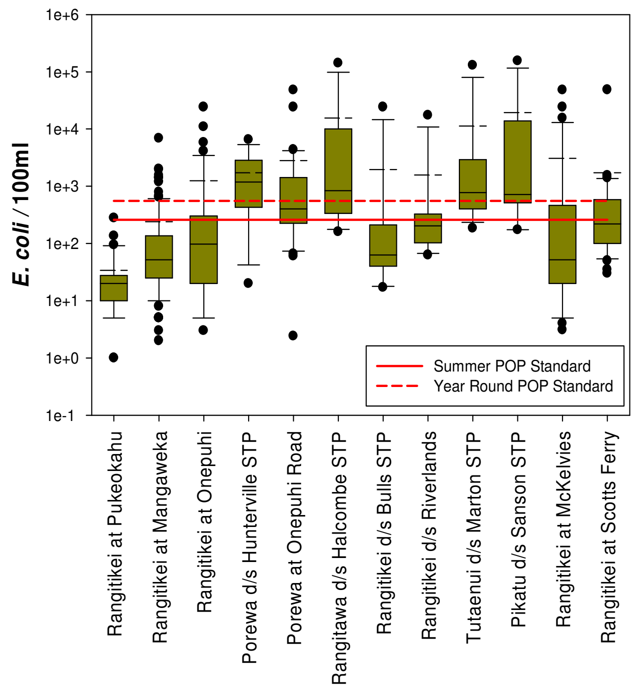


Figure 45. Log_{10} *Escherichia coli* concentration at sites within the Coastal Rangitīkei Water Management Zone collected over various timeframes since 1993. Sites are in order from upstream to downstream from left to right.

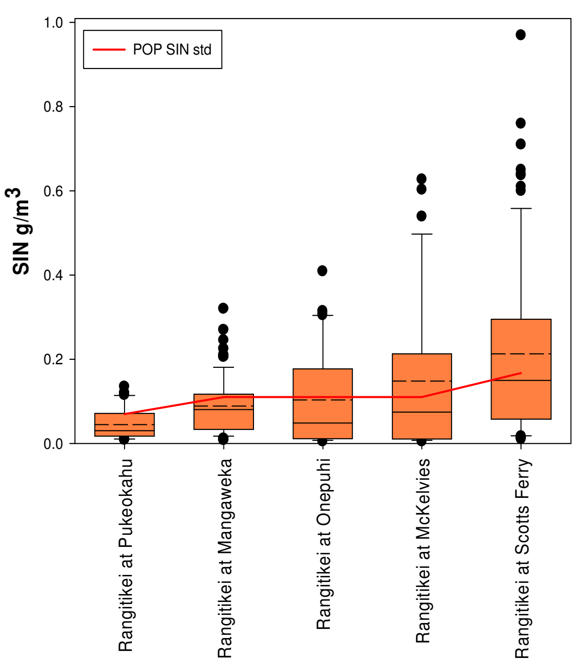


Figure 46. Soluble inorganic nitrogen (SIN) concentration at State of the Environment sites within the Coastal Rangitīkei Water Management Zone collected over various timeframes since 1993. Sites are in order from upstream to downstream from left to right.

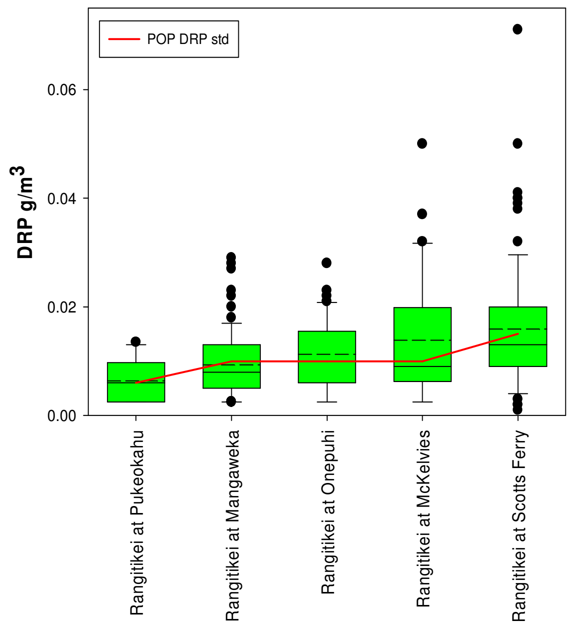


Figure 47. Dissolved reactive phosphorus (DRP) concentration at State of the Environment sites within the Coastal Rangitīkei Water Management Zone collected over various timeframes since 1993. Sites are in order from upstream to downstream from left to right.

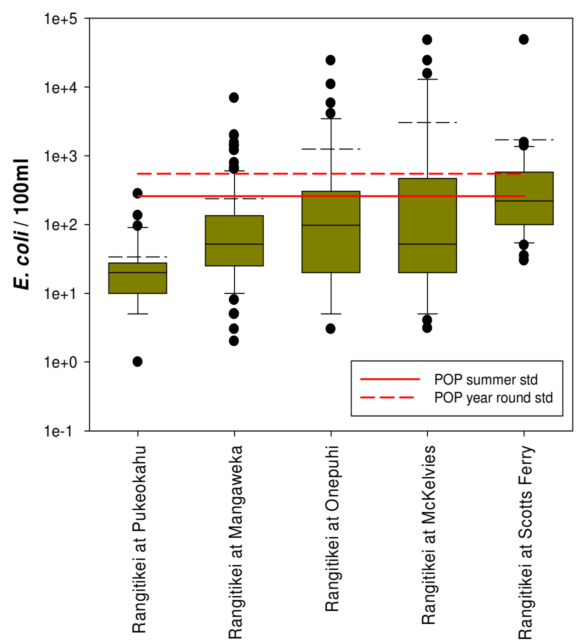


Figure 48. Log_{10} *Escherichia coli* concentration at State of the Environment sites within the Coastal Rangitīkei Water Management Zone collected over various timeframes since 1993. Sites are in order from upstream to downstream from left to right.

467. Land use in the Coastal Rangitīkei target catchment is predominantly Sheep & Beef farming (66%) with Dairy (20%) being the second most common land use (Table 41, Map 32). There are 95 dairy discharges to the Coastal Rangitīkei Water Management Zone, and of these three are to water. The predicted nitrogen load from Year 20 implementation of the FARM strategy (Table 42), based on LUC class (Map 33) in the Coastal Rangitīkei, is 204% of the Standard load limit calculated for the Rangitīkei at McKelvies site of 282 tonnes SIN/year. However, the predicted load from Table 42 includes loads from the land area in the Tidal Rangitīkei sub-zone between the McKelvies site and the river mouth. The SIN concentration standard for the tidal sub-zone is 167 mg/m^3 as opposed to the 110 mg/m^3 standard at McKelvies, from which the Standard load limit was calculated. Further calculations are required to directly compare the predicted losses by LUC for the target catchment area upstream of McKelvies with the Standard load limit calculated for that site.

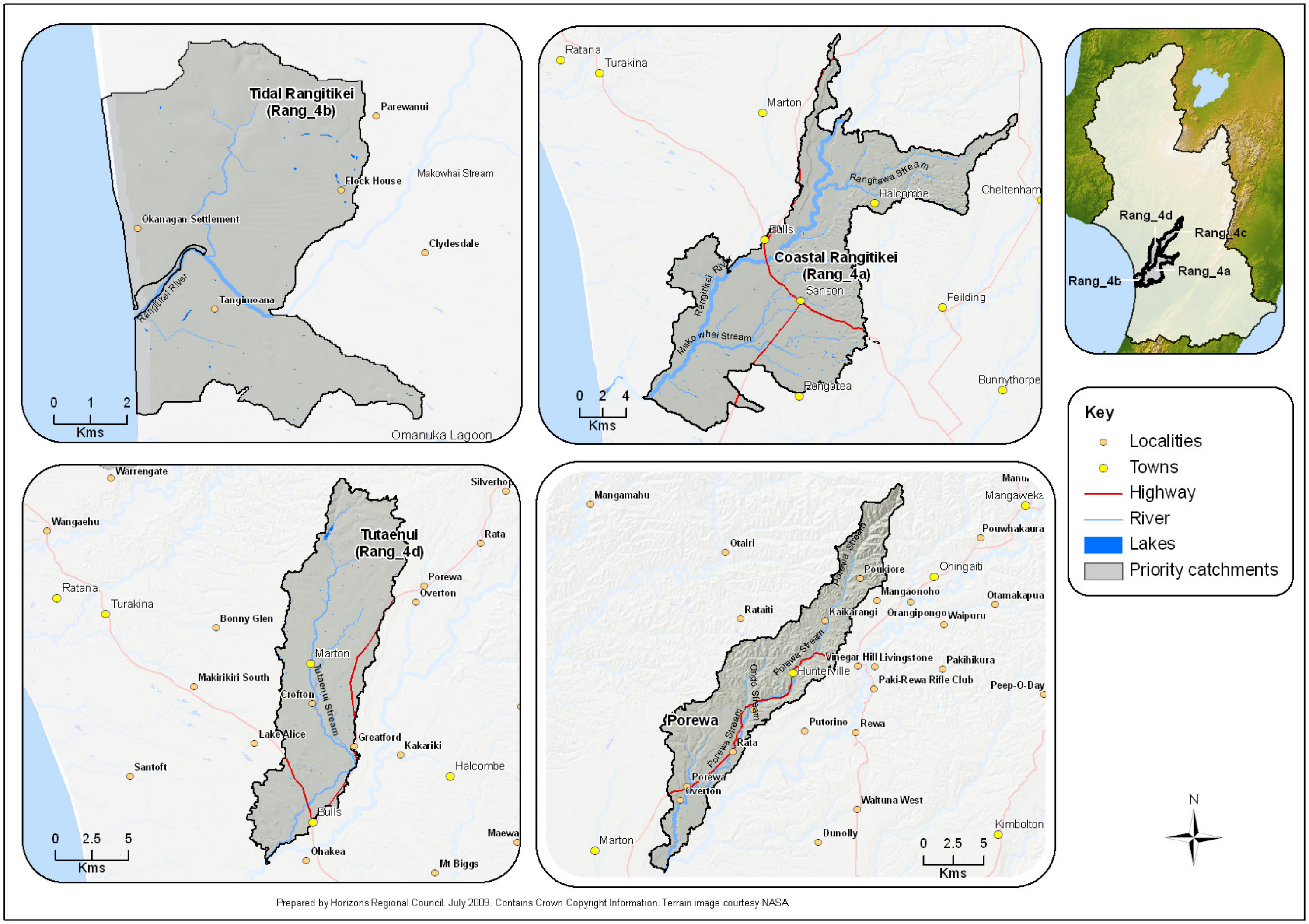
468. An additional complication (similar to the situation for the Manawatū above Gorge zone) arises from allowing for the cumulative contaminant inputs from the catchment area upstream of the target zone when comparing the impact of nitrogen loads from the target catchment to the Standard load limit for the zone.

Table 41. Proportional land use and Land Use Capability (LUC) class in the Coastal Rangitīkei Water Management Zone.

