BEFORE THE HEARINGS PANEL

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

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SECTION 42A REPORT OF DR JONATHON KELVIN FLETCHER ROYGARD ON BEHALF OF HORIZONS REGIONAL COUNCIL

CONTENTS

1. INTRODUCTION

1.1 Qualifications and experience

1. My full name is Jonathon Kelvin Fletcher Roygard. I have a Doctor of Philosophy degree (PhD in Natural Resources), with a specialisation in soil science, from Massey University, Palmerston North. My PhD involved measuring and modelling nutrient movement through soils in a land treatment research project. I hold a Bachelor of Science Honours Degree (Zoology) from Massey University, where my post graduate papers included Ecology, Limnology, and Conservation Biology. I have worked as a Post-Doctoral Scientist and Research Assistant Professor in the Department of Crop and Soil Environmental Science, at Virginia Polytechnic Institute and State University (Virginia Tech), in Blacksburg, Virginia, USA. My research during this time was primarily in the Mid-Atlantic Cropping Systems project.

2. I have been employed by Horizons for more than seven years in various roles, including Environmental Information Analyst, Environmental Scientist – Water, and Senior Environmental Scientist – Water. In these roles my duties have ranged from processing hydrological data through to leading water resource assessments, developing the Water Management Zones framework, technical reporting on resource consents, and contributing to design and reporting of the State of Environment (SoE) monitoring programme. For more than four years, I have held the role of Manager Science within the Regional Planning and Regulatory Group of Horizons. In this role, I lead and manage the science programme at Horizons. The science programme includes research in relation to land, water, air, biodiversity, and fluvial resources and Horizons' SoE and policy effectiveness monitoring programmes. As the manager of the science team, I maintain a science role as well as a management role. My role includes initiating, scoping, project managing, and contributing to many projects relating to water allocation (surface and groundwater), water quality, fluvial science, and land use interactions with water quality.

3. I have authored and co-authored a range of scientific reports and publications, including technical reports to support the Proposed One Plan. I have also authored and co-authored papers in international journals on topics relating to soil science, crop water use, water and nitrogen balances for land treatment of effluent systems, and ecology. I am a member of the New Zealand Hydrological Society, the New Zealand Freshwater Sciences Society, the Regional Council Group Surface Water Integrated Management (SWIM) and the taskforce for the proposed measurement of water takes standard. I am also Horizons' Envirolink coordinator, have roles as co-champion of two national

Envirolink tool projects and have participated as a part of the science advisory group of Envirolink.

4. I have read the Environment Court's practice note, Expert Witnesses – Code of Conduct and agree to comply with it.

1.2 My role in the Proposed One Plan

5. I have been involved in the Proposed One Plan (POP) since its very early stages. My role has involved scientific advice, management, and contributions to technical reports. Since early 2004, I have had a lead role in coordination of science projects to provide technical input into the Plan's development, primarily for the Land and Water sections. This role in coordinating science projects and scientific input started as part of the preparation of the initial internal draft of the POP and continued for the subsequent drafts through to the proposed Plan, and now for the hearings. I have been involved in numerous consultation meetings over the duration of the Plan's development.

1.3 Scope of evidence

6. This evidence provides a general overview of the technical material in relation to the water sections of the Proposed One Plan[1]. This includes the Water Management Zones and Values, water allocation and water quality. The overview includes some context to the development of the technical material, linkages within the material, and some of the key messages. In presenting this information, this evidence aims to provide linkages to the technical reports and the technical evidence that will be presented. For those projects where I have had specific involvement, this evidence provides some further technical detail. A further component of this report is the provision of information around the state of the environment and pressures in relation to water quantity and quality, and the ongoing programmes to monitor this.

[1] LINK TO FURTHER EVIDENCE: Ms Natasha James provides evidence the overview of technical material in relation to the beds of rivers and lakes section. This material is not discussed in my evidence.

2. EXECUTIVE SUMMARY OF EVIDENCE

7. Water allocation and water quality components of the Proposed One Plan (POP) have been developed based on a range of technical material and input. The detail of this technical work and how it relates to the POP is presented in a number of S42A reports and associated technical documents. This report aims to provide a broad overview of the technical material to provide the linkages to technical evidence and documents, and to present some key messages in the context of the POP. This includes documenting where technical amendments are recommended as a result of further work since the notification of the POP in May 2007.

8. The information in this report is arranged into five main chapters, the content of which is further described below. These five main chapters are:

   i. The fundamental framework for water management – zones and values (Chapter 3)
   ii. Surface water allocation (Chapter 4)
   iii. Groundwater allocation and quality (Chapter 5)
   iv. Surface water quality (Chapter 6)
   v. FARM strategies for non-point source contaminant management (Chapter 7)

9. Given the integrated nature of the work in the POP related to water management, the chapters contain overlapping content. Further, some authors present evidence in relation to more than one aspect of the water provisions of the POP. Footnotes are used throughout this report to identify evidence and technical documents in relation to particular aspects of the POP and to guide the selection of reading order for various technical evidence and reports.

2.1 The Water Management Framework – Water Management Zones and Values

10. Chapter 3 of this report outlines the proposed Water Management Zones and Values framework. This framework is the keystone around which the water allocation and water quality strategies in the POP were built. The Water Management Zones, Values and common catchment expiry dates provide simple, spatially defined tools to provide a customised water management regime for a large and highly-variable Region. The spatial framework of the Water Management Zones and Values provides a mechanism for integrated catchment management within a local area and in relation to the broader catchment. New work completed since notification of the POP has prompted a few minor amendments to fine-tune the Water Management Zones and values frameworks.

Chapter 3 provides an overview of the development of these components of the POP, and the proposed refinements.

2.2 The Surface Water Allocation Framework

11. Chapter 4 of this report overviews the technical projects and evidence in relation to the surface water allocation provisions of the POP. The proposed Surface Water Allocation Framework uses the Water Management Zones (and Sub-zones) framework, and the values of these water bodies, as methods to establish different categories of allocation takes and various flow thresholds where these can and cannot be abstracted. Further, the proposed framework outlines requirements for reasonable and justifiable use of water as a mechanism to enable as much possible efficient use of the resource available, within the defined limits that provide for environmental protection and surety of supply. The goal of the framework is to specify limits and thresholds to provide certainty in the policy document. This aims to reduce the need for debate about appropriate thresholds on a case by case basis through individual consent processes. New work completed since Plan notification has prompted amendments to the proposed Water Allocation Framework. These primarily relate to the setting of minimum flows and core allocation limits. Chapter 4 overviews the pressure and state of the resource and the proposed water allocation framework. This includes a summary of the proposed amendments to the framework. Some sections in Chapter 4 provide context in relation to both surface and ground water allocation eg. the sections on permitted takes and reasonable and justifiable use of water.

2.3 The Groundwater Management Framework

12. Chapter 5 overviews the technical projects and evidence in relation to Groundwater provisions of the POP. The Groundwater Management Framework uses Groundwater Water Management Zones that are consistent with the boundaries of the Surface Water Management Zones. The proposed framework for groundwater sets total limits for allocation of water for these zones. Groundwater-related provisions in the POP include requirements for reasonable and justifiable use of water as a mechanism to enable as much possible efficient use of the resource available, within these defined limits. Resource availability is not the major issue for groundwater allocation. However, accessing and using this groundwater requires management in relation to effects on other users, surface water bodies, and saline intrusion (ie. salt water from the coast being drawn into groundwater sources). Several technical projects in relation to groundwater have been completed since notification of the POP. These include a

comprehensive assessment of previous technical work in relation to groundwater in Horizons' Region, and documentation of current understanding of the resource. Other technical work has analysed and reported on groundwater quality information in the Region. Further work in relation to groundwater has aimed to provide a greater level of certainty to the provisions of the POP in relation to groundwater management. Chapter 5 provides a brief overview of the technical work and technical evidence in relation to groundwater management in the POP.

2.4 Surface water quality

13. Chapter 6 of this report overviews the technical projects and evidence in relation to surface water quality. The surface water quality approach includes the use of the Water Management Zones (and Sub-zones) framework, and the values of these water bodies, as methods to establish water quality standards in relation to these values. The spatial differences in water quality state and trends for various parameters require consideration of a range of scenarios in terms of managing water quality. The spatial framework of the Water Management Zones, values and standards provide for this. Determining the relative contributions of various sources of contamination to water quality at various flows has been a focus of the technical work to provide guidance on approaches to the management of water quality. The provisions of the POP provide guidance on the management of water quality in relation to the state of environment and the values identified, and the water quality standards within this spatial framework. Where thresholds have been defined, the aim has been to do so numerically rather than via a narrative approach. This aims to provide certainty in the policy document and to reduce the need for debate about appropriate thresholds on a case-by-case basis through individual consent processes. New work completed since notification of the POP has prompted amendments to some aspects of the proposed Water Quality Framework, which primarily relate to the setting of water quality standards. Chapter 6 overviews technical work in relation to pressure on, and state of, the resource, and the proposed Water Quality Management Framework. This includes a summary of the proposed amendments to this framework and linkages to the evidence being provided in relation to surface water quality. Subsequent chapters address the approach to managing land use impacts on water quality.

14. The technical work related to surface water has identified the state of water quality and trends in water quality through investigation of standard water quality parameters, including biomonitoring information. Technical projects have also identified the sources of contaminants in water bodies, including identifying relative contributions of water

quality at various flows. In some catchments of the Region, non-point source contributions of sediment, bacteria and nutrients from the landscape of the catchments, including the farmed areas, have been identified as a major component of overall loadings in the river and stream systems. These relative contributions vary over a range of flows. In some cases at low flows, the point source contributions to water quality become the major contributor to loadings at these flows. Much of the work in Chapter 6 focuses on nutrient parameters of water quality, reflecting my involvement in these aspects of the science and the links of this work with the subsequent chapter on managing non-point source contributions to water quality. Further information in relation to other water quality parameters is presented in the evidence of others in relation to water quality. Further, a range of evidence in relation to managing sediment inputs that influence phosphorus loadings, turbidity and water clarity in rivers has been presented as part of evidence for the Land hearing for the POP and is not repeated in this evidence.

2.5 The FARM strategy approach

15. Chapter 7 of this report outlines the technical work and evidence in relation to the proposed framework for management of non-point sources of nutrients, faecal contamination and sediment. The approach proposes intensive farms in targeted catchments are required to complete a Farmer Applied Resource Management (FARM) strategy. The selection of target catchment areas relates to Water Management Sub-zones and has been informed by the water quality state and trends, and the relative contributions of the non-point sources to water quality. Within these zones, the approach is further targeted to intensive farms only. Management of these intensive farms has been identified to have the greatest impact on overall catchment water quality. The FARM strategy document includes requirements in relation to nutrients, faecal and sediment management. These requirements include N loss limits for intensive farming systems for nitrogen that have been linked to water quality outcomes. Chapter 7 provides an overview of the technical work in relation to the development of the policy and the subsequent testing of the proposed policy. Some technical projects in relation to this work are documented in the previous chapter, due to the inherent link this approach has with water quality. New work completed since notification of the POP has provided further information in relation to this approach. This work is also overviewed in this Chapter 7, which also provides some feedback in relation to the Hearing Panel's Chairperson's Minute #6.

16. The FARM strategy approach is proposed to apply to existing intensive farming in the targeted catchments and to conversions to intensive farming within these target catchments and throughout the Region. There is considerable potential for expansion of intensive farming in Horizons Region. An estimate for dairy farming suggests dairying could possibly more than double in the Region. The FARM strategy approach provides a mechanism to design any future development within a framework that has considered water quality outcomes.

17. The FARM strategies approach provides a mechanism to deliver catchment water quality outcomes through customised farm-level assessments and management. These customised FARM strategy assessments incorporate a range of practices that are currently considered best practice, including some that are required already by existing consenting or policy requirements and some others that are required as a part of industry initiatives such as the Clean Streams Accord. The approach tackles many types of potential non-point source contributions of contaminants to water bodies, including nitrogen (N), phosphorus (P), and sediments. Gains in relation to multiple water quality outcomes can be achieved from some mitigation options, eg. deferred irrigation of effluent may reduce losses of N, P and faecal material to water bodies. Likewise, exclusion of stock from water bodies will likely reduce losses of N, P, sediment and faecal material to water bodies.

18. The major new item proposed as part of this FARM approach is the management on-farm of whole-farm N losses. Previously, the management of N has primarily been delivered only through policy around effluent management. Effluent management only addresses a small component of the overall N losses from farms, and only some types of farms produce effluent. The proposed approach in the POP targets N loss limits from the whole farm that relate through to catchment water quality outcomes. This allows for innovation and flexibility in management to achieve the N loss limits at the whole-farm level.

19. The proposed nutrient management approach has been tested in a number of ways, including modelling of catchment outcomes for N loadings and periphyton levels. The FARM strategy approach has been tested on more than 20 farms. The first six of these were studied very comprehensively and it was determined that the targets could easily be meet for the study farms without major changes to the farm system. The extrapolation from these results predicted similar outcomes for most farms in the Region. The exceptions identified to this were ultra-intensive farms in traditional marginal landscapes, and in areas where particular land use and environment combinations

occur, eg. high rainfall, coarse shallow soils such as sands, low capability land, few trees and non-farmed areas, and high stocking rates. The further testing of the FARM strategies approach completed by Horizons intentionally sought to find farms in such situations. In very broad terms, it may be difficult to meet the proposed N loss limits with current technologies where high rainfall, high proportions of the farm in LUC class 4 and above, and high stocking rate coincide. This may also be the case where only two of these variables coincide. Some farms in these situations have been able to meet the proposed N loss limits by incorporating associated support blocks to the farm, the adjustment of LUC class in relation to overcoming the limitation of water through irrigation, and though improved information in relation to on-farm LUC mapping. Overall however, the test FARM strategies project has shown that the N loss limits are achievable for a range of farming situations, with current technologies and without major requirements for changes in farm management.