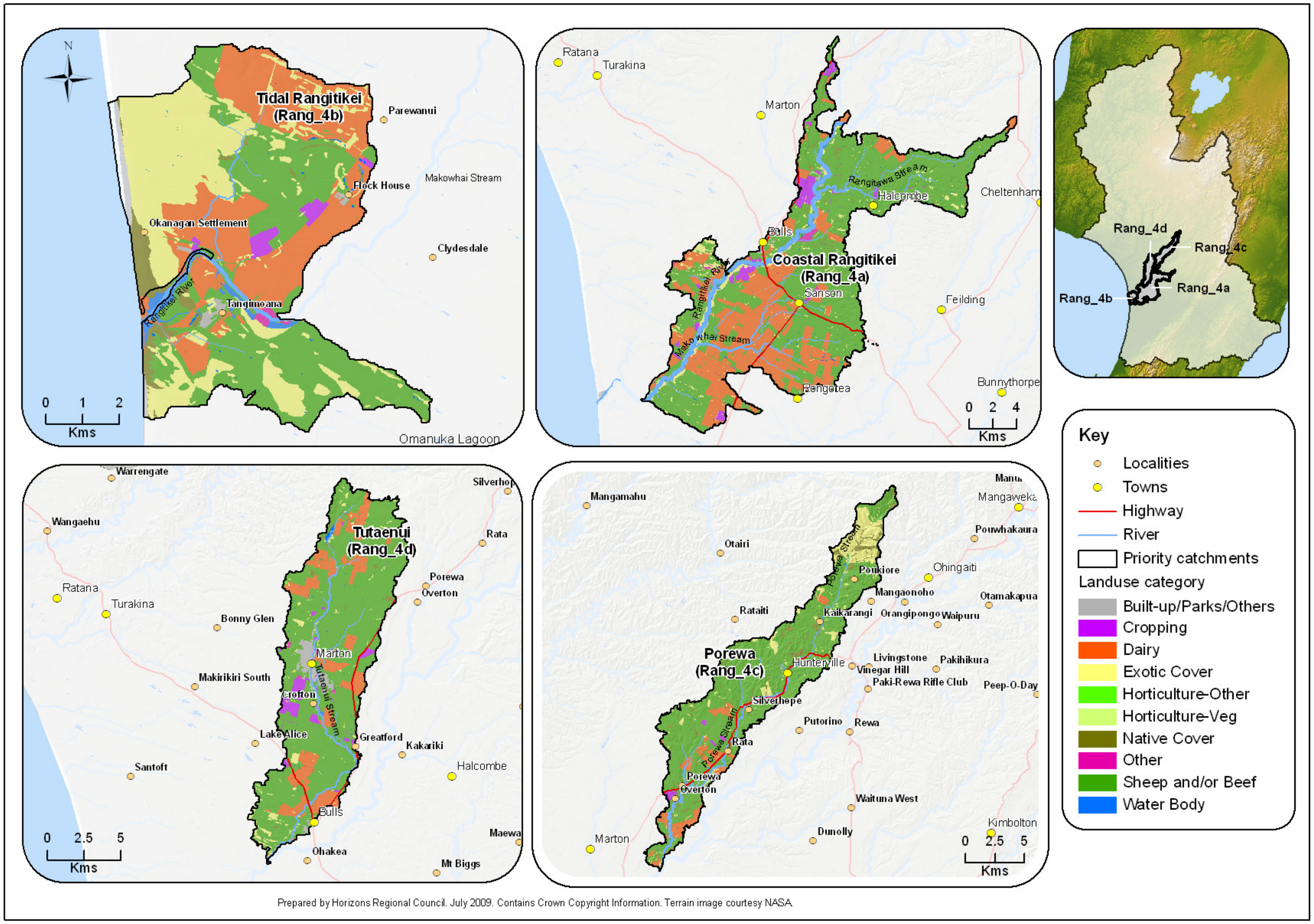
Land use type	Coastal Rangitīkei	LUC class	Coastal Rangitīkei
Built-up/Parks	1%	1	7%
Cropping	2%	2	44%
Dairy	20%	3	11%
Exotic Cover	8%	4	8%
Horticulture	-	5	-
Native Cover	2%	6	24%
Other	-	7	4%
Sheep & Beef	66%	8	1%
Water Body	1%	Blank	3%

Table 42. Proposed nitrogen output limits resulting from the implementation of Rule 13-1 of the Proposed One Plan for the Coastal Rangitīkei Water Management Zone. *Note: Nitrogen attenuation of 50% between the land and river was assumed according to Clothier et al. (2007) and Mackay et al. (2008).*

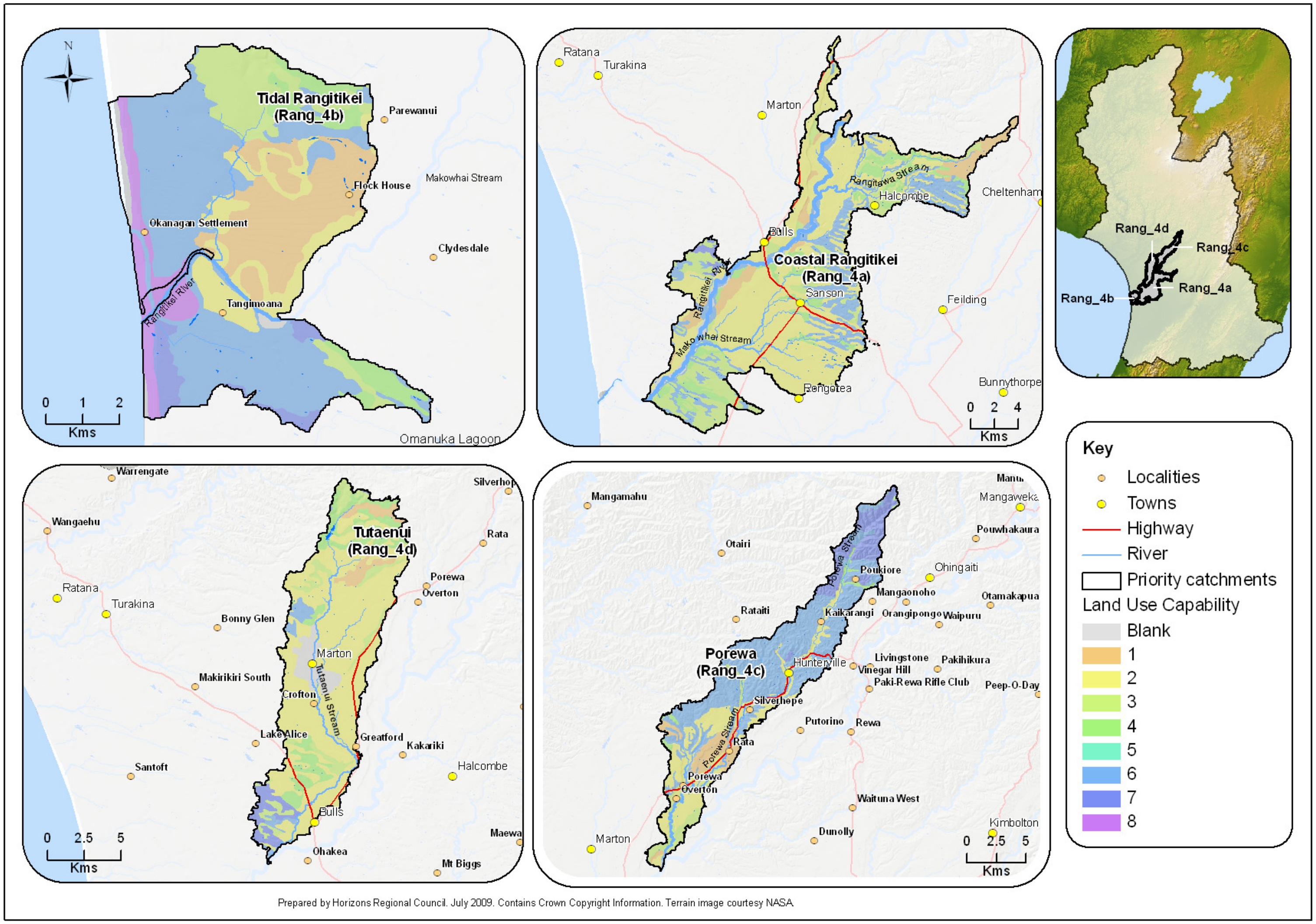
Coastal Rangitīkei		LUC I	LUC II	LUC III	LUC IV	LUC V	LUC VI	LUC VII	LUC VIII	Total
Output loss limit	**Year 1** (when rule comes into force) (kg of N/ ha/year)	32	29	22	16	13	10	6	2	
	Year 5 (kg N/ha/year)	27	25	21	16	13	10	6	2	
	Year 10 (kg N/ha/year)	26	22	19	14	13	10	6	2	
	Year 20 (kg N/ha/year)	25	21	18	13	12	10	6	2	
Area of LUC in Coastal Rangitīkei (ha)		4666	29367	7072	5011	0	16151	2768	414	67307
Measured load (in-river)	**Year 1** (Tonnes/year)	74.66	425.82	77.79	40.09	104.98	13.84	1.24	0.41	738.84
	Year 5 (Tonnes/year)	62.99	367.09	74.26	40.09	104.98	13.84	1.24	0.41	664.90
	Year 10 (Tonnes/year)	60.66	323.04	67.18	35.08	104.98	13.84	1.24	0.41	606.43
	Year 20 (Tonnes/year)	58.33	308.35	63.65	32.57	96.91	13.84	1.24	0.41	575.30
Standard load limit (Tonnes/year)										282



Map 31. Target catchments of the Coastal Rangitīkei Water Management Zone.



Map 32. Land use in Coastal Rangitīkei Water Management Zone.



Map 33. Land Use Capability (LUC) classes for the Coastal Rangitīkei Water Management Zone.

Key points: Coastal Rangitīkei target catchment

i. The Coastal Rangitīkei is a large zone covering the Rangitīkei mainstem and tributaries between Onepuhi and the coast (661 km^2).

ii. Nutrient concentrations are elevated in the lower river catchments, increasing downstream. Levels of *E. coli* are generally within the standards but also increase at downstream sites. Some of the contaminants come from point sources in the mainstem and tributaries, in particular the Riverlands meatworks discharge at the Bulls Bridge.

iii. Macroinvertebrate Community Index (MCI) decreases downstream and is often below the recommended standard at downstream sites. Periphyton proliferation has been considerable over recent summers throughout the mainstem.

iv. Land use in the catchment is predominantly Sheep & Beef (66%) with Dairy the second most common (20%). There are 95 dairy discharge consents in the catchment, three of which are to water.

v. Poor water quality and resultant high periphyton growth adversely affect Contact Recreation, Amenity, Life-Supporting Capacity, Stockwater and potentially Sites of Significance – Aquatic values.

vi. The year 20 output loss limits predicted from the application of Table 13.2 of the POP cannot be compared to the Standard load limit until the cumulative nutrient loads from upstream inflows are accurately accounted for.

9.12 Mangawhero and Makotuku (Whau_3b, Whau_3c, Whau_3d, Whau_3f)

469. The Mangawhero and Makotuku Rivers arise on the Western slopes of Mount Ruapehu. The sub-zones which make up these target catchments have a total catchment area of 264 km^2 and are tributaries of the Whangaehu River. The Makotuku flows into the Mangawhero just downstream of the township of Raetihi and the Mangawhero flows into the Whangaehu 17 km upstream of Whangaehu at Kauangaroa monitoring site, in the lower Whangaehu river catchment. Water is fully allocated in some sub-zones of the Whangaehu, including the Makotuku (for more information see the evidence of Raelene Hurndell).

470. The values identified for the upper Mangawhero and Makotuku Water Management Sub-zones are:

- Life-Supporting Capacity – Upland Volcanic Acidic (UVA) geology
- Contact Recreation
- Mauri

- Trout Fishery - other
- Stockwater
- Natural State
- Site of Significance – Aquatic for whio (blue duck)
- Site of Significance – Riparian for dotterel
- Trout Spawning
- Capacity to Assimilate Pollution
- Water Supply, Irrigation and Industrial Abstraction.

471. River health as measured by MCI is high at both of the upper catchment sites on the Mangawhero and Makotuku Rivers (Figure 49) and declines rapidly downstream. The recommended standard for MCI for both catchments is 120. Monitoring of the Mangawhero downstream of the Makotuku confluence shows that the MCI score over several years has been significantly lower than the recommended standard at this point and that the water quality class is fair rather than the excellent class that would be expected for an upper catchment in the UVA Life-Supporting Capacity class. These results show that water quality is having an adverse impact on the Life-Supporting Capacity value at this site.

472. There are two significant point sources in this target catchment (Map 34). Ohakune STP discharges to the Mangawhero River just downstream of the Ohakune township and the Raetihi STP discharges to the Makotuku just downstream of the township of Raetihi. Water quality monitoring for the catchment shows that there are significant increases in SIN between the upper site at DoC Headquarters and the site upstream of the Ohakune STP discharge (Figure 50). All sites except the Mangawhero at DoC Headquarters exceed the proposed standard. The site upstream of Ohakune STP is influenced by the land use within the Mangawhero catchment between these two sites and from inflow from tributaries such as the Mangateitei Stream. Elevated SIN at the Makotuku at State Highway 49A site is of some concern considering the small amount of land not in Native Cover upstream of the monitoring site; this area requires further investigation. Raetihi STP also contributes significantly to the elevated SIN concentrations measured at the Mangawhero downstream of the Makotuku confluence (Figure 53). Both point and non-point sources influence the concentrations at various points in the catchments.

473. Dissolved reactive phosphorus is high throughout the catchments (Figure 51). High background concentrations at DoC Headquarters are naturally sourced from the catchment geology. Both the Ohakune and Raetihi STPs contribute significantly to

concentrations measured at State of the Environment sites (Figure 54), although the elevated concentrations on the Makotuku at SH49A are of unknown origin.

474. *Escherichia coli* is very low at the top of the catchment but increases downstream (Figure 52 and Figure 55), with point sources appearing to cause a slight elevation at downstream sites. Again the Makotuku at SH49A site is of some concern. Values that are affected by elevated nutrient and faecal concentrations are Life-Supporting Capacity, Contact Recreation, Stockwater, Amenity and Trout Fishery.

475. There are five dairy effluent discharges to the upper Mangawhero and Makotuku Water Management Sub-zones (Map 35); of these one is to water. Land use in the sub-zones is predominantly Sheep & Beef (58%) with 38% of the catchment area in Native Cover (Table 43). Intensive land uses like Horticulture and Dairy make up 3% of the land use combined (Map 36 and Map 37). The predicted Year 20 nitrogen load of 186.5 tonnes SIN/year is 604% of the Standard load limit of 30.9 tonnes SIN/year (Table 44). However the Standard load limit for the sub-zones was calculated using flow from the Mangawhero at Ore Ore at the bottom of the lower Mangawhero sub-zone. Further work is needed to calculate the Standard load limit accurately for the Mangawhero at Makotuku confluence, which is the bottom of the target catchment.

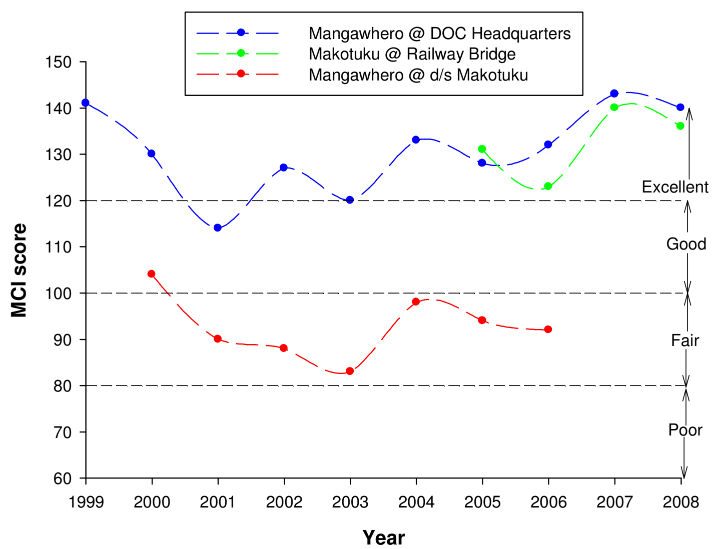
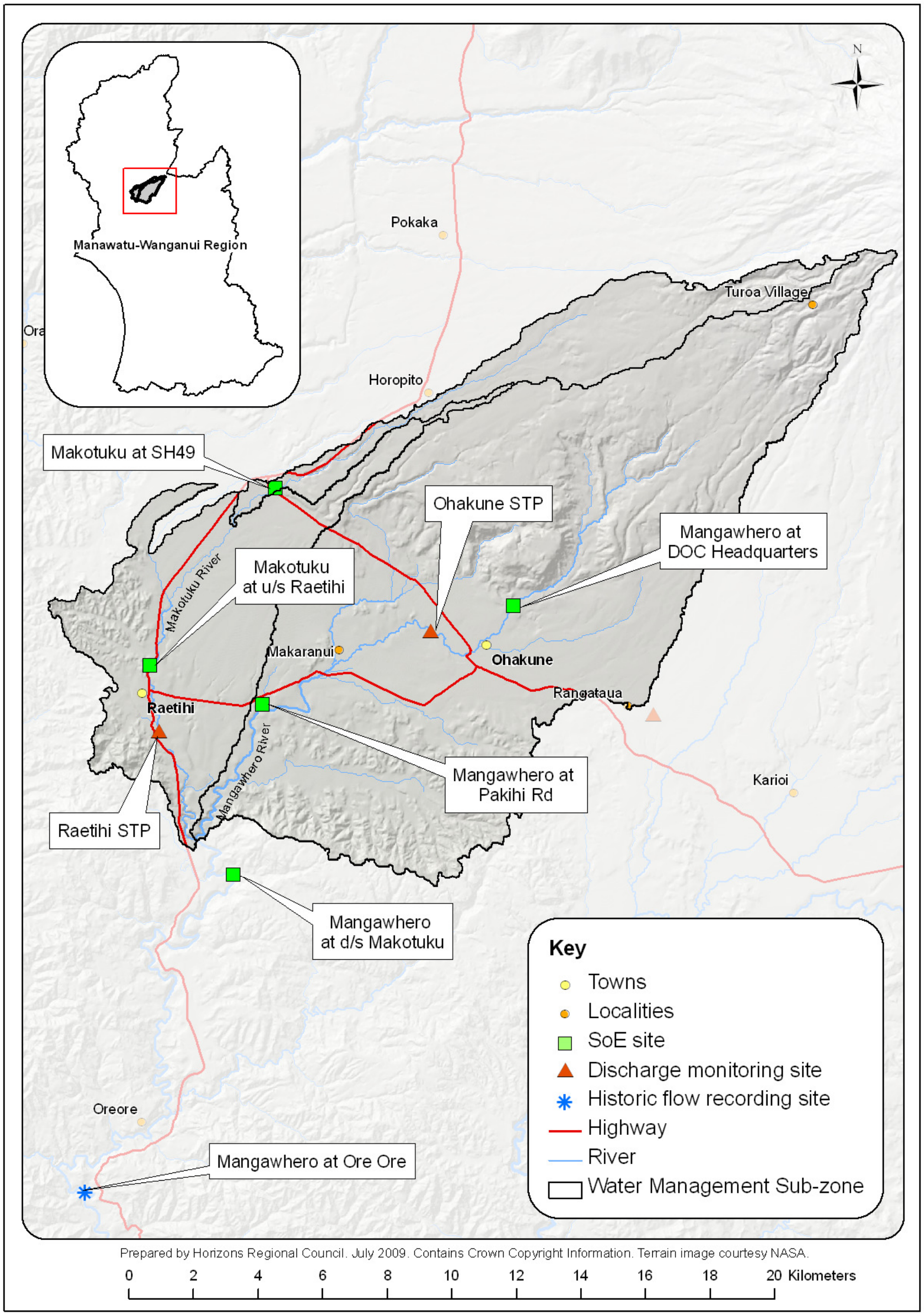


Figure 49. Changes in Macroinvertebrate Community Index (MCI) score between 1999 and 2008 at three sites on the Mangawhero and Makotuku Rivers. The upstream sites are Mangawhero at DOC Headquarters and Makotuku at Railway Bridge. The downstream site is Mangawhero at Makotuku. The water quality classes as shown on the graph are according to Stark and Maxted (2007).



Map 34. Upper Mangawhero and Makotuku River State of the Environment and discharge monitoring sites.

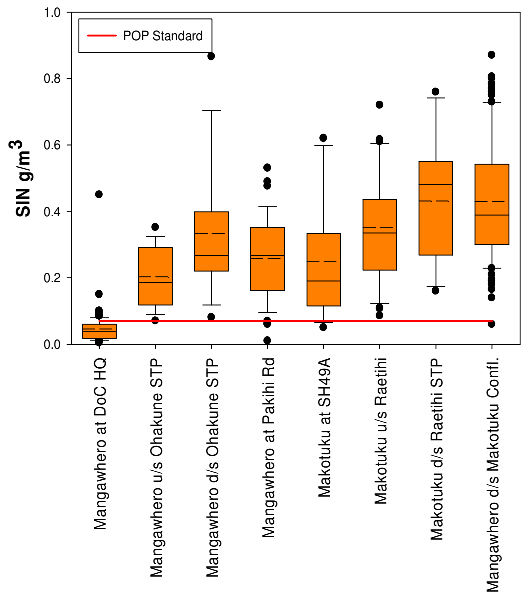


Figure 50. Soluble inorganic nitrogen (SIN) concentration at sites within the Mangawhero and Makotuku Water Management Sub-zones collected over various timeframes since 1989. Three outliers have been removed from the graph of the Mangawhero downstream Ohakune STP Site 10.66 g/m^3 (6/12/2007), 5.44 g/m^3 (13/11/2008) and 3.2 g/m^3 (16/10/2008).

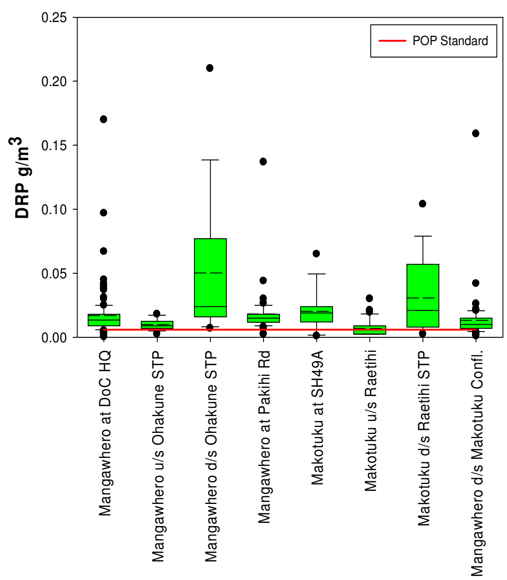


Figure 51. Dissolved reactive phosphorus (DRP) concentration at sites within the Mangawhero and Makotuku Water Management Sub-zones collected over various timeframes since 1989. Three outliers have been removed from the graph of the Mangawhero downstream Ohakune STP Site 1.725 g/m^3 (6/12/2007), 1.58 g/m^3 (13/11/2008) and 1.147 g/m^3 (16/10/2008).

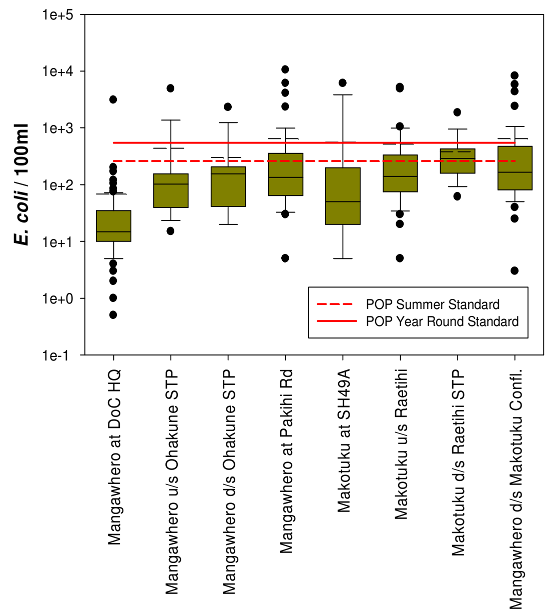


Figure 52. *Escherichia coli* concentration at sites within the Mangawhero and Makotuku Water Management Sub-zones collected over various timeframes since 1989. Outliers have been removed from the Makotuku upstream Raetihi (24200 on 6/12/2007), Makotuku downstream Raetihi (11198.7 on 11/09/2007 and 11200 on 06/12/2007) and Mangawhero downstream Makotuku (11200 on 29/04/2002).