EVIDENCE

3. THE FUNDAMENTAL FRAMEWORK FOR REGIONAL WATER MANAGEMENT – ZONES AND VALUES

Relates to key provisions of the Proposed One Plan:

- **Objective 6-1: Water Management Values**
- **Policy 6-1: Water Management Zones and Values**
- **Policy 11-4: Common Catchment Expiry Dates**

3.1 Chapter Theme Summary

20. **The proposed Water Management Zone and values framework are the keystones around which the water allocation and water quality strategies in the Proposed One Plan (POP) have been built. The Water Management Zones, values and common catchment expiry dates provide simple, spatially defined tools to provide a customised water management regime for a large and highly variable Region. The spatial framework of the Water Management Zones and values provide a mechanism for integrated catchment management within a local area and in relation to the broader catchment. New work completed since POP notification has prompted a few minor amendments to fine-tune the Water Management Zones and values frameworks. This chapter provides an overview of the development of these components of the POP and the proposed refinements.**

3.2 Introduction

3.2.1 Concepts and linkages

21. The proposed integrated water management framework of the POP is based on identification of the range of values of water bodies. These are applied through a spatial framework of Water Management Zones (WMZs), either at the whole-zone level or at reach-specific level. The POP provides for the management of activities within these zones in relation to the values. The common catchment expiry date provides a mechanism to review these management activities, where they are consented, at a single point in time rather than making decisions in a more case-by-case, sporadic approach. Common catchment expiry dates also provide for a structured timeframe for material to be prepared that will inform decision-making.

3.2.2 Chapter Contents

22. The following sections provide an overview of:
    i. The Water Management Zones (Section 3.3)
    ii. The values frameworks (Section 3.4), and
    iii. The proposed common catchment expiry dates (Section 3.5).

3.3 Water Management Zones (WMZs)

3.3.1 Introduction

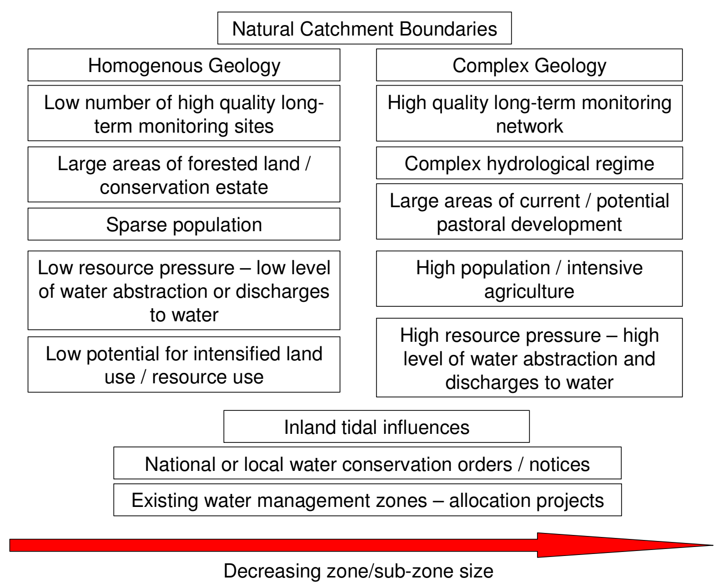
23. The Water Management Framework in Policy 6.1 of the POP is based on Water Management Zones (WMZs). These are geographical areas that have been defined to provide a common area for integrated management of the water resource. The definition of the values in these WMZs provides for managing activities in the zones for outcomes. The spatial framework of WMZs provides a mechanism for management in specific locations to be customised to the local situation and in the context of the wider catchment. The intention of the framework is that for some purposes the WMZs may be used individually and for some they may be combined. For example, in the case of water allocation, both the individual zone allocation limits and the cumulative zone allocation limits are considered when assessing allocation status (ie. is this area under-, fully- or over-allocated?). The WMZs also provide for efficiencies in policy effectiveness and State of Environment (SOE) monitoring.

3.3.2 Definition and Application of the WMZs

24. The derivation of the Surface Water Management Zones is documented in McArthur *et al*. (2007[2]). A short summary of this work is included in Box 1. The evidence of Ms Kate McArthur and Ms Maree Clark provides more detail in relation to the WMZ Framework[3]. In total, 44 WMZs (Map 1) and 117 Sub-zones have been defined across the Region (Map 2).

Box 1: Technical Project Summary – Definition of Water Management Zones

Defining the boundaries of the Water Management Zones (WMZs) and Sub-Zones was undertaken as a technical project, using a range of criteria. The figure below provides a schematic of the how the range of criteria was applied to derive the WMZs and their subsequent Sub-zones. The starting point was the natural catchment boundaries, and National Water Conservation Orders and Local Water Conservation Notices[4] were also taken into account. A key factor in defining boundaries was the ability to characterise the water resource in a zone through existing monitoring data using hydrological or water quality monitoring sites as defining points for many of the zone boundaries. This also enables policy effectiveness monitoring to be completed. Geology and known hydrological characteristics were also taken into account. Pressure on the resource was also considered, eg. areas with higher pressure for water abstraction generally had smaller WMZs or Sub-zones. WMZs defined in other projects were not changed. Tidal zones were also defined for the major river systems. The figure below provides a schematic of the how the range of criteria was applied to derive the WMZs and their subsequent Sub-zones.



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[2] LINK TO TECHNICAL REPORT: McArthur K., Roygard J., Ausseil A. and Clark M. (2007). Development of Water Management Zones in the Manawatu – Wanganui Region, Technical report to support policy development, *Horizons Regional Council Report No. 2006/EXT/733*. This report provides the full documentation of the derivation of the surface water management zones for the Proposed One Plan.

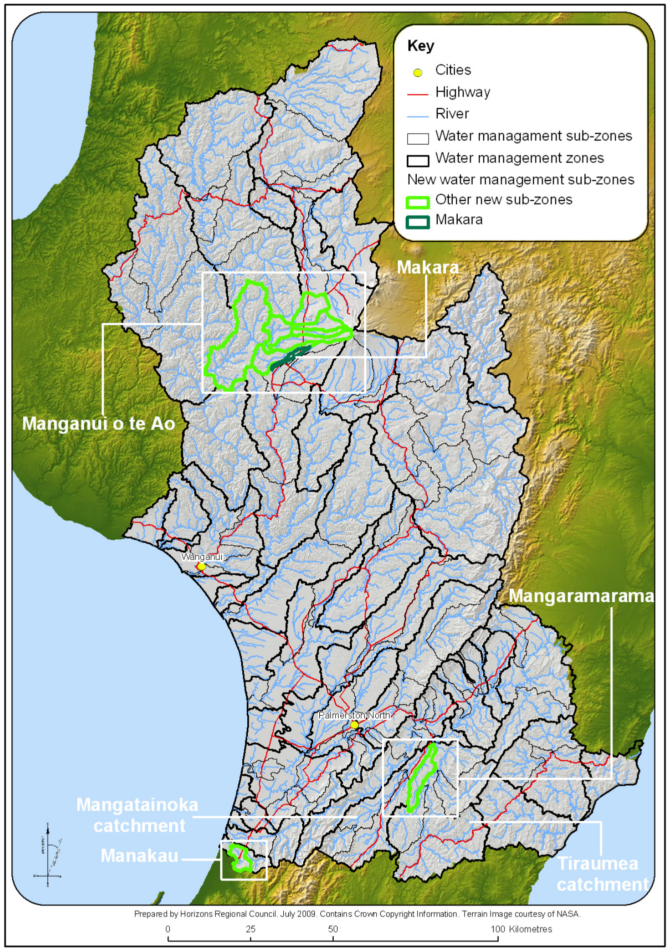
[3] LINK TO FURTHER EVIDENCE: The evidence of Ms Kate McArthur and Ms Maree Clark provides further detail on the derivation of the water Management Zone Framework and the recommended changes to the Water Management Zones.

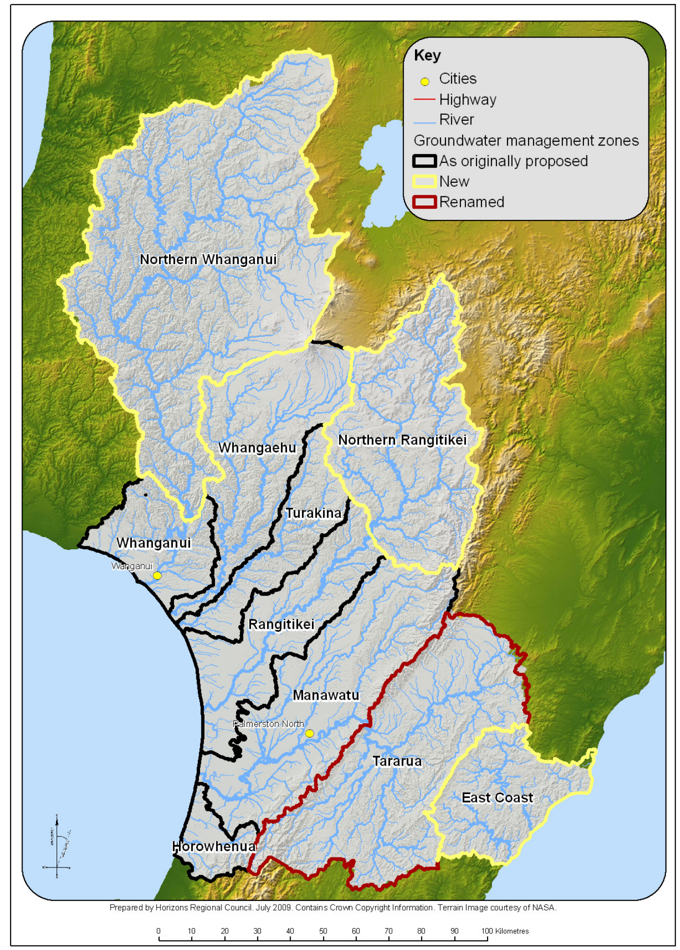
[4] Local Water Conservation Notices were replaced by provisions in the Land and Water Regional Plan (2003).

3.3.3 Definition of Groundwater Management Zones

25. Groundwater Management Zones also align with the boundaries of the Surface Water Management Zones. Zarour (2008)[5] provides detailed documentation of the derivation of the Groundwater Management Zones. Alignment with the Surface Water Management Zones is primarily provided by major catchment boundaries, or in the case of the Manawatu by the divide formed by the Ruahine Ranges and Tararua Ranges. Alignment of the management zones for the two water resources (groundwater and surface water) provides for integrated management of the water resource. This coordinated management approach is particularly important as the two sources interact as a part of the hydrological cycle.

[5] REFERENCE TO TECHNICAL REPORT: Zarour (2008). Groundwater resources in the Manawatu–Wanganui Region: Technical report to support policy development. This report documents the development of the Groundwater Management Zones. Horizons Report 2008/Ext/948.





Map 1. Left: Water Management Zones and Sub-zones identifying areas where changes are recommended. Right: Groundwater management Zones and Sub-zones identifying where changes are recommended. See text for details.

3.3.4 Recommended changes to the Water Management Zone Framework

26. Several technical amendments are recommended to the Water Management Zones as notified in the POP and documented in the report of McArthur *et al.* (2007). The amendments include the development of further Sub-zones, taking the total from 117 to 124. The 43 WMZs remain unchanged. The recommended amendments are summarised as[6, 7]:

    i. **Changing the Water Management Sub-zone for the Mangaramarama Creek** from a tributary of the Mangatainoka River to a tributary of the Tiraumea catchment. The Mangaramarama confluence occasionally enters the Mangatainoka River close to the Mangatainoka/Tiraumea confluence, and at other times it enters directly to the Tiraumea River.

    ii. **Changes to the Manganui o te Ao Water Management Sub-zones** to better reflect the areas identified in the schedules of the National Water Conservation Order. The two originally specified Sub-zones (5d and 5e) have been redefined into seven Sub-zones (5d, 5e, 5f, 5g, 5h, 5i, and 5j). The main implication of this change is in terms of water allocation and it provides for further allocation than was identified in the POP as notified.

    iii. **Addition of a further Sub-zone for the Makara Stream.** The new Sub-zone in the Lower Makotuku Sub-zone of the Lower Whangaheu Water Management Zone enables separate management of the minimum flows for the Makara and Makotuku water bodies.

    iv. **Addition of a further Sub-zone in the Waikawa Catchment** to enable separate management of the minimum flows in the Manakau Stream and the Waikawa Stream.

    v. **Amending the Water Management Zones Framework to better provide for the Coastal Marine Area (CMA).** This includes defining Seawater Management Sub-zones for the Coastal Marine Area (CMA). Ms McArthur's evidence explains the links between Schedule D (Water Quality) and Schedule H (Coast).

    vi. **Addition of further Groundwater Management Zones** to provide Groundwater Management Zones to cover the full extent of the Region. As a part of this, the Eastern Sub-zone was renamed the Tararua Sub-zone.

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6 LINK TO FURTHER EVIDENCE: The evidence of Ms Kate McArthur and Ms Maree Clark provides further detail on the proposed amendments to the Water Management Zone Framework.

7 LINK TO FURTHER EVIDENCE: The evidence of Ms Raelene Hurndell provides further detail on the implication of these changes in Water Management Zones for the Surface Water Allocation Framework.

3.3.5 Recommendation to the Hearing Panel

27. **I recommend that the Hearing Panel adopt the changes to the Water Management Zones and Sub-zones as recommended in the planning report of Ms Clare Barton[8].**

3.4 Water management values and purpose

3.4.1 Introduction

28. The values of each water body are at the core of integrated catchment management. As a part of defining the scope of the technical input to the values framework for inclusion in the POP, Horizons' planning team outlined the intent of the Water Values Framework as being to define, where possible, at the policy level the values of each water body. The aim of this approach was to avoid debates on these on a consent-by-consent basis. These values then provide a key mechanism to coordinate management of water bodies. This is particularly important where some values have the potential to conflict with other values.

3.4.2 Use of values in the past

29. Values have been used in Horizons' previous Plans including the various categorisations of the Manawatu Catchment Water Quality Regional Plan in relation to water supply, contact recreation, etc. Values have also been incorporated into the water allocation frameworks of water resource assessments (Roygard and Carlyon, 2004[9] and Roygard *et al.*, 2006[10]).