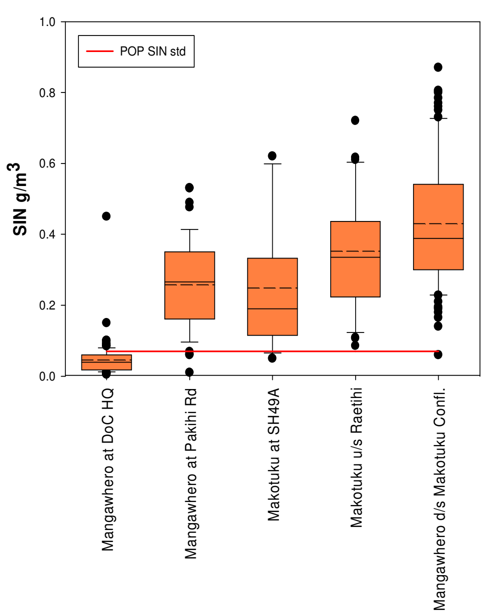


Figure 53. Soluble inorganic nitrogen (SIN) concentration at State of the Environment sites within the Mangawhero and Makotuku Water Management Sub-zones collected over various timeframes since 1989.

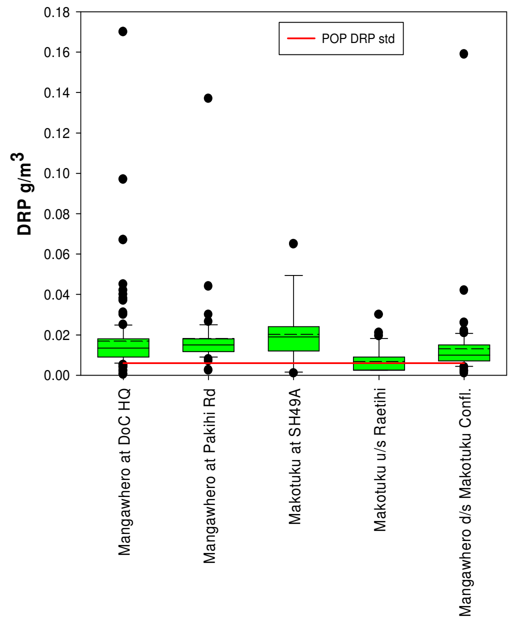


Figure 54. Dissolved reactive phosphorus (DRP) concentration at State of the Environment sites within the Mangawhero and Makotuku Water Management Sub-zones collected over various timeframes since 1989.

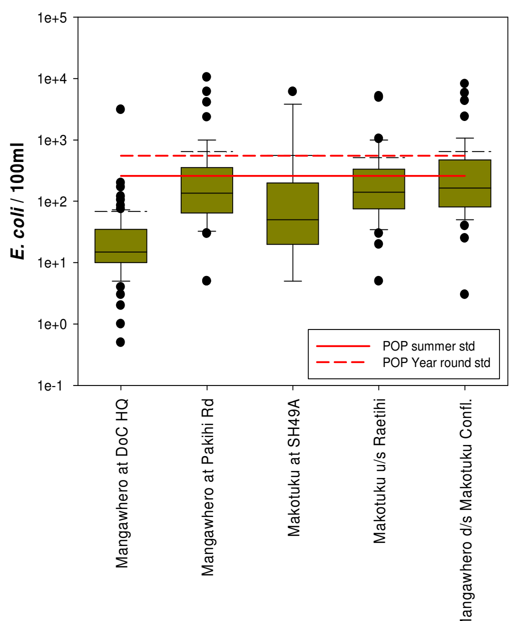
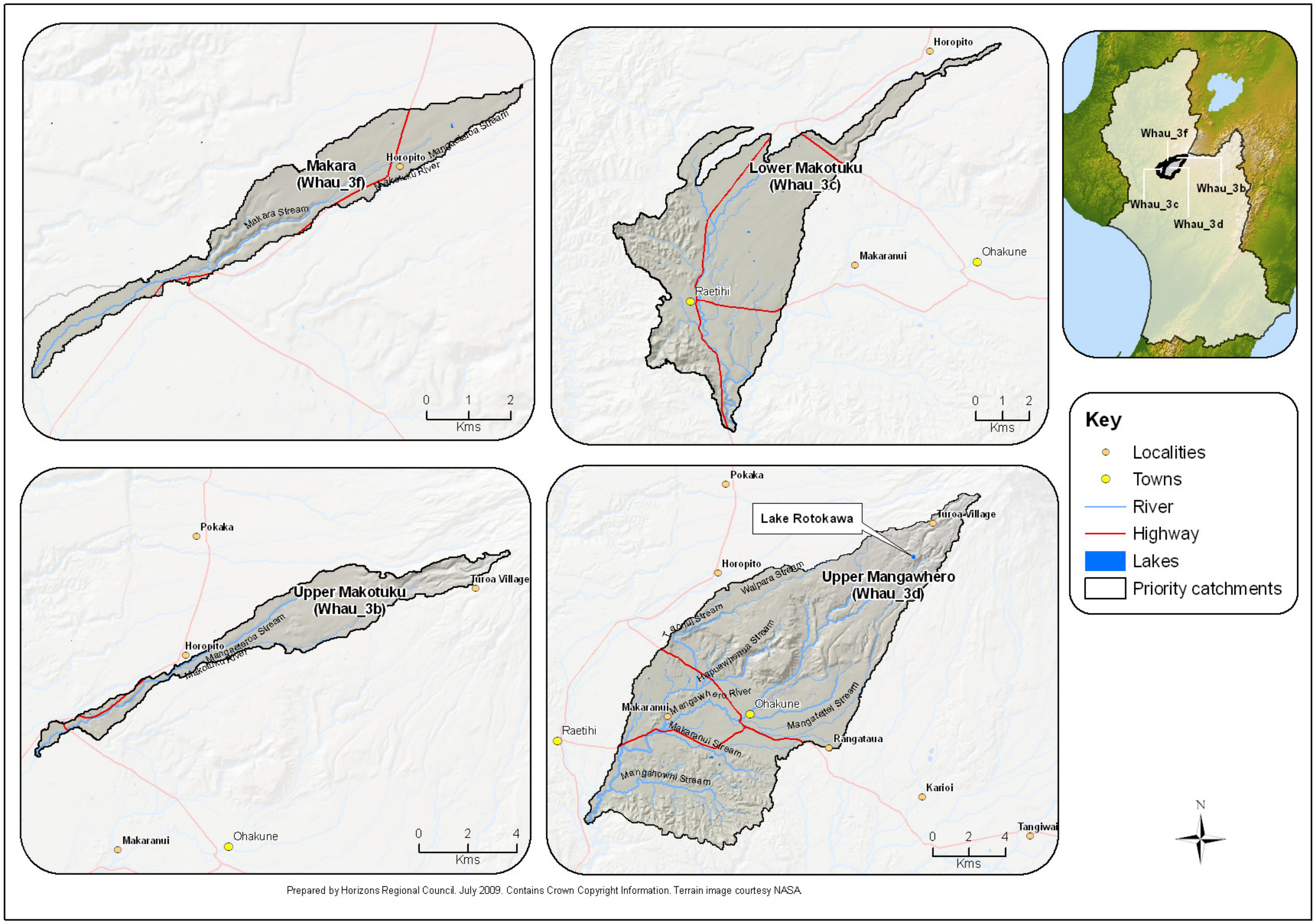


Figure 55. *Escherichia coli* concentration at State of the Environment sites within the Mangawhero and Makotuku Water Management Sub-zones collected over various timeframes since 1989. Outliers have been removed from the Makotuku upstream Raetihi (24200 on 6/12/2007) and Mangawhero downstream Makotuku (11200 on 29/04/2002).



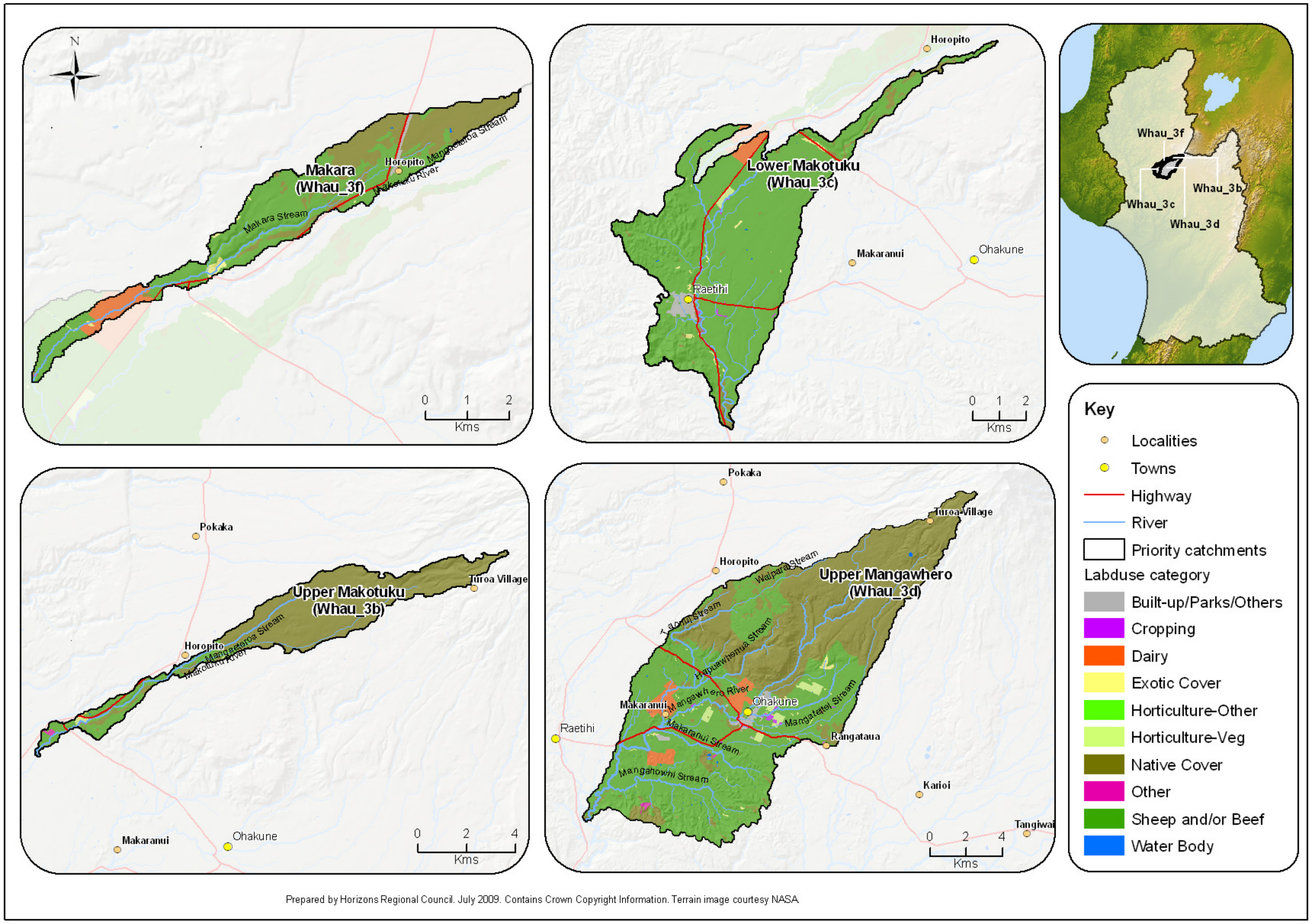
Map 35. Target catchments in the Mangawhero and Makotuku Water Management Sub-zones.

Table 43. Proportional land use and Land Use Capability (LUC) class in the Mangawhero and Makotuku Water Management Sub-zones.

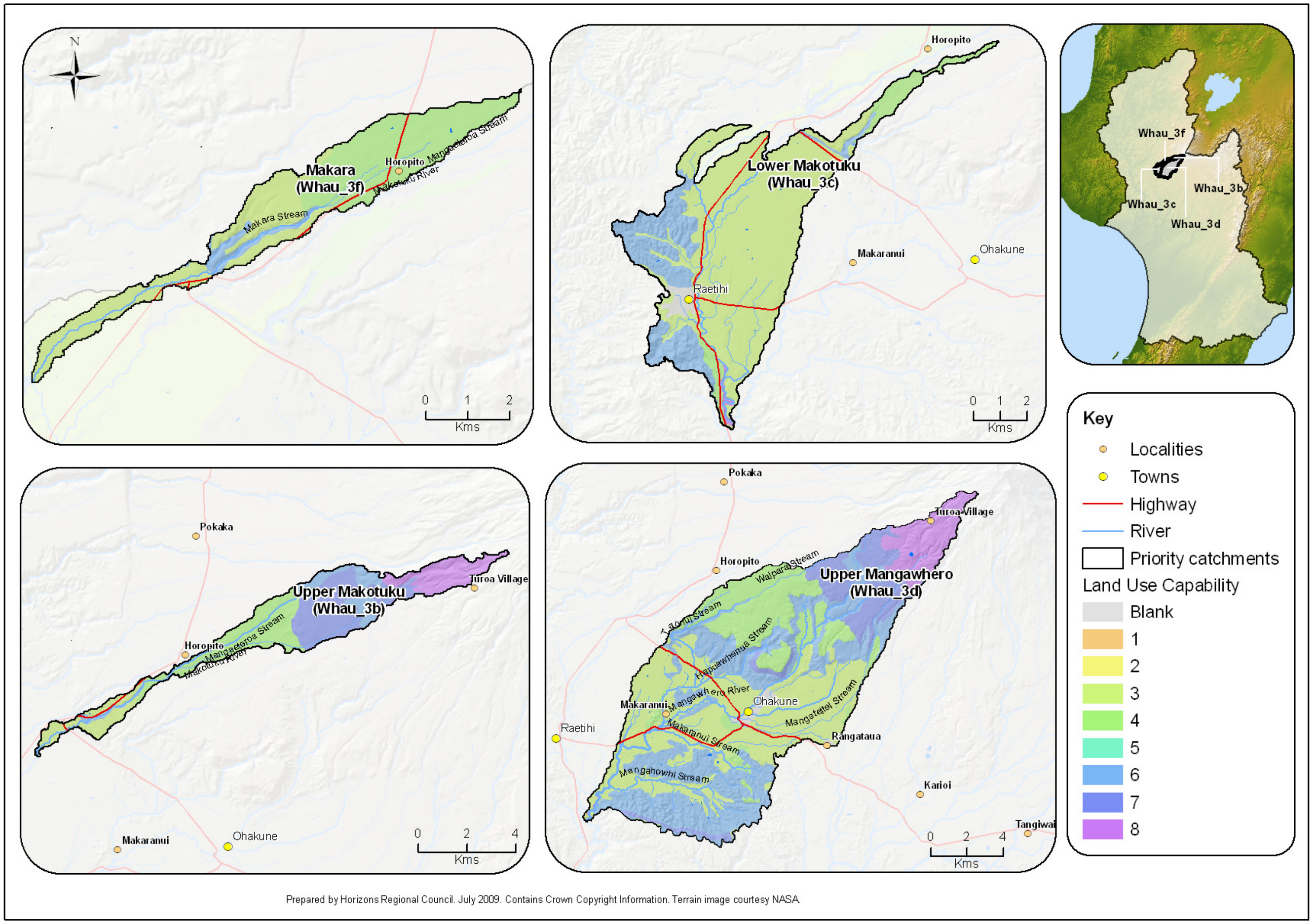
Land use type	Mangawhero/ Makotuku	LUC class	Mangawhero/ Makotuku
Built-up/Parks	1%	1	-
Cropping	-	2	-
Dairy	2%	3	41%
Exotic Cover	1%	4	17%
Horticulture	1%	5	-
Native Cover	38%	6	25%
Other	-	7	10%
Sheep & Beef	58%	8	7%
Water Body	-	Blank	1%

Table 44. Proposed nitrogen output limits resulting from the implementation of Rule 13-1 of the Proposed One Plan for the Mangawhero and Makotuku Water Management Sub-zones. *Note: Nitrogen attenuation of 50% between the land and river was assumed according to Clothier et al. (2007) and Mackay et al. (2008).*

Mangawhero/ Makotuku		LUC I	LUC II	LUC III	LUC IV	LUC V	LUC VI	LUC VII	LUC VIII	Total
Output loss limit	**Year 1** (when rule comes into force) (kg of N/ ha/year)	32	29	22	16	13	10	6	2	
	Year 5 (kg N/ha/year)	27	25	21	16	13	10	6	2	
	Year 10 (kg N/ha/year)	26	22	19	14	13	10	6	2	
	Year 20 (kg N/ha/year)	25	21	18	13	12	10	6	2	
Area of LUC Mangawhero/ Makotuku (ha)		0	0	10834	4534	0	6681	2515	1712	26537
Measured load (in-river)	**Year 1** (Tonnes/year)	0.00	0.00	119.17	36.27	43.43	12.58	5.14	1.71	218.30
	Year 5 (Tonnes/year)	0.00	0.00	113.76	36.27	43.43	12.58	5.14	1.71	212.88
	Year 10 (Tonnes/year)	0.00	0.00	102.92	31.74	43.43	12.58	5.14	1.71	197.51
	Year 20 (Tonnes/year)	0.00	0.00	97.51	29.47	40.09	12.58	5.14	1.71	186.49
Standard load limit (Tonnes/year)										31



Map 36. Land use in the Mangawhero, Makara and Makotuku Water Management Sub-zones.



Map 37. Land Use Capability (LUC) in the Mangawhero, Makara and Makotuku Water Management Sub-zones.

Key points: Mangawhero and Makotuku target catchments

i. The Mangawhero and Makotuku are two main tributaries of the Whangaehu catchment which arise on the western slopes of Mount Ruapehu, comprising an area of 264 km^2.

ii. Soluble inorganic nitrogen and DRP concentrations exceed POP standards and are contributed by a combination of point and non-point sources. *Escherichia coli* is generally within the standard but is elevated downstream of point source and at elevated flows.

iii. Macroinvertebrate Community Index score declines rapidly downstream from excellent at upper catchment sites to fair in sites downstream of township sewage discharges. This represents significant degradation for upper catchment sites in the UVA geology class.

iv. Poor water quality affects Life-Supporting Capacity, Contact Recreation, Amenity, Trout Fishery, Stockwater and potentially Sites of Significance – Aquatic values.

v. Land use is predominantly Sheep & Beef (58%) and Native Cover (38%), with a very small proportion of intensive land use in Dairy and Horticulture (3% combined). There are five dairy effluent discharges in the catchment.

vi. The year 20 output loss limits predicted from the application of Table 13.2 of the POP will be approximately 500% greater than the Standard load limit.

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APPENDIX 1

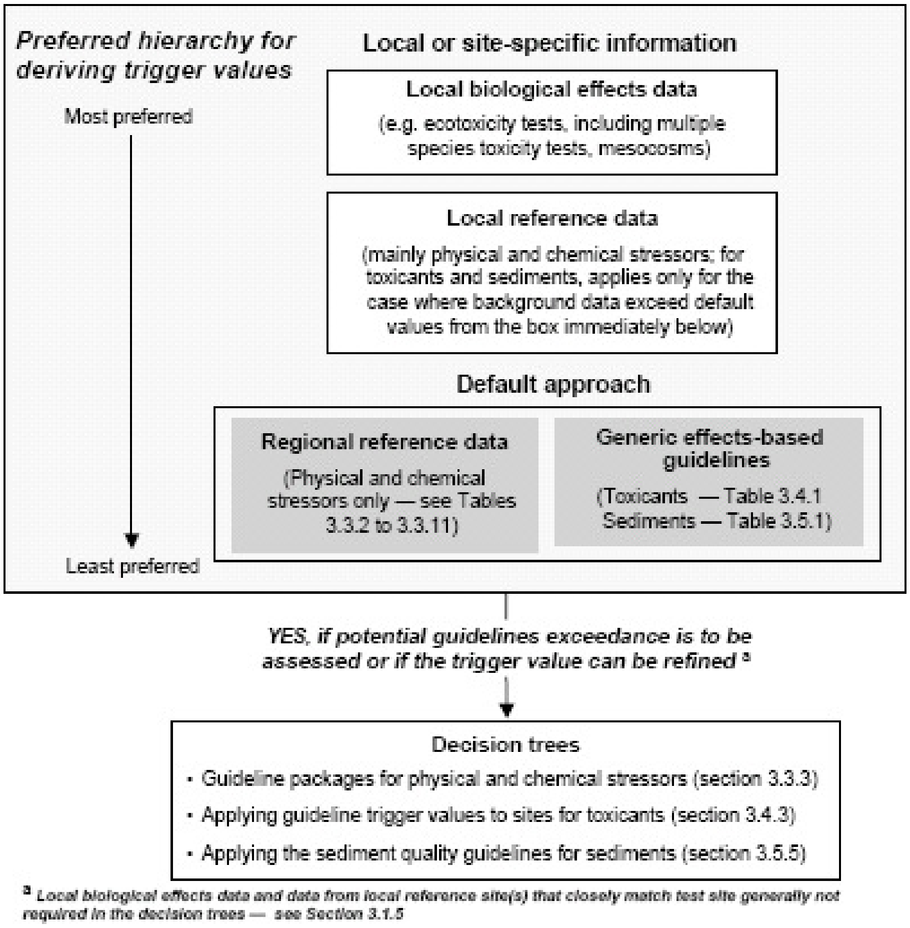

Figure 3.1.2 Procedures for deriving and refining trigger values, and assessing test sites, for physical and chemical stressors and toxicants in water and sediment. Dark grey shading indicates most likely point of entry for users requiring trigger values.

Reproduced from ANZECC (2000) Page 3.1-6.

APPENDIX 2

Table 45. Water Management Sub-zones identified as meeting the standards (✓), not meeting the standards (as a result of either point source (PS) or non-point source (NPS) contamination), or having insufficient data (ID) to assess against standards for nutrient concentration at low and high flows, Contact Recreation suitability and Life-Supporting Capacity. Technical references for available data are also shown. Suitability for Contact Recreation was determined by comparing *Escherichia coli* concentration with standards during low flows. Low flows were considered to be all flows approximately less than median, high flows were all flows approximately greater than median. Macroinvertebrate Community Index (MCI) scores were calculated from the mean across all years of record, (see Death (2009), Table 6, page 37). MCI categories were based on Stark and Maxted (2007) where green = "excellent"; yellow = "good"; orange = "fair"; and red = "poor" water quality.