3.4.3 Definition of values

30. The technical report outlining the detailed derivation of the values for the POP is by Ausseil and Clark (2007a)[11]. Box 2 provides a short summary of this work. Ms McArthur's evidence provides a summary of the technical role in determining the values, including 1) the associated management objective 2) how they were developed 3) where

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[8] LINK TO FURTHER EVIDENCE: The evidence of Ms Clare Barton provides further detail on the recommended changes to the Water Management Zones from a planning perspective.

[9] REFERENCE TO TECHNICAL REPORT: Roygard & Carlyon (2004). Water allocation project Rangitikei River, Water resource assessment, allocation limits and minimum flows - Technical report to support policy development. Horizons Report 2004/Ext/606.

[10] REFERENCE TO TECHNICAL REPORT: Roygard *et al.* (2006). Water allocation project upper Manawatu Catchment, Water resource assessment, allocation limits and minimum flows - Technical report to support policy development. Horizons Report 2006/Ext/684.

[11] REFERENCE TO TECHNICAL REPORT: Ausseil & Clark (2007a). Identifying community values to guide water management in the Manawatu Wanganui region –Technical report to support Policy Development. Horizons Report 2007/Ext/786.

they apply (if this is defined in the POP) and 4) details of the recommended amendments. Ausseil & Clark (2007b[12]) also informed the values defined in the POP. This report corrected some inaccurate information in the geology layer of NIWA's River Environment Classification (REC). The evidence of Ms Clark provides further detail on this report[13].

Box 2: Technical Project Summary – Water Management Values Definition

Ausseil & Clark (2007a) documented the development and identification of water body values for the POP. A total of 22 different values, applying to all or parts of the Region's rivers and lakes, were identified and classified into four groups (see table below). Within the POP, the Water Management Zone values and purposes provide the management objectives and are applied in a range of parts of the POP. The application of the values framework spatially within the Water Management Zones Framework is done in a way where some values apply zone-wide or Sub-zone-wide, and others to specific (specified) reaches (Table 1).

Table A. Water management values and links to POP policies that will give effect to the values (modified from Ausseil & Clark, 2007a).

Overarching Value Groupings	Individual values		Where the value applies		Translated into policies in the Proposed One Plan Chapters				
			Zone Wide Value	Reach Specific Value	Water Quality	Water Allocation	BRL	Living Heritage	Coastal
Ecosystem Values	NS	Natural State		✓	✓	✓	✓	✓	
	LSC	Life-Supporting Capacity	✓		✓	✓	✓		✓
	SOS-A	Sites of Significance-Aquatic		✓	✓	✓	✓	✓	✓
	SOS-R	Sites of Significance-Riparian		✓			✓	✓	✓
	NFS	Native Fish Spawning		✓	✓	✓	✓	✓	✓
Recreational and Cultural Values	CR	Contact Recreation	✓		✓	✓	✓		✓
	Am	Amenity		✓			✓		
	NF	Native Fishery		✓	✓	✓	✓	✓	✓
	Mau	Mauri	✓		✓	✓	✓	✓	✓
	SG	Shellfish Gathering	✓		✓				✓
	SOS-C	Sites of Significance-Cultural		✓	✓	✓	✓	✓	✓
	TF	Trout Fishery		✓	✓	✓	✓		
	TS	Trout Spawning		✓	✓	✓	✓		
	AT	Aesthetics		✓	✓	✓	✓	✓	✓
Consumptive Use Values	WS	Water Supply	✓		✓	✓	✓		
	IA	Industrial Abstraction	✓		✓	✓	✓		
	I	Irrigation	✓		✓	✓	✓		
	S	Stockwater	✓		✓	✓	✓		
Social/Economic Values	CAP	Capacity to Assimilate Pollution		✓	✓	✓			✓
	FC	Flood Control		✓			✓		
	EI	Existing Infrastructure	✓				✓		
	D	Drainage		✓			✓		

12 REFERENCE TO TECHNICAL REPORT: Ausseil & Clark (2007b). River classification of the Manawatu-Wanganui region to support the definition of the life supporting capacity value. Horizons Report 2007/Ext/791.

13 LINK TO FURTHER EVIDENCE: The evidence of Ms Maree Clark provides further detail on the changes to the River Environment Classification (REC) to inform the development of the life supporting capacity value for the POP.

3.4.4 Technical amendments

31. The proposed amendments to the values framework are outlined in the evidence of Ms McArthur and Ms Clark[14]. These amendments are summarised as:

    i. Reclassifying the Amenity Values and Trout Fishery Values from zone-wide to reach-specific.
    ii. Reclassifying from reach-specific values to zone-wide values (where they apply): Industrial Abstraction, Irrigation, Water Supply and Existing Infrastructure Values
    iii. Renaming the Native Fish Spawning (NFS) Value as Inanga Spawning (IS) Value, as the needs of other native fish species are provided for by Sites of Significance – Aquatic.
    iv. Moving the Native Fishery Value to "Whitebait Migration" and placing it in the Ecosystem Value group, as harvesting of native fisheries is not managed by the RMA.
    v. Removing Shellfish Gathering Value from Schedule D and applying it to locations within the Coastal Marine Area (CMA) as detailed in Schedule H.
    vi. Changes to where the Aesthetic Values apply. These changes provide for Rule 16.1 (Damming of protected rivers) and linking to the Aesthetic Value rather than an independent list of protected rivers. These changes are to provide for consistency in approach. Ms Natasha James provides further information in relation to this[15] .
    vii. Specifying the reach of the Manawatu River in the Manawatu Gorge (in Mana_10a) as having Aesthetic Values.
    viii. Removing the designation of the Aesthetic Values from the Mangaramarama Creek (that was Mana_8e). These Aesthetic Values were originally applied due to the Mangatainoka Local Water Conservation Notice. The Mangaramarama Creek is a tributary of the Tiraumea River .

3.4.5 Recommendation to the Hearing Panel

32. **I recommend that the Hearing Panel adopt the Water Management Values as recommended in the planning report of Ms Clare Barton[16].**

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[14] LINK TO FURTHER EVIDENCE: The evidence of Kate McArthur and Maree Clark will provide further detail on the proposed amendments to the Water Management Values Framework.

[15] LINK TO FURTHER EVIDENCE: The evidence of Natasha James provides further detail in relation to the values framework and protected rivers.

[16] LINK TO FURTHER EVIDENCE: The evidence of Clare Barton provides further detail on the recommended changes to the Water Management Values from a planning perspective.

3.5 Common Catchment Expiry Dates

3.5.1 Introduction

33. Common catchment expiry or review dates (see Policy 11.4) have been recommended as part of the overall water management framework to provide for more coordinated decision-making at the catchment level. In practice, the use of common catchment expiry dates has been in place within resource consents issued by Horizons for a number of years. Examples include the lower Manawatu River discharges, the Oroua River water allocation consents, and Rangitikei River and upper Manawatu River water allocation consents. Common catchment expiry dates were addressed at the General Hearing on the Proposed One Plan earlier this year. Section 3.5 provides a brief overview of these common catchment expiry dates, as they are a key part of the overall Water Management Framework where they provide the mechanism to align management of the water resource to the spatial Water Management Zone Framework and the specified water management values.

3.5.2 Their Function

34. Common catchment expiry dates provide a structured mechanism to address resource management issues within the spatial framework of the POP. They dates should provide for more consistency between decisions and the resultant consent requirements. The more sporadic approach to consent expiry that has historically occurred in the Region has naturally resulted in cases where decisions have been made at different times. These decisions have, in some cases, applied differing requirements for similar activities that are in close proximity to each other. The common catchment expiry date framework provides a structured set of dates to work to, in terms of compiling information and recommendations for the management of resources within a catchment.

3.5.3 Definition of Common Catchment Expiry Dates

35. A short summary of the work[17] carried out to derive the recommended common catchment expiry dates is included in Box 3. The common catchment expiry dates have been aligned to the proposed dates for Rule 13.1 for intensive land uses and existing common catchment expiry dates in relation to water allocation.

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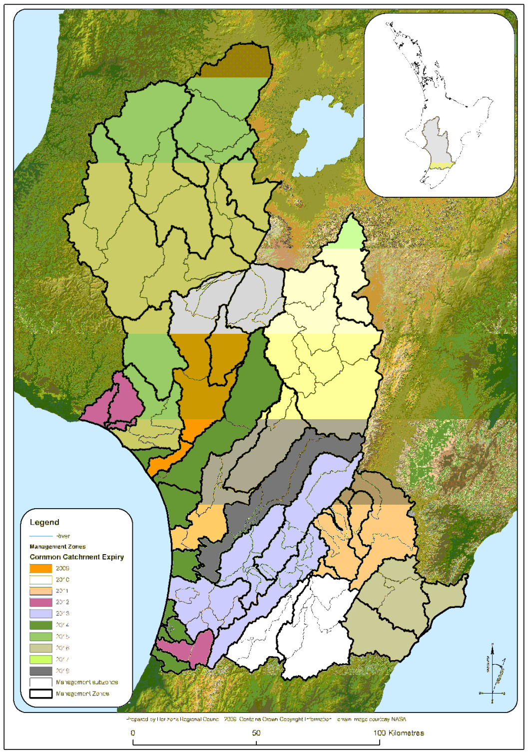
[17] CLARIFICATION ON MY ROLE: I have recommended the use of common catchment expiry dates as part of water resource assessments and resource consent technical reporting for a number of years. I also managed the technical project to determine the recommended common catchment expiry dates for the Proposed One Plan.

Box 3: Technical Project Summary – Common Catchment Expiry Definition



Map A. Common catchment expiry dates for the Region. It is noted that the upper Manawatu area (2011) is also identified with a common catchment expiry in 2016. The dates were set around a 10-year framework.

A range of factors were considered in determining these dates including:

1. The expiry dates of current consents in a Water Management Zone or Sub-zone;
2. Existing common expiry dates were used as a part of the framework, eg. the 2017 date for the Rangitikei catchment and the 2016 date for the upper Manawatu catchment water allocation; and
3. The dates for Rule 13.1 (Table 13.1), which proposes dates for intensive land uses. In some cases (the upper Manawatu catchments) this provided two dates, five years apart (see in Table 11.2 of the Proposed One Plan).

Implementation of these dates (Map A) across the catchments of the Region has been underway as a part of the consenting process following notification of the POP. These dates have been applied to a range of consents, including water takes, discharges to water, and discharges to land.

3.5.4 Technical amendments

36. There are no proposed changes to the common catchment expiry dates set out in the POP as notified.

4. SURFACE WATER ALLOCATION

Relates to key provisions in the Proposed One Plan:

- **Objective 6-3: Water quantity and allocation**
- **Policy 6-15: Overall approach for surface water allocation**

4.1 Chapter Theme Summary

37. **This chapter overviews the technical projects and evidence in relation to surface water allocation provisions of the Proposed One Plan (POP). The proposed Surface Water Allocation Framework uses the Water Management Zones (and Sub-zones) framework, and the values of these water bodies, as methods to establish different categories of allocation takes and various flow thresholds where these can and cannot be abstracted. Further, the proposed framework outlines requirements for reasonable and justifiable use of water as a mechanism to enable as much possible efficient use of the available resource, within the defined limits that provide for environmental protection and surety of supply. The goal of the framework is to specify limits and thresholds to provide certainty in the policy document. This aims to reduce the need for debate about appropriate thresholds on a case-by-case basis through individual consent processes. New work completed since notification of the POP has prompted amendments to the proposed water allocation framework. These primarily relate to the setting of minimum flows and core allocation limits. This chapter overviews the pressure on the resource and its state, and the proposed Water Allocation Framework. This includes a summary of the proposed amendments to the framework. Some sections in this chapter provide context in relation to both surface water and groundwater allocation, eg. the sections on permitted takes and reasonable and justifiable use of water.**

4.2 Introduction

4.2.1 Concepts and Linkages

38. The proposed Water Allocation Framework aims to provide certainty through definition of the thresholds at the policy level. The framework uses information from a range of Horizons' water allocation projects, including water resource assessments, minimum flow setting projects and projects in relation to efficiency of water use. The framework also draws on the work of other Regional Councils and research agencies in relation to water allocation. The framework takes into account existing water allocation decisions

and experience in implementing these, eg. resource consent decisions and previous Plans.

4.2.2 Chapter Contents

39. The following sections provide an overview of :

i. The pressure on the resource (Section 4.3, consented allocation in the Region).

ii. The state of the resource (Section 4.4).

iii. The response (Sections 4.5 to 4.16) overview of the proposed Water Allocation Framework)

4.3 Pressure on the resource - Consented Allocation in the Region

4.3.1 Introduction

40. The current allocation in the Region provides an indication of the pressure on the water resource from water allocation. A new analysis of this information has been completed to update the information in the State of the Environment (SoE) Report (Horizons, 2005a)[18]. A short summary of the technical work to derive the current allocation is included in Box 4[19].

Box 4: Technical Project Summary – Determining Consented Allocation in the Region

An analysis of consented water use was completed based on information collated in January 2009. The information included groundwater, surface water and riparian consents. Riparian consents (ie. takes from bores etc. that are connected to surface water bodies) are included in the numbers for surface water takes.

Building on the analysis for the SoE Report in 2005, the analysis below splits the consented water use into four groups: hydroelectricity, agriculture, industry, and water supplies. It is noted that these categories can have some overlap, eg. water supplies that provide stock water, which are common in the Region, or public water supplies that provide water for industries. The split into these categories provides some indicative context around the relative use of water between these sectors and how this use is trending.

To estimate the changes over time, the analysis is compared to levels published in the SoE Report in 2005. It is noted that the updated data set has been through further quality control than the set used for the SoE report.

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[18] REFERENCE TO TECHNICAL REPORT: Horizons (2005a). Horizons Regional Council State of Environment report 2005. Horizons Report 2004/Ext/608. Chapter 3 & Chapter 6 relate to surface water allocation and groundwater.