WMZ	Sub-zones	P low flows	P high flows	N low flows	N high flows	Contact Recreation (FIB source)	Life-Supporting Capacity (MCI)	Reference/s
Upper Manawatū (Mana_1)	Upper Manawatū (Mana_1a)	✓	NPS	NPS	NPS	✓	107	McArthur & Clark (2007) Clark *et al.* (2009) Death (2009)
	Mangatewainui (Mana_1b)	NPS	ID	✓	ID	✓	110	Clark *et al.* (2009)
	Mangatoro (Mana_1c)	✓	ID	NPS	ID	NPS	108	Clark *et al.* (2009) Ausseil & Clark (2007c) Death (2009)
Weber – Tamaki (Mana_2)	Weber-Tamaki (Mana_2a)	ID	ID	ID	ID	ID	ID	-
	Mangatera (Mana_2b)	PS Dannevirke STP	PS & NPS	PS	NPS	NPS	91	McArthur & Clark (2007) Clark *et al.* (2009)
Upper Tamaki (Mana_3)	Upper Tamaki (Mana_3)	NPS	ID	NPS	ID	✓	141	Clark *et al.* (2009) Ausseil & Clark (2007c)
Upper Kumeti (Mana_4)	Upper Kumeti (Mana_4)	NPS	ID	NPS	ID	✓	108	Clark *et al.* (2009)

WMZ	Sub-zones	P low flows	P high flows	N low flows	N high flows	Contact Recreation (FIB source)	Life-Supporting Capacity (MCI)	Reference/s
Tamaki – Hopelands (Mana_5)	Tamaki-Hopelands (Mana_5a)	PS + DOP from bed sediment	NPS	NPS	NPS	NPS	93	McArthur & Clark (2007) Ausseil & Clark (2007c) Parfitt *et al.* (2007) Roygard & McArthur (2008) Death (2009) Clark *et al.* (2009)
	Lower Tamaki (Mana_5b)	NPS	ID	NPS	NPS	✓	112	Ausseil & Clark, 2007c Clark *et al.* (2009) Death (2009)
	Lower Kumeti (Mana_5c)	NPS	ID	NPS	ID	NPS	99	Clark *et al.* (2009)
	Oruakeretaki (Mana_5d)	NPS	NPS	NPS	NPS	✓	104	Ausseil & Clark (2007c) Clark *et al.* (2009)
	Raparapawai (Mana_5e)	NPS	NPS	✓	NPS	NPS	110	Ausseil & Clark (2007c) Clark *et al.* (2009)
Hopelands-Tiraumea (Mana_6)	Hopelands-Tiraumea (Mana_6)	ID	ID	ID	ID	ID	ID	-
Tiraumea (Mana_7)	Upper Tiraumea (Mana_7a)	NPS	NPS	✓	NPS	NPS	70	Ausseil & Clark (2007c) Horizons WQ database Death (2009)
	Lower Tiraumea (Mana_7b)	✓	NPS	NPS	NPS	NPS	ID	Horizons WQ database
	Mangaone River (Mana_7c)	ID	ID	ID	ID	ID	ID	-
	Mākurī (Mana_7d)	✓	NPS	NPS	NPS	NPS	111	Ausseil & Clark (2007c) Ballantine & Davies-Colley (2009b)
	Mangaramarama (Mana_7e)	ID	ID	ID	ID	ID	ID	-

WMZ	Sub-zones	P low flows	P high flows	N low flows	N high flows	Contact Recreation (FIB source)	Life-Supporting Capacity (MCI)	Reference/s
Mangatainoka (Mana_8)	Upper Mangatainoka (Mana_8a)	✓	NPS	NPS	NPS	✓	138[26]	Clark (unpublished data) Ausseil & Clark (2007c) Death (2009)
	Middle Mangatainoka (Mana_8b)	ID	ID	ID	ID	ID	ID	-
	Lower Mangatainoka (Mana_8c)	PS Pahiatua STP	PS Pahiatua STP	NPS	NPS	✓	101.1	McArthur & Clark (2007) Ausseil & Clark (2007c) Roygard & McArthur (2008) Ballantine & Davies-Colley (2009b) Death (2009) Clark (unpublished data)
	Mākākahi (Mana_8d)	PS Eketahuna STP & NPS (Ngatahaka Stream)	PS Eketahuna STP & NPS (Ngatahaka Stream)	NPS	NPS	NPS	96.2	Ausseil & Clark (2007c) Death (2009)
Upper Gorge (Mana_9)	Upper Gorge (Mana_9a)	NPS	NPS	NPS	NPS	NPS	93.6	Ausseil & Clark (2007c) Death (2009)
	Mangapapa (Mana_9b)	NPS	NPS	NPS	NPS	NPS	96	Ausseil & Clark (2007c) Clark *et al.* (2007)
	Mangaatua (Mana_9c)	PS & NPS	NPS	PS ammonia an issue NPS	NPS	NPS	ID	Ausseil & Clark (2007c)
	Upper Mangahao (Mana_9d)	✓	✓	✓	✓	✓	111	Ausseil & Clark (2007c) Death (2009)
	Lower Mangahao (Mana_9e)	ID	ID	ID	ID	ID	ID	-

26 Data from Mangatainoka at Putara monitoring site upstream of the Mangatainoka at Larsons Rd monitoring site which is the bottom of the sub-zone.

WMZ	Sub-zones	P low flows	P high flows	N low flows	N high flows	Contact Recreation (FIB source)	Life-Supporting Capacity (MCI)	Reference/s
Middle Manawatū (Mana_10)	Middle Manawatū (Mana_10a)	✓	NPS	✓	NPS	NPS	92	McArthur & Clark, (2007) Ausseil & Clark (2007c)
	Upper Pohangina (Mana_10b)	✓	✓	✓	✓	✓	109	Ausseil & Clark (2007c) Death (2009)
	Middle Pohangina (Mana_10c)	ID	NPS	ID	NPS	✓	112	Ausseil & Clark (2007c) Death (2009)
	Lower Pohangina (Mana_10d)	ID	ID	ID	ID	ID	96	Death (2009)
	Aokautere (Mana_10e)	ID	ID	ID	ID	ID	ID	-
Lower Manawatū (Mana_11)	Lower Manawatū (Mana_11a)	PS	NPS	PS	NPS	PS & NPS	72	McArthur & Clark (2007) Ausseil & Clark (2007c) Death (2009)
	Turitea (Mana_11b)	ID	ID	ID	ID	ID	ID	-
	Kahuterawa (Mana_11c)	ID	ID	ID	ID	ID	83	Death (2009)
	Upper Mangaone (Mana_11d)	NPS	NPS	NPS	NPS	NPS	77	Ausseil & Clark (2007c)
	Lower Mangaone (Mana_11e)	ID	ID	ID	ID	ID	ID	-
	Main Drain (Mana_11f)	ID	ID	ID	ID	ID	ID	-
Oroua (Mana_12)	Upper Oroua (Mana_12a)	NPS (however, see footnote)[27]	NPS	✓	NPS	✓	106	Death (2009) Horizons WQ database
	Middle Oroua (Mana_12b)	PS	PS	PS ammonia a problem	PS	PS	73	McArthur & Clark (2007) Ausseil & Clark, (2007c) Death (2009)
	Lower Oroua (Mana_12c)	ID	ID	ID	ID	ID	ID	-

[27] Data skewed by occasional high values associated with low flows, this requires further investigation.

WMZ	Sub-zones	P low flows	P high flows	N low flows	N high flows	Contact Recreation (FIB source)	Life-Supporting Capacity (MCI)	Reference/s
	Kiwitea (Mana_12d)	ID	ID	ID	ID	ID	95	Death (2009)
	Makino (Mana_12e)	NPS	ID	✓	ID	NPS	74	Ausseil & Clark (2007c) Death (2009)
Coastal Manawatū	Coastal Manawatū (Mana_13a)	Cumulative NPS & PS	Cumulative NPS & PS	Cumulative NPS & PS	Cumulative NPS & PS	Cumulative NPS & PS	73	Ausseil & Clark (2007c) Death (2009)
	Upper Tokomaru (Mana_13b)	✓	✓	✓	✓	✓	122	Ausseil & Clark (2007c) Death (2009)
	Lower Tokomaru (Mana_13c)	NPS[28]	NPS	NPS	NPS	NPS	ID	Horizons WQ database
	Mangaore (Mana_13d)	PS (Shannon STP)	✓	PS (Shannon STP)	✓	✓	ID	Shannon STP consent report data
	Koputaroa (Mana_13e)	ID	ID	ID	ID	ID	ID	-
	Foxton Loop (Mana_13f)	PS & NPS	PS & NPS	✓	ID	✓	ID	Ausseil & Clark (2007c)
Upper Rangitīkei (Rang_1)	Upper Rangitīkei (Rang_1)	ID	ID	ID	ID	ID	ID	-
Middle Rangitīkei (Rang_2)	Middle Rangitīkei (Rang_2a)	✓	✓	✓	✓	✓	115	Death (2009)
	Pukeokahu – Mangaweka (Rang_2b)	✓	✓	✓	✓	PS Taihape STP & NPS	104	McArthur & Clark (2007) Death (2009)
	Upper Moawhango (Rang_2c)	ID	ID	ID	ID	ID	ID	-
	Middle Moawhango (Rang_2d)	ID	ID	ID	ID	ID	112	Death (2009)
	Lower Moawhango (Rang_2e)	ID	ID	ID	ID	ID	ID	-
	Upper Hautapu (Rang_2f)	NPS	ID	✓	ID	NPS	103	Ausseil & Clark (2007c) McArthur & Clark (2007) Death (2009)

28 No flow data available.

WMZ	Sub-zones	P low flows	P high flows	N low flows	N high flows	Contact Recreation (FIB source)	Life-Supporting Capacity (MCI)	Reference/s
	Lower Hautapu (Rang_2g)	PS Taihape STP	PS Taihape STP	PS Taihape STP	PS & NPS	PS Taihape STP	84	McArthur & Clark (2007) Ausseil & Clark (2007c) Ballantine & Davies-Colley (2009b) Death (2009)
Lower Rangitīkei (Rang_3a)	Lower Rangitīkei (Rang_3a)	✓	NPS	✓	✓	✓[29]	96[30]	Ausseil & Clark (2007c) Horizons WQ database Death (2009)
	Mākōhine (Rang_3b)	NPS	NPS	NPS	NPS	NPS	90	Death (2009) Ausseil & Clark (2007c)
Coastal Rangitīkei (Rang_4)	Coastal Rangitīkei (Rang_4a)	PS[31]	PS	PS	PS	PS	ID	Ausseil & Clark (2007c) McArthur & Clark (2007)
	Tidal Rangitīkei (Rang_4b)	PS & NPS	PS & NPS	PS & NPS	PS & NPS	PS & NPS	83	Ausseil & Clark (2007c) McArthur & Clark (2007) Death (2009)
	Porewa (Rang_4c)	PS Hunterville STP	PS & NPS	PS Hunterville STP	PS & NPS	PS & NPS	92	McArthur & Clark (2007) Death (2009)
	Tutaenui (Rang_4d)	PS Marton STP	PS & NPS	PS Marton STP	PS & NPS	PS & NPS	72	McArthur & Clark (2007) Death (2009)
Upper Whanganui (Whai_1)	Upper Whanganui (Whai_1)	ID	ID	ID	ID	ID	122	Death (2009)

29 This assessment differs from Ausseil & Clark (2007c) due to the use of flow data now available for the Onepuhi site.

30 Biomonitoring site Rangitīkei at Kākāriki.

31 Sub-zone point sources are: Riverlands meat processing discharge, Bulls STP, Sanson STP and Ohakea STP enter the Rangitīkei River below the Bulls Bridge. Riverlands is the most significant contributor.

WMZ	Sub-zones	P low flows	P high flows	N low flows	N high flows	Contact Recreation (FIB source)	Life-Supporting Capacity (MCI)	Reference/s
Cherry Grove (Whai_2)	Cherry Grove (Whai_2a)	✓	✓	NPS	NPS	✓	107	Ausseil & Clark (2007c) Ballantine & Davies-Colley (2009b) Death (2009)
	Upper Whakapapa (Whai_2b)	ID	ID	ID	ID	ID	117	Death (2009)
	Lower Whakapapa (Whai_2c)	ID	ID	ID	ID	ID	ID	-
	Piopiotea (Whai_2d)	NPS	NPS	NPS	NPS	NPS	ID	Ausseil & Clark (2007c) McArthur & Clark (2007)
	Pungapunga (Whai_2e)	ID	ID	ID	ID	ID	ID	-
	Upper Ongarue (Whai_2f)	ID	ID	ID	ID	ID	109	Death (2009)
	Lower Ongarue (Whai_2g)	NPS	NPS	NPS	NPS	ID	ID	Ausseil & Clark (2007c)
Te Maire (Whai_3)	Te Maire (Whai_3)	PS Taumarunui STP	✓	NPS	NPS	✓	102	McArthur & Clark (2007) Ausseil & Clark (2007c) Ballantine & Davies-Colley Death (2009b)
Middle Whanganui (Whai_4)	Middle Whanganui (Whai_4a)	✓	✓	NPS	NPS	✓	101	Ausseil & Clark (2007c) Ballantine & Davies-Colley (2009b) Death (2009)
	Upper Ohura (Whai_4b)	NPS	NPS	NPS	NPS	NPS	ID	Ausseil & Clark (2007c)
	Lower Ohura (Whai_4c)	ID	ID	ID	ID	ID	ID	-
	Retaruke (Whai_4d)	ID	ID	ID	ID	✓	115	Ausseil & Clark (2007c) Death (2009)