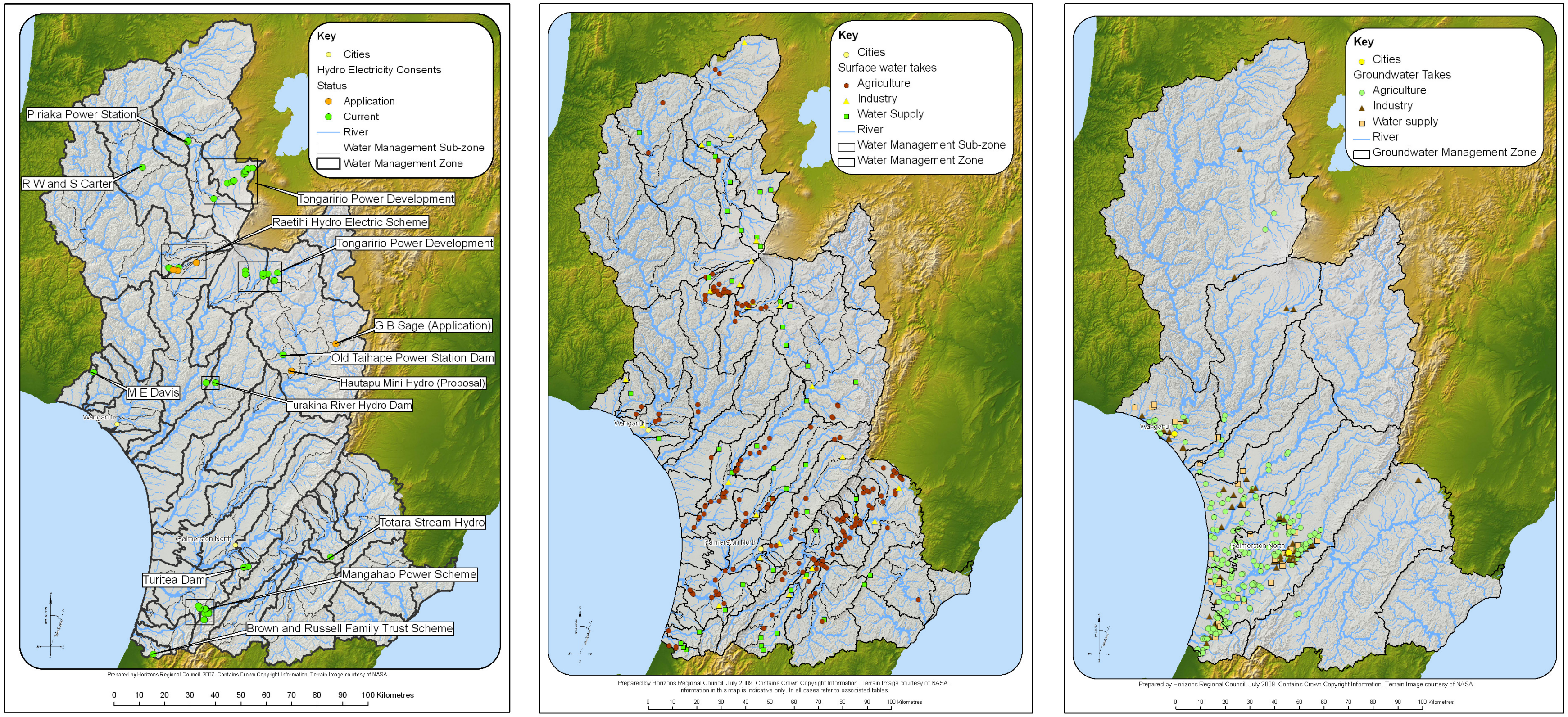
[19] CLARIFICATION ON MY ROLE: I completed this analysis of the current state of allocation in the Region based on numbers available in January 2009. I also completed the analysis of consented volumes for the surface water chapter (Chapter 3) of the State of the Environment Report 2005.

4.3.2 Summary of consented allocation

41. The hydroelectricity sector is by far the largest user of water in Horizons' Region, with an estimated average use of 55 m^3/s or 4,752,000 m^3/day (SoE Report, Horizons 2005a). This is more than 7.7 times greater than the combined maximum daily consented rate from groundwater and surface water for agriculture, water supply and industry which combined account for 1,153,799 m^3/day or approximately 13.354 m^3/s. Map 2 shows the relative locations of these takes.

4.3.3 Overview of consented hydroelectricity abstraction

42. The hydroelectricity takes in the Region use an estimated average of 55 m^3/s or 4,752,000 m^3/day (Horizons' SoE Report, 2005). Of this:
    i. More than half of the volume (approximately 29.7 m^3/s) is abstracted and exported from the Manawatu-Wanganui Region to the Waikato Region as part of the Tongariro Power Development (TPD) scheme. This is the largest abstractive use of water in the Region and is about 2.2 times greater than the combined maximum consented daily rate for water use by agriculture, industry and water supplies from groundwater and surface water.
    ii. The remaining hydroelectricity use totals approximately 25 m^3/day. This includes use by schemes such as the Mangahao power scheme, Piriaka Loop on the Whanganui River, and the Raetihi power scheme along with various smaller hydroelectricity takes (Map 2). At a regional and long-term scale, this use is largely non-abstractive as the water is, in one way or another, released back into river systems of the Region after use. When considered over shorter terms and on more local scales, some of these takes can be considered abstractive due to operational methods that include storage and/or diversion of water.



Map 2. Locations of consented takes in the Region. Left: consents for hydroelectricity (surface water takes). Middle: surface water takes for agriculture, industry and water supply. Right: Groundwater takes for agriculture, industry and water supply.

4.3.4 Overview of consented abstraction for agriculture, industry and water supply

43. The key messages for the combined consented maximum daily rate for agriculture, water supply and industry are:

    i. Total consented volume in January 2009 was 1,153,799 m^3/day or 13.354 m^3/s (see Table 2).
    ii. Approximately 62% of the total consented volume is for agriculture, 13% is for industry and 25% for water supplies.
    iii. Combined use for agricultural, industry and water supply has more than doubled (increased by 105%) since 1997.
    iv. Increases are predominately in the agricultural category. Reduced take volumes for water supplies reflect some true reductions and also improved accuracy of the categorisation of takes in Horizons' database, which generally has resulted in more takes being reassigned to the agricultural category).
    v. Surface water allocation has more than doubled compared to 1997 levels (ie. increased by 127%) and groundwater allocation has increased by 85%.
    vi. Surface water takes have increased from 48% of the allocation in 1997 to 53% in 2009.
    vii. There are a total of 641 consents (347 groundwater and 294 surface/riparian takes). Of the 294 surface/riparian takes, 52 were considered riparian ie. likely taking from a bore or a source connected to a surface water body.
    viii. Locations of the surface water/riparian takes and the groundwater takes differ (Map 2), reflecting areas of availability of the two water resources in the Region and areas where there is a demand for water.

Table 1. Consented maximum daily volumes for agriculture, industry and water supply (January 2009).

Category	Surface/ riparian (m^3/day)	Ground-water (m^3/day)	Total surface plus groundwater	Percentage surface/ riparian	Percentage ground-water
Agriculture	385,579	328,672	714,251	54%	46%
Industry	97,782	57,817	155,599	63%	37%
Water supply	133,259	150,690	283,949	47%	53%
Total	616,620	537,179	1,153,799	53%	47%
Percentage by category					
Agriculture	63%	61%	62%		
Industry	16%	11%	13%		
Water supply	22%	28%	25%		
Count of consents					
Agriculture	201	234	435		
Industry	40	68	108		
Water supply	53	45	98		
Total	294	347	641		

Table 2. Consented maximum daily takes for surface water and groundwater from 1997 to 2009, excluding hydroelectricity power generation.

Total volume	Surface/ riparian (m^3/day)	Groundwater (m^3/day)	Total surface plus groundwater (m^3/day)	Source
1997	271,527	290,172	561,699	SOE Report (2005)
2004	567,040	426,267	993,307	SOE Report (2005)
2009	616,620	537,179	1,153,799	Analysis Jan 2009
Total increase 1997-2007	345,093	247,008	592,101	
Increase 1997 to 2004	109%	47%	77%	
Increase 1997 to 2009	127%	85%	105%	

4.4 State of the water resource

4.4.1 Introduction

44. Allocation in the Region, when combined with information on the availability of the resource, provides an indication of the pressure on the water resource from water allocation. The primary mechanism for measuring the quantity of the water resource is

Horizons' SoE water quantity monitoring programme[20]. The sources of flow information available in the Region include:

i. Horizons' monitoring sites providing continuous flow data (66).

ii. NIWA monitoring sites providing continuous flow data, including national network sites (7) and client sites.

iii. Historic monitoring sites for various agencies, that have now been closed.

iv. Sites with individual or repeated measurements at various times (Map 3).[21]

v. Modelling of flows for particular locations in the Region. In some cases, modelling flow may well be the only practical way to get information on flows without establishing considerable structures to stabilise the substrate.

45. Aspects of the state of the resource in relation to water quality are presented in subsequent chapters of this report[22].

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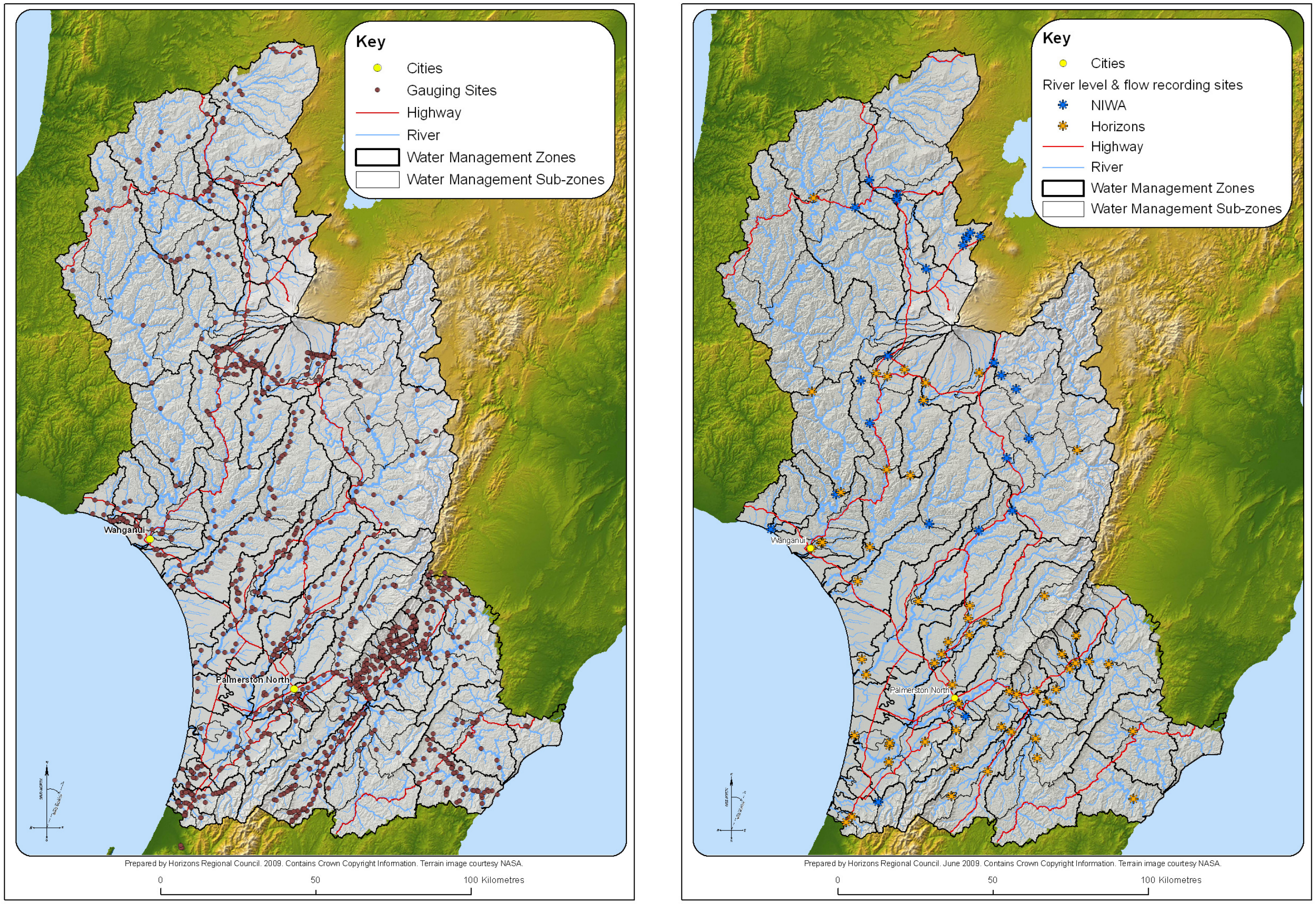
[20] CLARIFICATION ON MY ROLE: I manage the State of the Environment monitoring programme for Horizons.

[21] REFERENCE TO TECHNICAL WORK: Horizons has created a comprehensive archive of this flow information from a variety of organisations and locations, through project work that I have managed.

[22] REFER TO: Section 6.7 of this report overviews State of the Environment reporting re water quality.



Map 3. Left: locations of the river level and flow recording sites operated by Horizons Regional Council and National Institute of Water and Atmospheric Research (NIWA). Right: locations of flow gauging sites throughout the Region.

4.5 Surface water allocation response

46. The following sections provide an overview of the Water Allocation Framework proposed in the POP to manage surface water allocation, and the proposed changes to this framework. The sections cover:

    i. Water Allocation Framework types of allocation (Section 4.6).
    ii. Setting minimum flows and core allocations (Section 4.7).
    iii. Recommended amendments to minimum flows and core allocations (Section 4.8).
    iv. Comparison of Horizons' approach to that taken in the Proposed NES (Section 4.9).
    v. Monitoring water takes (Section 4.10).
    vi. Reasonable and justifiable use of water / efficient use (Sections 4.11 to 4.15).
    vii. Permitted takes (Section 4.16).