WMZ	Sub-zones	P low flows	P high flows	N low flows	N high flows	Contact Recreation (FIB source)	Life-Supporting Capacity (MCI)	Reference/s
Pipiriki (Whai_5)	Pipiriki (Whai_5a)	✓	✓	NPS	NPS	✓	85	McArthur & Clark (2007) Ausseil & Clark (2007c) Ballantine & Davies-Colley (2009b) Death (2009)
	Tangarakau (Whai_5b)	ID	ID	ID	ID	ID	ID	-
	Whangamomona (Whai_5c)	ID	ID	ID	ID	ID	ID	-
	Upper Manganui o te Ao (Whai_5d)	ID	ID	ID	ID	ID	ID	-
	Mākātote (Whai_5e)	ID	ID	ID	ID	ID	ID	-
	Waimarino (Whai_5f)	ID	ID	ID	ID	ID	ID	-
	Middle Manganui o te Ao (Whai_5g)	✓	✓	✓	✓	✓	133	Ausseil & Clark (2007c) Death (2009)
	Mangaturuturu (Whai_5h)	ID	ID	ID	ID	ID	ID	-
	Lower Manganui o te Ao (Whai_5i)	ID	ID	ID	ID	ID	ID	-
	Orautoha (Whai_5j)	ID	ID	ID	ID	ID	ID	-
Paetawa (Whai_6)	Paetawa (Whai_6)	✓	✓	NPS	NPS	✓	ID	Ausseil & Clark (2007c) Ballantine & Davies-Colley (2009b)
Lower Whanganui (Whai_7)	Lower Whanganui (Whai_7a)	✓	✓	NPS	NPS	ID	ID	Ausseil & Clark (2007c)
	Coastal Whanganui (Whai_7b)	✓	✓	NPS	NPS	PS & NPS	87	Ausseil & Clark (2007c) Death (2009)
	Upokongaro (Whai_7c)	ID	ID	ID	ID	ID	ID	-
	Matarawa (Whai_7d)	ID	ID	ID	ID	ID	ID	-
Upper Whangaehu	Upper Whangaehu (Whau_1a)	PS Winstone Pulp & Waiouru STP	ID	PS Winstone Pulp & Waiouru STP	ID	ID	ID	McArthur & Clark (2007)

WMZ	Sub-zones	P low flows	P high flows	N low flows	N high flows	Contact Recreation (FIB source)	Life-Supporting Capacity (MCI)	Reference/s
(Whau_1)	Waitangi (Whau_1b)	ID	ID	ID	ID	ID	ID	-
	Tokiahuru (Whau_1c)	Natural	Natural	NPS	NPS	NPS	107	Ausseil & Clark (2007c) Death (2009)
Middle Whangaehu (Whau_2)	Middle Whangaehu (Whau_2)	PS	ID	PS	ID	PS & NPS	ID	McArthur & Clark (2007) Ausseil & Clark (2007c)
Lower Whangaehu (Whau_3)	Lower Whangaehu (Whau_3a)	✓	ID	PS & NPS	ID	PS & NPS	33	McArthur & Clark (2007) Ausseil & Clark (2007c) Death (2009)
	Upper Makotuku (Whau_3b)	Natural	Natural	NPS	ID	✓	137	Ausseil & Clark (2007c) Death (2009)
	Lower Makotuku (Whau_3c)	PS Raetihi STP	ID	✓	ID	PS & NPS	85[32]	Ausseil & Clark (2007c) McArthur & Clark (2007) Death (2009)
	Upper Mangawhero (Whau_3d)	PS Ohakune STP	PS Ohakune STP	PS Ohakune STP	PS Ohakune STP	✓	107	McArthur & Clark (2007) Death (2009) Horizons WQ database
	Lower Mangawhero (Whau_3e)	PS & NPS	PS & NPS	PS & NPS	PS & NPS	PS & NPS	75	Ausseil & Clark (2007c) Death (2009)
	Makara (Whau_3f)	ID	ID	ID	ID	ID	ID	-
Coastal Whangaehu (Whau_4)	Coastal Whangaehu (Whau_4)	ID	ID	ID	ID	ID	ID	-
Turakina (Tura_1)	Upper Turakina (Tura_1a)	NPS	NPS	NPS	NPS	NPS	66	Ausseil & Clark (2007c) Death (2009)

32 Invertebrate samples collected from upstream of Raetihi STP discharge.

WMZ	Sub-zones	P low flows	P high flows	N low flows	N high flows	Contact Recreation (FIB source)	Life-Supporting Capacity (MCI)	Reference/s
	Lower Turakina (Tura_1b)	NPS	NPS	NPS	NPS	NPS	68	Ausseil & Clark (2007c) Death (2009)
	Ratana (Tura_1c)	ID	ID	ID	ID	ID	ID	-
Ohau (Ohau_1)	Upper Ohau (Ohau_1a)	✓	✓	✓	✓	✓[33]	114	Ausseil & Clark (2007c) Death (2009)
	Lower Ohau (Ohau_1b)	✓	✓	NPS	NPS	✓	108	Ausseil & Clark (2007c) Death (2009)
Owahanga (Owha_1)	Owahanga (Owha_1)	✓	NPS	✓	NPS	ID	87	Death (2009) Horizons WQ database McArthur & Clark (2007)
East Coast (East_1)	East Coast (East_1)	ID	ID	ID	ID	ID	85[34]	Death (2009)
Akitio (Akit_1)	Upper Akitio (Akit_1a)	✓	✓	✓	✓	NPS	103	Ausseil & Clark (2007c) Death (2009)
	Lower Akitio (Akit_1b)	NPS	NPS	✓	✓	NPS	87	Ausseil & Clark (2007c) Death(2009)
	Waihi (Akit_1c)	ID	ID	ID	ID	ID	94	Death (2009)
Northern Coastal (West_1)	Northern Coastal (West_1)	ID	ID	ID	ID	ID	ID	-
Kai Iwi (West_2)	Kai Iwi (West_2)	NPS	NPS	NPS	NPS	NPS	ID	Ausseil & Clark (2007c)
Mōwhānau (West_3)	Mōwhānau (West_3)	NPS	NPS	NPS	NPS	NPS	ID	McArthur (unpublished data)
Kaitoke Lakes (West_4)	Kaitoke Lakes (West_4)	NPS[35]		NPS		✓	ID	Horizons WQ database

[33] Note: Ballantine and Davies-Colley (2009b) found increasing trends in *E. coli* at this site.
[34] Data from Wainui at Herbertville Road biomonitoring site.
[35] Assessed for Lakes Pauri and Wiritoa, other lake water quality in zone assumed to be similar.

WMZ	Sub-zones	P low flows	P high flows	N low flows	N high flows	Contact Recreation (FIB source)	Life-Supporting Capacity (MCI)	Reference/s
Southern Whanganui Lakes (West_5)	Southern Whanganui Lakes (West_5)	NPS[36]		NPS		✓	ID	Horizons WQ database
Northern Manawatū Lakes (West_6)	Northern Manawatū Lakes (West_6)	NPS		NPS		NPS	ID	Swimming spots data (Kaikōkopu Stream only)
Waitarere (West_7)	Waitarere (West_7)	ID		ID		ID	ID	-
Lake Papaitonga (West_8)	Lake Papaitonga (West_8)	NPS		NPS (ammonia an issue)		NPS	ID	Horizons WQ database
Waikawa (West_9)	Waikawa (West_9a)	NPS	NPS	NPS	NPS	NPS	120	Ausseil & Clark (2007c) Death (2009)
	Manakau (West_9b)	NPS	ID	NPS	ID	NPS	102	Horizons WQ database Death (2009)
Lake Horowhenua (Hoki_1)	Lake Horowhenua (Hoki_1a)	NPS		NPS		✓	ID	Ausseil & Clark (2007c) Ballantine & Davies-Colley (2009b) Horizons WQ database
	Hokio (Hoki_1b)	NPS		NPS		✓	ID	Horizons WQ database

36 Assessed for Lake Dudding, other lake water quality in zone assumed to be similar.

APPENDIX 3

Table 46. Proportion of land use categories within each LUC class for the Mangapapa Water Management Sub-zone.

	LUC class									
Land use (% cover)	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**Blank**	**Total**
Builtup/Parks/Others	-	0.8	-	-	-	-	-	-	0.3	**1.1**
Cropping	-	0.2	-	-	-	-	-	-	-	**0.2**
Dairy	-	3.7	4.7	1.9	-	7.4	0.5	-	-	**18.3**
Exotic Cover	-	0.1	0.9	-	-	0.5	-	-	-	**1.4**
Horticulture-Other	-	1.4	0.4	0.2	-	-	-	-	-	**2.0**
Native Cover	-	-	0.4	0.0	-	11.1	4.2	10.5	-	**26.2**
Other	-	1.0	-	-	-	-	-	-	-	**1.0**
Sheep and/or Beef	-	5.8	11.7	3.3	0.0	27.4	0.6	-	0.9	**49.8**
TOTAL	**-**	**12.9**	**18.2**	**5.5**	**0.0**	**46.4**	**5.3**	**10.5**	**1.2**	**100.0**

Table 47. Proportion of landuse categories within each LUC class for the Mōwhānau Water Management Zone.

	LUC class									
Landuse (% cover)	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**Blank**	**Total**
Builtup/Parks/Others	-	-	-	-	-	-	-	-	-	**-**
Cropping	0.1	-	-	-	-	-	-	-	-	**0.1**
Dairy	7.3	0.5	1.1	2.6	-	8.5	-	-	-	**20.1**
Exotic Cover	0.7	0.1	0.4	0.2	-	1.6	-	-	-	**2.9**
Horticulture-Other	0.7	-	-	-	-	0.1	-	-	-	**0.8**
Horticulture-Veg	0.2	-	-	-	-	-	-	-	-	**0.2**
Native Cover	0.5	0.1	-	-	-	1.8	-	-	-	**2.4**
Other	0.1	-	-	-	-	0.6	-	-	-	**0.7**
Sheep and or Beef	1.8	-	-	-	-	5.5	-	-	-	**7.4**
Sheep and/or Beef	18.9	9.8	2.9	1.0	-	32.9	-	-	-	**65.4**
TOTAL	**30.3**	**10.4**	**4.5**	**3.8**	**-**	**51.0**	**-**	**-**	**-**	**100.0**

Table 48. Proportion of land use categories within each LUC class for the Mangatainoka Water Management Zone.

	LUC class									
Land use (% cover)	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**Blank**	**Total**
Builtup/Parks/Others	-	0.1	-	-	-	-	-	-	0.4	**0.6**
Cropping	-	0.0	-	-	-	-	-	-	-	**-**
Dairy	0.9	12.7	5.8	1.5	0.0	8.4	0.6	0.2	-	**30.1**
Exotic Cover	-	0.2	0.2	-	-	0.6	0.4	-	-	**1.5**
Horticulture-Other	-	-	-	-	-	-	-	-	-	**-**
Native Cover	-	0.4	0.3	0.1	-	2.5	8.6	8.1	-	**20.1**
Other	-	0.2	0.1	-	-	-	-	-	-	**0.4**
Sheep and/or Beef	0.4	10.8	6.2	1.6	0.6	22.8	4.0	0.4	0.2	**46.9**
Water Body	-	0.1	0.1	-	-	-	-	-	-	**0.3**
TOTAL	**1.4**	**24.5**	**12.8**	**3.3**	**0.6**	**34.4**	**13.7**	**8.8**	**0.6**	**100.0**

Table 49. Proportion of land use categories within each LUC class for the Water Management Zones of the Manawatū River upstream of Hopelands.

	LUC class									
Land use (% cover)	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**Blank**	**Total**
Builtup/Parks/Others	-	-	-	-	-	-	-	-	0.3	**0.4**
Cropping	-	-	0.3	-	-	-	-	-	-	**0.4**
Dairy	-	4.6	6.0	2.6	0.1	1.9	1.0	-	-	**16.2**
Exotic Cover	-	0.2	0.4	0.2	-	1.5	0.7	-	-	**3.0**
Horticulture-Other	-	-	-	-	-	-	-	-	-	**-**
Native Cover	-	0.2	0.3	0.1	-	1.7	3.9	4.1	-	**10.3**
Other	-	0.1	0.2	0.1	-	0.4	0.1	-	-	**0.7**
Sheep and/or Beef	-	4.4	8.8	5.8	0.5	38.3	10.9	-	0.1	**68.9**
Water Body	-	-	-	-	-	-	-	-	-	**0.1**
TOTAL	**-**	**9.5**	**16.1**	**8.8**	**0.6**	**43.8**	**16.5**	**4.2**	**0.4**	**100.0**

Table 50. Proportion of land use categories within each LUC class for the Lake Horowhenua Water Management Zone.