4.6 The Proposed One Plan Water Allocation framework – Types of allocation

47. Relates to key provisions in the Proposed One Plan:

    - Policy 6-15: Overall approach for surface water allocation
    - Policy 6-16: Core water allocation and minimum flows
    - Policy 6-17: Approach to setting minimum flows and core allocations
    - Policy 6-18: Supplementary allocation
    - Policy 6-19: Apportioning, restricting and suspending takes in times of low flows
    - Policy 6-20: Surface water allocation – lakes

4.6.1 Concepts and linkages

48. The proposed Water Allocation Framework[23] uses the Water Management Zones (and Sub-zones) framework and the values of the water bodies as a method to establish six different categories of allocation takes and various flow thresholds where these takes can and cannot be abstracted. The proposed categories of allocation are:

    i. **Permitted Takes.** These are small takes that are permitted and can be taken at all flows. These are linked to Policy 6-19 and Rule 15-1 as a Permitted Activity.
    ii. **Core Allocation Takes.** These takes are proposed to be able to be taken at any time when the flow is above a minimum flow. These are linked to Policy 6-16 and Rule 15-5 as a Controlled Activity.

[23] CLARIFICATION ON MY ROLE: I have assisted Horizons' Policy Team throughout the development of the Proposed One Plan in relation to the technical aspects of the Water Allocation Framework.

iii. **Essential Takes**. The Essential Takes allocation provides for some consented takes to continue to below the minimum flow. These are linked to Policy 6-19.

iv. **Supplementary Allocation Takes**. This is a supplementary allocation to provide for consented takes at above median flow for storage or use. The taking at high flows is limited to takes that do not compromise the values of the water body or the surety of supply for the core allocation users. These are provided for by Policy 6-18 and Rule 15-6(b) as a Discretionary Activity.

v. **Existing Hydroelectricity Takes that are not included in the core allocations.** These are linked to Policy 6-16, Rule 15-6 and Rule 15-8 as a Discretionary Activity.

vi. **Takes from lakes and wetlands**. These are linked to Policy 6-20 and Rule 15-5.

49. Consented takes may include components from one or more categories via specified consented take limits at various flows. An example of this is town water supplies that have consented allocation above the minimum flow (as a part of the core allocation component), and may have reduced consented volumes below minimum flow (as part of the essential take component). An irrigation consent could contain a core allocation component to provide water when the river is above the minimum flow and a supplementary allocation component that provides for topping up a storage facility. This storage facility could then provide for use when flows were below minimum flow.

4.7 Setting minimum flows and core allocation limits for the POP as notified

50. Relates to key provisions in the Proposed One Plan:

- Policy 6-15: Overall approach for surface water allocation
- Policy 6-16: Core water allocation and minimum flows
- Policy 6-17: Approach to setting minimum flows and core allocations
- Schedule B
- Policy 6-18: Supplementary allocation
- Policy 6-19: Apportioning, restricting and suspending takes in times of low flows
- Policy 15-6: Transfer of water permits
- Policy 6-12: Reasonable and justifiable need for water
- Policy 6-13: Efficient use of water

4.7.1 Concepts and linkages

51. Since the notification of the POP in May 2007, MfE has released a proposed National Environmental Standard (NES) for ecological, or minimum flows[24] (MfE, 2008[25]). The discussion document includes proposed interim limits (minimum flows and allocation limits) for streams where these have not been defined in a Regional Plan or Proposed Regional Plan. The NES on ecological flows is discussed in section 4.9 of this report which includes a comparison between the locally developed minimum flows and allocation limits, and the proposed national interim limits.

52. The core allocation limits and minimum flows are a central part of the POP Water Allocation Framework. The minimum flows provide the mechanism for restricting use at low flows to protect values (Policy 6-19). The frequency with which these minimum flows will potentially occur is directly related to the level at which the minimum flow is set and the current level of allocation.

53. The setting of core allocations and minimum flows at the policy level provides certainty for stakeholders about the management of the resource, the amount of water potentially available from a Water Management Zone, and the impact of this on the frequency of low flow conditions. For example, consent applicants can be provided with information indicating the frequency of minimum flows under current levels of allocation and how these might change if full allocation (and use) is reached.

54. Core allocation limits link to other policies within the proposed framework, including:
    i. Supplementary allocation takes (Policy 6-18) are required to consider both the effects on frequency and duration of low (minimum) flows, and the ability of anyone to take water under the core allocation limit.
    ii. The efficiency criteria of the Policy 6-12 (ie. reasonable and justifiable need for water) and Policy 6-13 (ie. efficient use of water) provide for the maximum efficient use of water within the available allocation limits, and the minimum frequency of minimum flow conditions.
    iii. Defined core allocation limits and minimum flows provide for ease of assessing the feasibility of transfer of water takes (Policy 15-6).

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24 TECHNICAL DEFINITION: Horizons uses the term minimum flow to characterise the flow at which core allocation takes are required to cease abstraction. Other terms for this type of flow threshold include ecological flow or environmental flow. These flows should not be confused with the flow statistic for lowest flow ever recorded in the river (the extreme low flow).

25 REFERENCE TO REPORT: MfE (2008). Proposed National Environmental Standard on Ecological Flows and Water Levels Discussion Document. MfE publication ME 868.

55. In setting the core allocation limits and minimum flows, emphasis has been placed on determining numerical thresholds to create certainty. Where numerical thresholds have not been possible, narrative thresholds have been recommended (eg. the wording for a flow statistic). Where numerical values have been determined, further analysis has been completed, where possible, to determine the expected frequency of minimum flows. This analysis considered scenarios of current levels of allocation, full allocation (ie. allocation of the full recommended core allocation limit) and comparison, where possible, with the proposed interim methods of the NES for ecological flows.

56. Determining the minimum flows and core allocation limits for the Region's Water Management Zones and Sub-zones has been an iterative process, as described in the following sections. The first component of this process was the design of the framework.

4.7.2 Design of the proposed framework

57. The design of the proposed framework for determining minimum flows and allocation limits has drawn on a range of information sources, including:
   - i. Existing water allocation decisions and experience in implementing these.
   - ii. The work of other Regional Councils and research agencies.
   - iii. Horizons' water allocation projects, including water resource assessments and minimum flow setting projects.
   - iv. Assessments of flow series and flow statistics.

4.7.2.1 Existing water allocation decisions and experience implementing these

58. A brief overview of the methodologies used for setting minimum flows and core allocation limits within the Region is provided in Box 5. In summary, there are historical water allocation decisions that provide guidance on setting minimum flows and allocation limits, and reflect how existing allocations were determined. There has been a progression over time from having multiple levels of flow restrictions, with corresponding allocation limits, to a less complex framework with a single minimum flow and allocation limits above and below that flow.

Box 5: Methods used for setting minimum flows in Horizons' Region

A range of existing water allocation decisions and project work within the Region have considered appropriate minimum flow/s and levels of allocation. These include:

1. National Water Conservation Orders for the Rangitikei River and Manganui o te Ao River.
2. The Hearings in relation to the Tongariro Power Development.
3. The Oroua Catchment Water Allocation and River Flows Regional Plan Change 1 (1997). This Plan adopted a methodology that used monthly flow statistics to set up to three differing levels of reductions in take volumes, based on a range of flow-based restrictions. Plan implementation includes a detailed roster for irrigators.
4. Resource consent decisions in relation to the Land and Water Regional Plan (2003). A typical methodology that has been implemented is the reduction of irrigation take volumes by 50% when river flows reached or were below the 1-day Mean Annual Low Flow (MALF) and a complete cessation of take volume when flows reached or were below 80% of the MALF. These splits in take volumes were typically difficult for consent holders to manage (particularly where pumps were not set up to reduce take volumes by 50%).
5. Horizons water resource assessment work from 2003 to 2006 and subsequent work on the regional water allocation framework has typically used a single minimum flow for the cessation or reduction of take volumes at low flows. Methodologies used to define these thresholds are described in detail in subsequent sections of this report.

4.7.2.2 Work of other Regional Councils and research agencies

59. To inform the development of a framework, a project was commissioned[26] to report on options available to Horizons for setting defensible minimum flows for the rivers and streams within the Region (a report by Hay & Hayes, 2007[27]). This report included some information on approaches by Environment Southland (Regional Council) and the work of various research agencies, including the National Institute for Water and Atmospheric Research (NIWA) and the Cawthron Institute, in relation to water allocation. The report provided information in relation to ecologically relevant flow statistics, maintaining flow variability, and methods for setting minimum flows and allocation limits. The evidence of John Hayes provides further detail in relation to this report[28] and its linkages with the proposed Water Allocation Framework in the POP. These linkages relate to setting minimum flows, setting core allocation limits, setting supplementary allocation, and maintaining flow variability.

[26] CLARIFICATION ON MY ROLE: I initiated this project and project-managed it for Horizons.

[27] REFERENCE TO TECHNICAL REPORT: Hay, J., & Hayes, J., (2007). Instream flow assessment options for Horizons Regional Council. Cawthron *Report No. 1242*.

[28] LINK TO FURTHER EVIDENCE: John Hayes provides evidence in relation to the report by Hay & Hayes (2007) and in relation to the use of Instream Flow Incremental Methodology (IFIM) within the Manawatu-Wanganui Region.

60. The instream flow assessment options report of Hay & Hayes (2007) for Horizons suggested a tiered approach to instream flow assessment and minimum flow setting. The approach provided different methods to be employed, depending on the level of abstraction demand and the significance of the instream values.

61. Horizons has adopted a tiered approach to setting minimum flows and allocation limits that includes detailed instream habitat analysis (see section 4.7.2.3 below) and historic flow methods. Horizons' approach has expanded on the concepts of this tiered approach by using the information obtained from the more detailed instream habitat assessments to inform the use of historic flow methods (as outlined in subsequent sections). The aim of this being to increase the accuracy of the application of historic flow methods. The instream habitat studies are therefore the core mechanism used for setting minimum flows, and have strongly influenced the design of the proposed Water Allocation Framework.

4.7.2.3 Instream habitat analyses

62. The various instream habitat studies that have been completed in the Region provided a key source of information used in setting minimum flows for the POP. These Instream Flow Incremental Methodology (IFIM) studies model the amount of habitat available at a range of flows for various species in water bodies. These studies use detailed field measurements to construct a computer model to predict how habitat availability varies with flow for selected species. This modelling can then be utilised as a decision support tool to determine appropriate minimum flows, in tandem with assessments of the critical values and considerations of the degree of hydrological alteration. The evidence of John Hayes provides further context on how this methodology is used nationally and internationally. Further, his evidence states, "*The use of IFIM habitat methods in New Zealand is supported by good scientific understanding of river ecosystems and their relationships with flow regime (ie. they are scientifically defensible)*".

63. Horizons has undertaken IFIM studies in a robust manner to ensure the accuracy of recommendations. This included working closely with Cawthron Institute scientists over the past six years to ensure the methods, and analysis, were carried out appropriately and in accordance with best practice. As part of this process, Horizons commissioned the Cawthron Institute to review, and in some cases then reanalyse, the IFIM studies that were completed prior to the Cawthron Institute's involvement in Horizons' programme. Cawthron Institute scientists have also been involved in all IFIM projects

undertaken by Horizons since 2003. The evidence of Joe Hay[29] documents the specific project work and recommendations to Horizons by Cawthron Institute regarding IFIM studies. Results of the IFIM analyses are discussed further in the sections below.

4.7.2.4 Water resource assessments

64. One of the primary uses of the IFIM information has been to inform Water Resource Assessments (WRAs), to define minimum flows and allocation limits. Horizons has undertaken three comprehensive water resource assessments[30] that have informed the design of the Proposed Water Allocation Framework. These are:

   i. The Ohau River WRA (Horizons, 2003[31]).

   ii. The Rangitikei River WRA (Roygard & Carlyon, 2004[32]).

   iii. The upper Manawatu Catchment WRA (Roygard *et al.*, 2006[33]).

4.7.2.5 Flow statistics and flow series

65. Flow statistics and flow series are an essential component of defining minimum flows and allocation limits. The design of the framework was premised on having numerical values rather than prescribing the narrative name of a flow statistic (eg. stating the flow of 3.7 m^3/s rather than writing the words mean annual low flow) . To establish flow statistics to inform the development of the POP, Horizons used the flow information available from the river monitoring network, including current and historic sites. The flow statistics project Henderson & Diettrich (2007)[34] sought to provide a single reference document for these flow statistics[35].

66. The fitness for purpose of flow statistics relates to their accuracy. One of the limitations of the flow statistics recorded in a river is that they represent flows that are influenced by the level of abstraction from the river and discharges into the river. The recorded flows

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29 LINK TO FURTHER EVIDENCE: The evidence of Joe Hay provides details in relation to the use of IFIM within Horizons' Region.

30 CLARIFICATION ON MY ROLE: I was a co-author of the Ohau River WRA and the lead author and project manager for the Rangitikei River and upper Manawatu catchment WRA's.

31 REFERENCE TO TECHNICAL REPORT: Horizons (2003). Water allocation project Ohau River, Water resource assessment, allocation limits and minimum flows – Technical report to support policy development. Horizons Report 2003/EXT/575.

32 REFERENCE TO TECHNICAL REPORT: Roygard & Carlyon (2004). Water allocation project Rangitikei River, Water resource assessment, allocation limits and minimum flows – Technical report to support policy development. Horizons report 2004/Ext/606.

33 REFERENCE TO TECHNICAL REPORT: Roygard *et al.* (2006). Water allocation project upper Manawatu Catchment, Water resource assessment, allocation limits and minimum flows - Technical report to support policy development. Horizons report 2006/Ext/684.

34 REFERENCE TO TECHNICAL REPORT: Henderson & Diettrich (2007). Statistical analysis of river flow data in the Horizons Region. NIWA client report CHC2006-154 for Horizons Regional Council.

35 CLARIFICATION ON MY ROLE: I initiated, sought funding for and project-managed this project for Horizons.

therefore do not typically represent the flow that would have naturally occurred (termed the naturalised flow). An example in relation to naturalising flows is provided in Box 6.

Box 6: Technical Concept – naturalising flows

Calculating an accurate naturalised flow series is a key part of understanding or characterising the water resource. The natural flow series for a river is that which would have occurred had there been no abstraction, damming, diversion, or discharge into the river. Naturalising the flow is not as simple as adding the consented maximum daily abstraction rate upstream of the flow recording site to the recorded flow in the river. Most water users do not abstract to their maximum daily take rate every day during the year. Irrigators are a good example of this, where water use is generally seasonal and adjusted in accordance with climatic conditions. Accurate water use records are required to accurately calculate a naturalised flow series.

To provide some context for this, an example of calculating a flow statistic for the flow recording station for the Manawatu River at Hopelands is used.

1. The catchment is estimated to have a mean annual low flow (MALF) of 3,734 l/s (Henderson & Diettrich, 2007) from the continuous flow record from 1989 to 2005.
2. The continuous flows are measured, to ISO standard, to be within ± 8% for 95% of the time, ie. the MALF is 3,700 ± 299 l/s.
3. The question then remains as to how to naturalise the MALF when consented maximum daily volumes in 1997 were in the order of 300 l/s and had increased to 971 l/s in 2009. This is further complicated by the seasonality of some takes, particularly irrigation, as well as the partial use or no use at all of some consented takes.
4. The only way to accurately naturalise the flows is through the use of water use records.

4.7.2.6 Naturalising flows for the Proposed One Plan

67. The naturalisation of flows has been addressed as a part of the minimum flow and core allocation methodologies of the POP. The flow statistics report (Henderson & Diettrich, pp 13-14) provides some very broad background to the major abstractions that may have influenced the hydrology in the Region. The report also provides very detailed information on the influence of some major hydroelectricity takes on river flows[36]. However, the statistics in flow statistics document are not necessarily naturalised. Attempts by Horizons to naturalise flow records in some catchments have been hampered by unavailability of accurate water use records[37], despite requirements for these to have been provided in many cases. To address the shortfall of accurate water use records, alternate methods have been utilised in naturalising flows as a part of the proposed Water Allocation Framework. The methodologies used for naturalising flows

[36] REFER TO: The following section (4.7.2.7) of this report documents the use of flows statistics in relation to hydroelectricity consents.

[37] REFER TO: The section of this report relating to water take volume monitoring (Section 4.3).

as part of setting minimum flows and core allocation limits for the POP are documented in the associated technical reports.

4.7.2.7 Naturalising flows for hydroelectricity

68. The concept of assessing core allocations and minimum flows after any [existing] takes for hydroelectricity (Policy 6-16) was incorporated into the design of the framework. Many of the existing hydroelectricity consents that are abstractive are located in the upper catchments, and flow recorders downstream of these provide flows records after abstraction by the hydroelectricity consents. Therefore, calculating any remaining allocation after the abstraction for hydroelectricity reflects a pragmatic approach to setting minimum flows and allocation limits from the residual recorded flows. Box 7 provides an example of this. This approach recognises the existence of hydroelectricity infrastructure in the water bodies of the Region, many of which have been in place for significant periods of time.

Box 7: Technical concept – Setting core allocation limits and minimum flows after assessing existing hydroelectricity

As an example, the Tongariro Power Development abstracts water from the Region. In the case of the impact of this scheme on water allocation in the Rangitikei catchment, the minimum flow setting methods have used naturalised mean annual low flow (MALF) statistics. These naturalised MALF's have been calculated using long-term average take rates by the TPD at the MALF. However, the surety of supply calculations that determine the core allocation limits have been based on the expected flow record, ie. using the as recorded excluding water already abstracted by the hydroelectricity consent. Therefore, this approach defines the amount that is available after the abstraction via the hydro scheme and accounts for the variation in take volumes on a daily basis (Figure A). The minimum flow setting methodologies in the proposed framework have not always used naturalised flow statistics, as was the case in the Rangitikei River and Whangaehu River. In other cases, it was not possible to establish naturalised flows statistics, eg. for the rivers affected by the Mangahao power scheme.

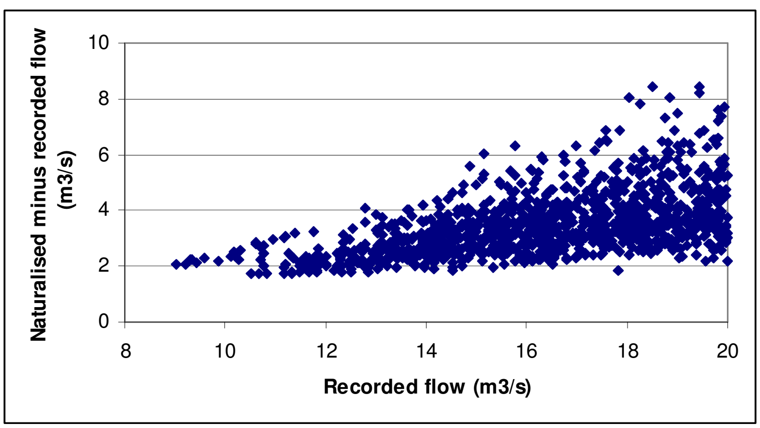

Figure A. Mangaweka River recorded flow plotted against the residual of naturalised flow minus recorded flow at Mangaweka during low-flow conditions (source Roygard & Carlyon, 2004).

69. The Raetihi power scheme, operated by NZ Energy, is the exception referred to in Policy 6-18 to the approach of having core allocations exclude existing hydroelectricity abstractions. In this case, the core allocation in Schedule B was intended in the POP to be calculated to include the allocation from this take. The exception for this consent reflected the mid-catchment location of these takes in the Whangaheu catchment, and the abstraction from the Whangaheu Catchment and discharge into Whanganui Catchment. The exception also reflected the ability to characterise the maximum daily take for this consent over a range of flows. The revised framework recommends treating this take in a similar manner to the other existing hydroelectricity takes.

4.7.3 The proposed framework for setting minimum flows and core allocation limits

70. The methodologies used for setting minimum flows and core allocation limits for the POP as notified are documented in Volume One of the Water Allocation Framework report[38] (Hurndell *et al*., 2007[39]). Box 8 provides a brief summary of the methodologies used in this report. In summary, the project identified six main scenarios for setting allocation limits and minimum flows. The six scenarios are described in Box 8.

71. Overall, the framework defined numerical allocation limits and minimum flows where possible, and some narrative limits as a default method where there was insufficient information. The project also provided direction for where monitoring programmes should focus to get further information. The flow chart used in setting these minimum flows and allocation limits is shown in Box 9, with a map showing the location of where the various scenarios were applied to provide recommendations.

4.7.3.1 Determining allocation limits

72. The recommended core allocation limits have, in the majority of cases, been determined via a surety-of-supply analysis. The aim of this analysis has been to use the frequency at which the minimum flow will occur under various allocation limits as a guide to recommending allocation limits. Results of the surety-of-supply analysis for the work completed prior to the notification of the POP are documented in Volume Two of the Water Allocation Framework report (Hurndell *et al*., 2007). The evidence of Ms Raelene Hurndell includes further surety-of-supply information.

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[38] CLARIFICATION ON MY ROLE: I conceptualised and initiated this project for Horizons and have led and managed the project work.

[39] REFERENCE TO TECHNICAL REPORT: Hurndell R., Roygard J., and Watson J. (2007). Regional Water Allocation Framework: Technical Report to Support Policy Development - Volume 1. Horizons Regional Council Report 2007/Ext/809.

Box 8: Technical Project Summary – Regional Water Allocation Framework as proposed in the Proposed One Plan as Notified

The Regional Water Allocation Framework Report (Hurndell *et al*., 2007) documents the technical work that produced the core allocation limits and minimum flows in the POP as notified. The report primarily used existing information from a range of water allocation projects and identified six scenarios for setting minimum flows and allocation limits. These scenarios are:

a. **Scenario 1: National Water Conservation Order (NWCO)**

Implementing the NWCOs for the:

(i) Rangitikei River - Water Conservation (Rangitikei River) Order 1993.

(ii) Manganui o te Ao River - National Water Conservation (Manganui o te Ao) Order 1988.

b. **Scenario 2: Water Resource Assessments (WRA)**

This scenario used the recommendations from the three detailed projects to determine water allocation management in specific catchments, ie.:

(i) The Ohau River WRA.

(ii) The Rangitikei River WRA.

(iii) The upper Manawatu Catchment WRA.

c. **Scenario 3: Instream Flow Incremental Methodology (IFIM) studies**

IFIMs were also used in the WRAs. This scenario used the recommendations from the IFIM studies for the locations where WRAs had not been completed, ie.:

(i) Pohangina IFIM

(ii) Oroua IFIM

(iii) Makotuku/Makara IFIM.

d. **Scenario 4: Local Water Conservation Notice (LWCN)**

This scenario recommended a default minimum flow of MALF to provide for the values identified. Allocation limits are based on the wording of the three LWCNs, ie.:

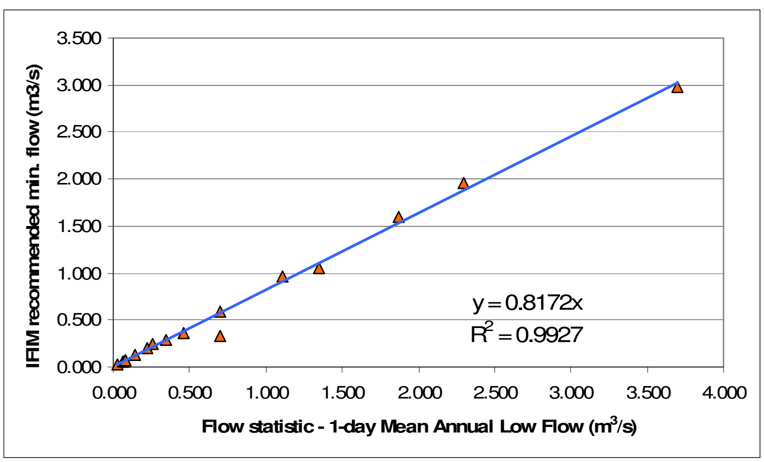
(i) Makuri.

(ii) Mangatainoka.

(iii) Upper Hautapu.

e. **Scenario 5: Good hydrological record – (a historic flow statistics based method)**

This scenario used the relationship between the minimum flows predicted by IFIM and the MALF (see graph below). The minimum flows for these sites were set at 90% of MALF and core allocation limits were set at 20% of the MALF. This method required good hydrological record (the source of this record is outlined in Hurndell *et al*., 2007).



f. **Scenario 6: Default rule**

This scenario was applied where information was limited. The minimum flows were defined as MALF and core allocation limits were set at 20% of the MALF.

Box 9: Technical Project Summary – Regional Water Allocation Framework for the POP as notified

The process used in defining minimum flows and allocation limits is summarised in the flow chart below (Figure A). The results of this process, in terms of which Water Management Zones were processed by the various scenarios, is shown in Map A.

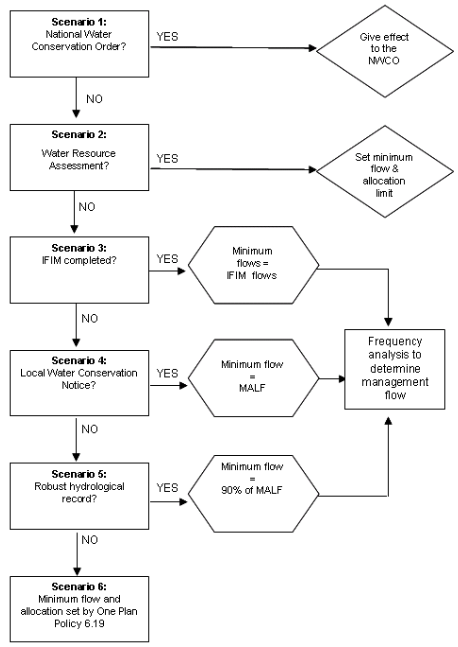
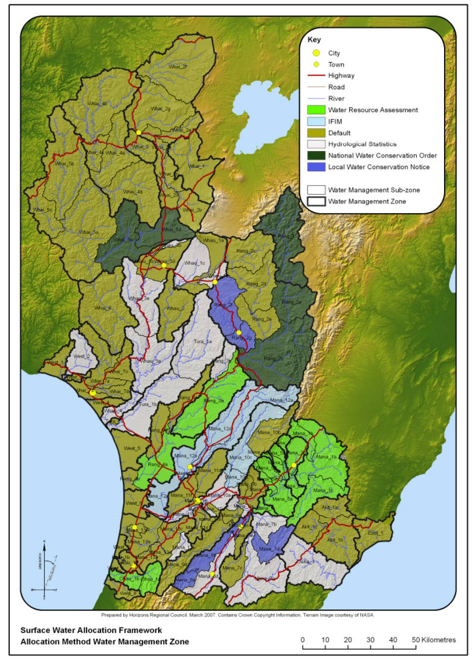


Figure A. Flow chart of the process for setting allocation limits and minimum flows for the POP as notified.



Map A. Locations where the various scenarios were applied

73. For the majority of the sites where surety-of-supply analyses have been completed, the analysis used scenarios of allocation levels that were determined by various percentages of MALF (eg. 5%, 10%, 15%, 30%). The analysis results showed the frequency at which minimum flows would occur under that allocation regime (ie. minimum flow plus core allocation limit), based on the available historic flow record. The calculations assume full allocation and use (ie. every consent holder is using all of the time). These estimates can be considered to be worst case scenarios due to:

i. The historic flow record is likely influenced by some of the current allocation, unless it has been naturalised, so the estimate of frequency of occurrence of the minimum flow plus the core allocation limit may be overestimating the use. Given the relatively recent increase in water takes in the Region, some long-term flow records for the region do contain periods where records have not been substantially influenced by abstraction. Some long-term records are influenced by abstraction or diversion for hydroelectricity and water supply takes.

ii. The assumption that everyone always uses their full allocation does not necessarily hold true. Reasons for this include:

a. Consent holders having no infrastructure at all for use of the consented volume;
b. Consents having allocation that is not fully utilised;
c. Consent holders using water efficiently and therefore not using at all, or not using full amounts, at all times;
d. Some consents being downstream of the flow recorder site; and
e. Lag times in the catchment, the surety of supply analysis assumes these are non-existent.

74. The following may be used as a guide to interpreting the frequency of occurrence of minimum flow information that is provided in the evidence of Ms Hurndell: The frequency of occurrence of a minimum flow is likely to be somewhere between the frequency of the minimum flow (without any allocation) from the historic record and the frequency of the minimum flow plus the full allocation limit. Where in this range the frequency is likely to be can be narrowed down by considering the length of flow record, abstraction patterns during this period of record, the locations of the consents in relation to the flow recorder site and the degree of naturalisation of the flow series.