	LUC class									
Land use (% cover)	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**Blank**	**Total**
Builtup/Parks/Others	0.3	-	1.0	-	-	-	-	-	10.5	**11.8**
Cropping	2.9	0.1	0.3	-	-	-	-	-	-	**3.3**
Dairy	1.5	1.5	10.9	0.6	-	3.3	0.3	-	-	**18.1**
Exotic Cover	0.4	0.1	0.9	-	-	1.4	0.5	-	0.1	**3.4**
Horticulture-Other	0.6	0.2	0.1	-	-	0.0	-	-	-	**1.0**
Horticulture-Veg	2.2	0.2	0.1	-	-	0.0	-	-	-	**2.5**
Native Cover	0.1	0.1	1.0	0.3	-	1.3	0.4	0.1	0.2	**3.5**
Other	0.3	0.1	0.9	-	-	0.1	-	-	-	**1.4**
Sheep and/or Beef	8.3	5.7	20.0	0.8	-	12.3	1.2	0.2	2.0	**50.5**
Water Body	-	-	0.3	0.4	-	0.0	-		3.6	**4.4**
TOTAL	**16.8**	**8.0**	**35.3**	**2.2**	**-**	**18.4**	**2.5**	**0.3**	**16.5**	**100.0**

Table 51. Proportion of land use categories within each LUC class for the Waikawa Water Management Zone.

	LUC class									
Land use (% cover)	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**Blank**	**Total**
Builtup/Parks/Others	0.1	0.1	0.2	-	-	-	0.1	-	0.2	**0.6**
Cropping	0.1	0.1	0.1	-	-	-	-	-	-	**0.3**
Dairy	1.9	3.2	11.9	1.8	-	3.1	1.2	0.5	-	**23.6**
Exotic Cover	0.1	0.1	1.2	0.2	-	7.4	3.6	-	0.1	**12.6**
Horticulture-Other	0.1	-	-	-	-	-	-	-	-	**0.2**
Horticulture-Veg	0.4	0.3	0.3	-	-	-	-	-	-	**1.1**
Native Cover	-	-	0.8	0.1	-	1.8	26.9	5.5	-	**35.2**
Other	-	-	-	-	-	-	-	-	-	**0.0**
Sheep and/or Beef	2.7	1.8	12.2	0.8	-	7.3	1.2	0.1	0.1	**26.3**
Water Body	-	-	-	-	-	-	-	-	0.1	**0.1**
TOTAL	**5.4**	**5.7**	**26.7**	**2.9**	**-**	**19.6**	**33.0**	**6.1**	**0.5**	**100.0**

Table 52. Proportion of land use categories within each LUC class for the Water Management Zones of the Manawatū above the Gorge target catchment.

	LUC class									
Land use (% cover)	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**Blank**	**Total**
Builtup/Parks/Others	-	-	-	-	-	-	-	-	0.3	**0.4**
Cropping	-	-	-	-	-	-	-	-	-	**-**
Dairy	-	10.5	10.4	5.3	-	13.0	1.6	-	-	**40.8**
Exotic Cover	-	0.2	0.2	0.3	-	0.4	0.4	-	-	**1.6**
Horticulture-Other	-	-	-	-	-	-	-	-	-	**-**
Native Cover	-	0.2	0.1	0.1	-	1.6	3.9	3.2	-	**9.1**
Other	-	-	-	-	-	-	-	-	-	**-**
Sheep and/or Beef	-	5.0	5.9	5.2	-	24.0	7.2	-	0.3	**47.7**
Water Body	-	0.1	-	0.2	-	-	-	-	-	**0.3**
TOTAL	**-**	**16.0**	**16.6**	**11.2**	**-**	**39.2**	**13.2**	**3.2**	**0.6**	**100.0**

Table 53. Proportion of land use categories within each LUC class for the Waitarere Water Management Zone.

	LUC class									
Land use (% cover)	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**Blank**	**Total**
Builtup/Parks/Others	-	-	-	-	-	-	0.1	-	1.8	**2.0**
Cropping	-	-	0.5	-	-	-	-	-	-	**0.5**
Dairy	-	-	11.2	0.8	-	13.7	8.5	-	-	**34.2**
Exotic Cover	-	-	0.6	-	-	3.7	40.1	3.1	0.3	**47.7**
Native Cover	-	-	0.7	0.1	-	0.1	0.9	-	-	**1.7**
Sheep and/or Beef	-	-	3.9	0.1	-	5.5	3.4	0.2	0.6	**13.8**
Water Body	-	-	0.03	-	0.03	-	-	-	0.01	**0.1**
TOTAL	**-**	**-**	**16.8**	**1.0**	**0.03**	**23.1**	**53.1**	**3.4**	**2.7**	**100.0**

Table 54. Proportion of land use categories within each LUC class for the Lake Papaitonga Water Management Zone.

	LUC class									
Land use (% cover)	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**Blank**	**Total**
Builtup/Parks/Others	-	-	-	-	-	-	0.2	-	0.2	**0.4**
Cropping	-	-	0.2	-	-	-	-	-	-	**0.2**
Dairy	-	0.8	11.5	0.8	-	2.8	3.0	-	-	**18.8**
Exotic Cover	-	0.1	3.3	0.2	-	4.8	8.6	0.1	-	**17.1**
Native Cover	-	0.1	3.5	0.1	-	0.4	2.0	0.3	0.9	**7.2**
Other	-	-	-	0.1	-	-	-	-	-	**0.1**
Sheep and/or Beef	-	2.6	19.4	1.7	-	11.9	16.7	1.0	0.2	**53.5**
Water Body	-	-	0.8	-	-	-	0.3	0.1	1.5	**2.7**
TOTAL	**-**	**3.6**	**38.6**	**2.8**	**-**	**19.9**	**30.8**	**1.5**	**2.8**	**100.0**

Table 55. Proportion of land use categories within each LUC class for the Kaitoke Lakes Water Management Zone.

	LUC class									
Land use (% cover)	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**Blank**	**Total**
Builtup/Parks/Others	-	-	0.7	-	-	-	0.1	0.1	-	**1.0**
Cropping	0.5	-	0.2	-	-	-	-	-	-	**0.8**
Dairy	0.1	0.6	0.2	-	-	3.0	-	-	-	**3.9**
Exotic Cover	0.1	0.6	0.3	2.1	-	3.4	17.4	0.7	-	**24.4**
Native Cover	-	0.2	0.1	0.1	-	0.5	0.9	2.6	-	**4.4**
Sheep and/or Beef	8.1	14.9	8.9	1.4	-	16.9	13.6	1.1	0.3	**65.2**
Water Body	-	-	-	-	-	-	0.2	-	-	**0.3**
TOTAL	**8.8**	**16.3**	**10.3**	**3.6**	**-**	**24.0**	**32.3**	**4.4**	**0.4**	**100.0**

Table 56. Proportion of land use categories within each LUC class for the Southern Whanganui Lakes Water Management Zone.

	LUC class									
Land use (% cover)	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**Blank**	**Total**
Builtup/Parks/Others	-	-	-	-	-	-	-	-	-	**-**
Cropping	-	0.3	-	-	-	-	-	-	-	**0.3**
Dairy	-	0.1	7.1	0.5	-	0.3	1.0	-	0.1	**9.2**
Exotic Cover	-	0.2	5.4	3.5	-	6.4	17.6	2.3	-	**35.6**
Horticulture-Other	-	-	-	-	-	-	-	-	-	**-**
Native Cover	-	-	0.1	0.1	-	0.2	0.2	0.2	-	**0.8**
Other	-	-	0.2	0.1	-	0.3	-	-	-	**0.5**
Sheep and/or Beef	-	5.9	21.6	8.9	-	6.3	10.7	0.2	-	**53.6**
Water Body	-	-	-	-	-	-	-	-	-	**-**
TOTAL	**-**	**6.6**	**34.5**	**13.1**	**-**	**13.5**	**29.6**	**2.7**	**0.1**	**100.0**

Table 57. Proportion of land use categories within each LUC class for the Northern Manawatū Lakes Water Management Zone.

	LUC class									
Land use (%)	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**Blank**	**Total**
Builtup/Parks/Others	-	-	-	-	-	0.2	-	0.1	-	**0.3**
Cropping	-	-	-	-	-	-	-	-	-	**-**
Dairy	-	-	23.1	11.7	-	11.7	3.7	-	0.1	**50.4**
Exotic Cover	-	-	1.8	2.5	-	8.1	5.3	1.4	-	**19.2**
Horticulture-Other	-	-	-	-	-	-	-	-	-	**-**
Horticulture-Veg	-	-	-	0.3	-	-	-	-	-	**0.3**
Native Cover	-	-	0.3		-	0.6	0.5	0.5	0.1	**1.9**
Other	-	-	-	0.1	-	0.2	-	-	-	**0.3**
Sheep and/or Beef	-	-	8.2	7.1	-	8.4	3.5	0.2	0.1	**27.4**
Water Body	-	-	-	-	-	-	-	-	0.1	**0.1**
TOTAL	**-**	**-**	**33.5**	**21.6**	**-**	**29.1**	**13.0**	**2.3**	**0.4**	**100.0**

Table 58. Proportion of land use categories within each LUC class for the Coastal Rangitīkei Water Management Zone.

	LUC class									
Land use (% cover)	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**Blank**	**Total**
Builtup/Parks/Others	-	0.3	-	-	-	-	-	-	0.5	**0.9**
Cropping	0.4	1.4	0.2	0.1	-	0.1	-	-	0.1	**2.1**
Dairy	1.4	11.9	3.1	1.3	-	1.7	0.1	-	0.1	**19.6**
Exotic Cover	0.2	0.8	0.6	0.3	-	3.3	1.6	0.2	0.6	**7.6**
Horticulture-Veg	-	-	-	-	-	-	-	-	-	**-**
Horticulture-Other	-	-	-	-	-	-	-	-	-	**-**
Native Cover	0.1	0.6	0.2	0.1	-	0.6	0.4	0.2	-	**2.1**
Other	-	0.2	-	-	-	0.1	-	-	-	**0.4**
Sheep and/or Beef	4.8	28.3	6.4	5.6	-	18.1	2.0	0.1	1.0	**66.3**
Water Body	-	0.1	-	-	-	0.2	-	0.1	0.4	**0.8**
TOTAL	**6.9**	**43.6**	**10.5**	**7.4**	**-**	**24.0**	**4.1**	**0.6**	**2.8**	**100.0**

Table 59. Proportion of land use categories within each LUC class for the Mangawhero and Makotuku Water Management Sub-zones.

	LUC class									
Land use (% cover)	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**Blank**	**Total**
Builtup/Parks/Others	-	-	0.3	0.1	-	-	-	-	0.6	**1.0**
Cropping	-	-	0.2	-	-	-	-	-	-	**0.2**
Dairy	-	-	1.7	0.1	-	0.5	-	-	-	**2.2**
Exotic Cover	-	-	0.3	-	-	0.2	-	-	-	**0.5**
Horticulture-Veg	-	-	0.7	-	-	-	-	-	-	**0.7**
Native Cover	-	-	2.4	10.4	-	9.5	9.1	6.3	0.1	**37.7**
Other	-	-	0.1	-	-	0.1	-	-	-	**0.1**
Sheep and/or Beef	-	-	35.2	6.4	-	14.9	0.4	0.1	0.3	**57.4**
Water Body	-	-	-	-	-	-	-	-	-	**-**
TOTAL	**-**	**-**	**40.8**	**17.1**	**-**	**25.2**	**9.5**	**6.4**	**1.0**	**100.0**