75. Other factors were also considered in determining allocation limits. These included requirements of NWCOs, current allocation, and pressure on the resource. Details of the selected allocation limits for the POP as notified are provided in Hurndell *et al*. (2007).

4.8 Recommended changes to core allocation limits and minimum flows

4.8.1 Overview of recommended changes

76. Determining the minimum flows and core allocation limits for the Region's Water Management Zones and Sub-zones has been an iterative process. Following the work of Hurndell *et al*. (2007) to establish the minimum flows and allocation limits for the POP as notified, further work has been undertaken to refine the setting of minimum (min.) flows and allocation limits for the Region[40]. This work has included targeted flow monitoring, updating flow series and flow statistics, and further technical projects. The revised flow statistics produced as part of this work are reported on by Mr Brent Watson[41]. The details of the revised methodologies and their application to the framework, including a revised version of Schedule B, are provided in the evidence of

[40] CLARIFICATION ON MY ROLE: I have led the team completing this project work and defined the primary refinements to the methodology.
[41] LINK TO FURTHER EVIDENCE: The evidence of Brent Watson provides further detail on the revision of flow statistics.

Ms Hurndell[42]. In preparation for the POP Hearings, Horizons commissioned the Cawthron Institute to recheck all of the IFIM studies based on the latest information on habitat suitability curves and flow statistics, and at the suggestion of the Cawthron Institute, some of the data sets were revisited. These revisions included updated flow statistics, correction for a software bug and reanalysis and correction of shortcomings in the field data. The documentation of this work is presented in the evidence of Mr Hay[43].

4.8.2 Updates to Scenarios 2, 3 and 5 as a result of revision of the IFIM studies

77. The updated information from IFIM analyses (Box 10) influences the outcomes of the scenarios in relation to Scenario 2 (WRAs), Scenario 3 (IFIMs), Scenario 4 (LWCNs) and Scenario 5 (Good Hydrological Record).

78. Following the update to the IFIM analyses, the relationships used to recommend minimum flows for the POP as notified using Good Hydrological Record (Scenario 5) have been recalculated. As a result, a three-tiered approach to setting minimum flows based on historic flow records (Scenario 5) is recommended. The recommended three-tiered system is:

i. Where the MALF is less than 0.460 m^3/s
   a. the recommended minimum flow = 0.95 x MALF (ie. 95% of MALF)
   b. the equation for the IFIM data where MALF is less than 0.275 is min. flow = 0.909 x MALF r^2 = 0.9997

ii. Where the MALF is equal to or between 0.460 to 3.700 m^3/s
   a. the recommended minimum flow is 0.85 x MALF (ie. 85% of MALF)
   b. the equation for the IFIM data is min. flow = 0.8263 x MALF r^2 = 0.9968

iii. Where the MALF is greater than 3.700 m^3/s
   a. the recommended minimum flow is 0.80 x MALF (ie. 80% of MALF)
   b. the equation for the IFIM data (all flows) is min. flow = 0.7116 x MALF r^2 = 0.9869

79. The selection of the threshold of 0.460 m^3/s reflects the relationships in Box 11, Figure A and Figure B. Box 11, Figure A shows the relationship between MALF and recommended IFIM minimum flow for rivers with a MALF less than 0.275 m^3/s. Box 12, Figure B shows the relationship between MALF and recommended IFIM minimum flow for rivers with a MALF between 0.460 m^3/s and 3.7 m^3/s (Box 12, Figure B). There are no rivers in the IFIM data set with a MALF that is greater than 0.275 m^3/s and less than

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[42] LINK TO FURTHER EVIDENCE: The evidence of Raelene Hurndell provides further detail on the proposed changes to minimum flows and allocation limits in Schedule B.

[43] LINK TO FURTHER EVIDENCE: Joe Hay provides evidence in relation to reanalysis of the IFIM studies.

0.460 m^3/s. For this range, where MALF is greater than 0.275 m^3/s and less than 0.460 m^3/s, the more conservative relationship has been applied (ie. that for flows <0.275 m^3/s). The selection of 3.7 m^3/s as a threshold reflects the differing relationships between Figure B and Figure C of Box 12.

80. It is noted that the 80% of the MALF approach for larger rivers is consistent with many minimum flows set through consent conditions in the Region under the Land and Water Regional Plan (2003). The three-tier system uses conservative relationships between MALF and IFIM predictions because at some sites, the relationships (Box 11) may under- predict the IFIM results as can be seen in the IFIM results table (Box 10). These relationships are built using only the IFIM surveys that maintained 90% of habitat retention at MALF (ie. sites identified as having high values).

Box 10: Technical project summary – Recommendations from IFIM analyses in the Region

The IFIM studies results have been reanalysed to improve their accuracy (as documented in the evidence of Dr Joe Hay). The updated results for these studies are shown in Table A below. Horizons has completed IFIM studies at 21 sites in the Region.

Table A. Results from the IFIM studies showing the level of habitat retention and suitability criteria used. The relationship between the recommended minimum flow and MALF is also shown.

Count	IFIM study reach	Report	Suitability Criteria	Level of habitat retention (%)	MALF (m^3/s)	IFIM recommended minimum flow (m^3/s)	Percentage of MALF represented by IFIM flow
	Sites with 90% habitat retention						
1	Mangapapa Stm at Oxford Rd	1	Brown trout yearling	90	0.030	0.028	93.3%
2	Raparapawai Stm at Gaisford Rd	2	Brown trout yearling	90	0.044	0.040	90.9%
3	Kumeti Stm at Te Rehunga	1	Brown trout yearling	90	0.059	0.055	93.2%
4	Kumeti Stm at State Highway 2	1	Brown trout yearling	90	0.070	0.064	91.4%
5	Manawatu at State Highway 2	1	Brown trout yearling	90	0.140	0.130	92.9%
6	Manawatu at Ormondville TakapauRd	1	Brown trout yearling	90	0.222	0.200	90.1%
7	Tamaki Rvr at Water Supply Weir	1	Brown trout yearling	90	0.260	0.238	91.5%
8	Oruakeretaki Stm at State Highway 2	2	Brown trout yearling	90	0.275	0.249	90.5%
9	Tamaki Rvr at State Highway 2	3	Brown trout yearling	90	0.460	0.367	79.8%
11	Mangatoro Stm at Weber Rd	1	Brown trout adult	90	0.700	0.590	84.3%
12	Manawatu at Maunga Rd	1	Brown trout adult	90	1.113	0.970	87.2%
13	Manawatu at Weber Rd	1	Brown trout adult	90	1.875	1.600	85.3%
14	Pohangina at Mais Reach	4	Brown trout adult	90	2.300	1.960	85.2%
15	Manawatu at Hopelands Bridge	1	Brown trout adult	90	3.700	2.980	80.5%
16	Rangitikei at Mangaweka	2	Rainbow trout adult	90	15.800	12.250	77.5%
17	Rangitikei at Onepuhi	2	Rainbow trout adult	90	16.400	12.100	73.8%
18	Rangitikei at Hamptons	2	Rainbow trout adult	90	16.500	10.180	61.7%
	Average of sites						
	MALFs of 0.275 m^3/s or less						91.7%
	MALFs of 0.460 to 3.7 m^3/s						83.5%
	MALFs of 16.5 or less						85.2%
	MALFs of 15.8 to 16.5 m^3/s						71.0%
	Sites <90% habitat retention						
19	Makara at d/s power intake weir	2	Brown trout yearling	70	0.060	0.047	78.3%
20	Makotuku at d/s power intake weir	5	Brown trout yearling	70	0.116	0.094	81.0%
21	Oroua at Boness Road	2	Brown trout adult	80	1.355	1.030	76.0%

Reports

1. Hay and Hayes, 2007b. Instream flow assessment for the upper Manawatu River and tributaries additional analysis with addendum. Cawthron Report 1029.
2. Hay, 2009. Changes to some of Horizons' instream habitat datasets and recommended minimum flows. Cawthron Report 1601.
3. Hay and Hayes, 2005. Addendum to instream flow assessment for the upper Manawatu river and tributaries additional analysis. Addendum to Cawthron Report 1029.
4. Hay and Hayes, 2006. Instream flow assessment for the Pohangina River. Cawthron Report 1080.
5. Hay and Hayes, 2007c. Instream flow assessment for the Makotuku River and Makara River. Cawthron Report 1350.

Box 11: Setting minimum flows using flow statistics and information from IFIM surveys

The following three graphs show the relationship between the one-day MALF and the minimum flow recommended by IFIM analysis based on 90% of habitat retention for the recommended species at MALF. This information has been used to revise the approach around setting minimum flows based on flow statistics (Scenario 5).

Figure A. MALF as a predictor of IFIM recommended flows for the flow range MALF <=0.275 m³/s

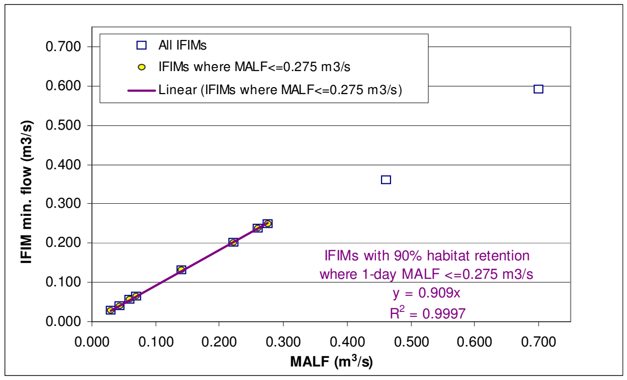


Figure B. MALF as a predictor of IFIM recommended flows for the flow range MALF is 0.460 to 3.7 m³/s

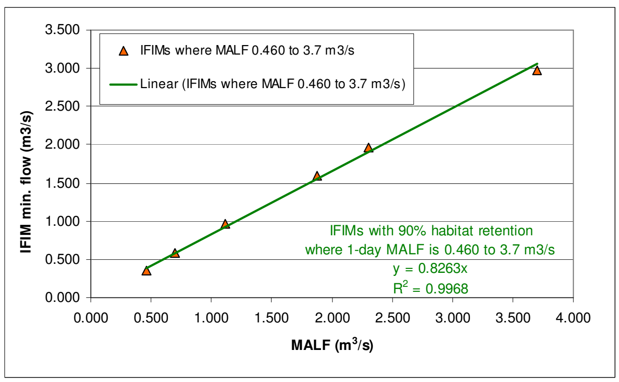
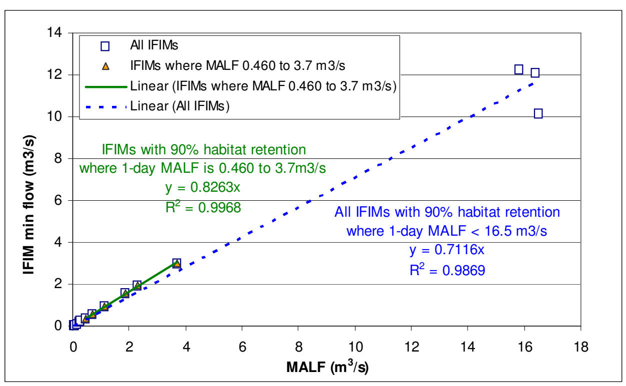


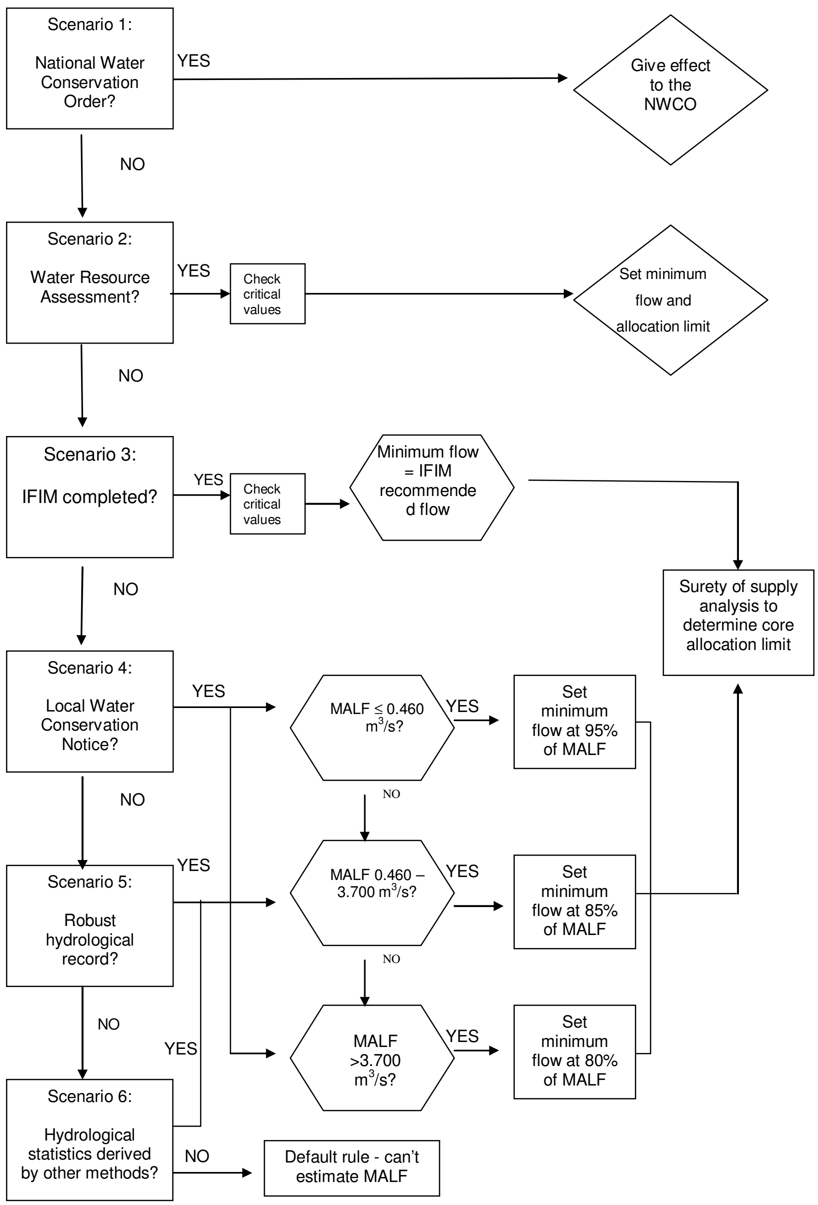
Figure C. MALF as a predictor of IFIM recommended flows for the flow range MALF is 0.030 to 16.5 m³/s



4.8.3 Overall approach used to determine minimum flows and allocation limits

81. The further work on the Water Allocation Framework following notification of the POP has resulted in some amendments to the overall framework, as shown in Figure 1. The main changes to the scenarios are further outlined below. The full documentation of revised recommended minimum flows from this approach is documented in the evidence of Ms Hurndell[44].

Figure 1. Revised flow chart for determining minimum flows and allocation limits.



[44] LINK TO FURTHER EVIDENCE: Raelene Hurndell provides evidence in relation to the revised minimum flows and allocation limits that are recommended to the Water Hearings.

4.8.4 Updates to Scenario 1: National Water Conservation Orders

82. The IFIM updates influenced the proposed allocation regime for the Middle Rangitikei Water Management Zone. The revised IFIM recommended a minimum flow of 12.250 m^3/s for the Mangaweka site, which is lower than the 12.790 m^3/s recommended minimum flow of the Rangitikei water resource assessment. Further, a new surety-of-supply analysis was completed for this zone to generate an allocation limit that was consistent with requirements for the allocation to be less than 5% of the natural flow. The resultant core allocation limit is lower than that originally proposed.

83. Further refinement of the Manganui o te Ao Water Management Zones has provided for a revised allocation framework in these zones that better reflects the intention of the NWCO. This has provided some allocation availability in contrast to the original recommendation of zero allocation for this entire area.

4.8.5 Updates to Scenario 2: Water Resource Assessments (WRA's)

84. Ohau WRA. There are no proposed changes the water allocation recommendations for the Ohau catchment.

85. Rangitikei WRA. The Rangitikei mainstem sites have revised IFIM recommendations. The minimum flow for the Onepuhi site has reduced from 14.5m^3/s to 12.5 m^3/s (lower Rangitikei Zone, Rang 3). There is no change recommended for the minimum flow at the McKelvies site (Coastal Rangitikei Zone, Rang 4). Both of these sites are recommended to have reduced allocation limits. This is to improve surety of supply under full allocation conditions. Both zones are considered to have allocation available (as at August 2009).

86. The upper Manawatu WRA. These zones were reviewed as a part of the further work. A technical report on the minimum flows and allocation limits of the Oruakeretaki and Raparapawai has been completed (Hurndell *et al*. 2008[45]). Allocation recommendations for the Oruakeretaki have been amended and recommendations are for a revised minimum flow, based on 70% habitat retention at MALF, and a lower allocation limit. Other Sub-zones of the upper Manawatu have had some core allocation limits reduced as a result of further surety-of-supply analysis. These changes do not impact on current allocation. Allocation recommendations for the Raparapawai Catchment were revised in the same study. The Raparapawai catchment was considered over allocated by the

[45] REFERENCE TO TECHNICAL REPORT: Hurndell, R., Watson, B., and Roygard, J., (2008). Raparapawai and Oruakeretaki Minimum flow review Horizons Regional Council Report No. 2008/EXT/939.

upper Manawatu WRA (Roygard *et al.,* 2006). Following the upper Manawatu WRA, consents were granted allowing this level of over allocation to continue with the introduction of a minimum flow in the Raparapawai Stream. The combination of the minimum flow and high levels of allocation provides for many periods of restriction in this catchment. The study of Hurndell *et al.* (2008) furthered knowledge of this catchment and recommended lower minimum flows and allocation limits than the upper Manawatu WRA. The recommendations of Hurndell *et al.* 2008 have been carried over to the newly recommended Schedule B for the One Plan hearings. Careful consideration of the minimum flows and allocation limits in this catchment is required in relation to the current and future allocation in this catchment.

4.8.6 Updates to Scenario 4: Local Water Conservation Notices (LWCNs)

87. In reviewing the framework, consideration has been given to the appropriate minimum flow to provide for the values identified in the LWCNs. In each case, these values are trout fishery values. In the values framework of Ausseil & Clark (2007a) Trout Fishery Values are classified into categories of outstanding, regionally significant and other. Each of the LWCN areas has been identified as a regionally significant trout fishery. Where Horizons' IFIM studies have identified regionally significant Trout Fishery Values, 90% of habitat retention at MALF has been used to determine the minimum flow, eg. the upper Manawatu mainstem sites (brown trout) and the Rangitikei mainstem sites (rainbow trout). This approach of 90% of habitat retention at MALF has been used to determine the minimum flows at sites identified as outstanding fishery value, eg. Rangitikei at Mangaweka (rainbow trout). To be consistent in approach, it is considered that 90% of habitat retention would be used if IFIMs were undertaken in the areas with Local Water Conservation Notices (Scenario 4). As the hydrological record method (Scenario 5) provides prediction for IFIM recommended minimum flows based on 90% of habitat retention at MALF, this methodology is recommended for the sites previously included in Scenario 4. As a result, the newly recommended minimum flows are lower and surety-of-supply analyses have been completed to determine allocation limits.

4.8.7 Updates to Scenario 6: Default Rule

88. Some areas that were recommended to fall into the default rule of the POP as notified have been resolved to a point where a numerical recommended minimum flows have subsequently been recommended. These include zones where MALF's were calculated using flow relationships between flow gaugings and flow recorder sites (Scenario 6a), flow gauging pair relationships (Scenario 6b), and through catchment area

extrapolations or specific yields (Scenario 6c). In each of these cases, the minimum flows have been recommended using the derived MALF statistic and three tiered method of Scenario 5.

89. Other sites originally identified as falling under the default rule have also been further analysed and numeric minimum flows and allocation limits have been recommended. These include :

i. The Moawhango catchment, which was originally recommended to have allocation available in the lower Sub-zone (Sub-zone Rang_2e). Based on feedback from a recent application to abstract water from this area, this Sub-zone is now recommended to have zero allocation available (further to the abstraction by the Tongariro Power Development (TPD)). These zones have been grouped as Scenario 6d.

ii. The Water Management Zones and Sub-zones upstream of Whanganui at Te Maire, which are currently recommended to have the minimum flows and allocation limits as per the default rule. A further option would be to specify minimum flows as per the consent conditions for the TPD, with allocation limits (assessed after the abstraction by the TPD) at the current level of allocation. It is noted that at present some of these consented minimum flows only apply between certain dates. At present in the newly recommended Schedule B, these zones remain under the default rule of Policy 6-17. These zones are grouped as Scenario 6e.

iii. The Porewa Sub-zone (Rang_4c), which naturally dries up in the lower reaches, is recommended to have an allocation limit of zero, and minimum flow requirements linked to the minimum flows in the nearby Rangitikei mainstem site (ie. Rangitikei at Onepuhi). It is noted that this catchment contains a number of abstractions specified as groundwater takes in the consents database.

iv. The Tutaenui Sub-zone (Rang_4d) contains a large water supply dam in its headwaters and dries up naturally in the lower reaches. This zone is recommended to have an allocation limit equal to the current allocation and minimum flow requirements linked to the minimum flows in the downstream Rangitikei mainstem site (ie. Rangitikei at McKelvies). The allocation for the water supply dam is included in the recommended allocation limit. The take rate specified is as per the current consented daily take from the dam. This catchment has been grouped into Scenario 6f, which is strongly influenced by storage in the catchment.

v. The Turitea water supply dam, in subzone Mana_11b, that provides some of the water for Palmerston North City is another example where established storage facilities have been incorporated into the framework. As when the POP was notified, the daily allocation limit for this dam had been calculated based on reasonable and justifiable need for water for drinking water. The minimum flow was recommended based on a policy call. This was two times the current consented minimum flow below the dam. This catchment has been grouped into Scenario 6f, which is strongly influenced by storage in the catchment.

90. Some zones remain in the category of the default rule. The recommended thresholds for these areas have also been revised based on the newly available information. A default rule of MALF as the minimum flow and 10% of MALF as the allocation limit are recommended. Previously recommendation was 20% of MALF as the allocation limit. The reduction to 10% of MALF as the default allocation limit is consistent with many zones in the Region having lower levels of allocation recommended as a result of further surety of supply analysis. The zones remaining in the category of the default rule have been grouped as Scenario 6g.

4.8.8 Changes to recommended core allocation limits

91. The core allocation recommendations were completed following the establishment of a minimum flow to provide for the environmental needs of the river concerned. The surety analysis then gave consideration to the frequency of those minimum flows occurring and their impacts on the environment and the users who would be required to cease or reduce abstraction. Where possible, the framework has aimed to provide for a relatively secure supply. Based on information from further analysis, many of the previously recommended core allocation limits have been reduced. However, in some catchments the minimum flow itself has a relatively frequent frequency of occurrence (due to influence from storage or abstraction by hydroelectricity) and any allocation above this can only increase this frequency. The evidence of Ms Hurndell provides details of the predicted frequency of minimum flows for the combined minimum flow and core allocation recommendations. Further, Ms Hurndell provides an assessment of the proposed allocation limits in relation to consented allocation in the region as at July 2009.

4.8.9 Recommendation to the Hearing Panel

92. **I recommend that the Hearing Panel adopt the changes to Schedule B as recommended in the planning report of Clare Barton.**

4.9 Comparison of approaches in the Proposed One Plan and the Proposed NES

4.9.1 Introduction

93. The NES for ecological flows is outlined in the report by MfE (2008[46]) and the technical supporting document by Beca (2008[47]). The NES was proposed in March 2008 and submissions closed on 31 July 2008. In its proposed form, the NES provides a framework to set minimum flows and allocation limits in catchments where water allocation regimes are not defined in Regional Policy Statements, Regional Plans or Proposed Regional Plans. This implies that the defined allocation limits and minimum flows that are prescribed for all Water Management Zones and Sub-zones via Schedule B of the POP would override the minimum flow and core allocation setting methods of the proposed NES. The water allocation framework proposed by the NES were determined for national application, after the development of the POP Water Allocation Framework. Horizons was not engaged by MfE to participate in the development of the NES for ecological flows prior to the notification of the proposal.

94. Dr John Hayes[48], who has been involved in the development of Horizons' POP approach and has also been involved in the subsequent development of the NES, provides an overview of the relationship between the NES and the POP approach. Dr Hayes concludes that in broad terms, Horizons' approach to setting minimum flows is consistent with the methodologies outlined in the NES. I agree with this summary.

95. The following section overviews where the details of two approaches differ in relation to the application of historical flow methodologies to water allocation decision-making. While the approaches are similar at a broad level, the technical details vary. It is my view that the locally developed framework for setting minimum flows for Horizons' Region is more appropriate than the nationally derived NES framework. The main reasons for this are that Horizons' approach was calibrated locally and uses information from detailed assessments in the Region to determine minimum flow setting methods.

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[46] REFERENCE TO REPORT: MfE (2008). Proposed National Environmental Standard on Ecological Flows and Water Levels Discussion document. MfE publication ME 868.

[47] REFERENCE TO TECHNICAL REPORT: Beca (2008). Draft guidelines for the selection of methods to determine ecological flows and water levels. Report prepared by Beca Infrastructure Ltd. for MFE, Wellington: Ministry for the Environment, New Zealand. Supporting document for the National Environmental Standard (NES) on methods for establishing ecological flows and water levels for rivers, lakes, wetlands, and groundwater resources. Contributors: Section 2 (Rivers) – I. Jowett (NIWA), J. Hayes, Barry Biggs; Section 3 (Lakes and Wetlands) – C. Howard-Williams, B. Sorrell; Section 4 (Groundwaters) – P. White, T. Heller.

[48] LINK TO FURTHER EVIDENCE: John Hayes provides evidence on the proposed NES on ecological flows and how it relates to the POP approach.

96. The proposed NES for ecological flows defines a formula for setting minimum flows and allocation limits. This approach, using historical flow methods, is based on two categories, one for smaller rivers and a second for larger rivers. Large rivers are defined in the proposed NES as those where the mean flow exceeds 5 m^3/s. For clarity, the mean flow is the average flow of the river and should not be confused with the mean annual low flow (MALF) of the river. Horizons' proposed approach uses three categories of flow based on the one-day MALF's to determine the methodology for setting minimum flows, based on historic flow statistics. The flow thresholds for Horizons' approach have been determined from the detailed IFIM studies (as outlined in previous sections).

97. To identify the one-day MALF's of rivers with mean flows in the order of 5 m^3/s, an assessment was completed to identify all sites with mean flows of 4-6 m^3/s in the flow statistics report for Horizons' Region (Henderson & Diettrich, 2007[49]). Four sites were identified, as shown in Table 3. The range of MALFs was from 0.395 m^3/s to 2.156 m^3/s. For comparison, Horizons' three-tiered approach uses MALF thresholds of 0.460 m^3/s and 3.7 m^3/s. From the sites in Table 3, it is difficult to draw any strong relationship between the mean flow and MALF. Horizons' approach of using MALF thresholds is preferred, given water allocation management has to relate to the critical periods of low flows.

Table 3. Mean annual low flows of rivers with mean flows of 4-6 m^3/s in Horizons' Region

Site	Mean flow (m^3/s)	Mean annual low flow (m^3/s)
Makuri at Tuscan Hills	5.464	2.156
Hautapu at Taihape	4.460	0.745
Mangatainoka at Larsons Road	5.170	0.395
Tamaki at Stephensons	4.032	0.395
Range	4.032 to 5.464	0.395 to 2.156

4.9.2 The proposed interim limits of the NES

98. The proposed NES specifies the smaller rivers, with a mean flow less than or equal to 5 m^3/s the minimum flow shall be equal to 90% of the seven-day MALF and the allocation limit shall be the greater of:

i. 30% of the seven day MALF; or

[49] REFERENCE TO TECHNICAL REPORT: Henderson R. & Diettrich J. (2007). Statistical analysis of river flow data in the Horizons Region. Prepared for Horizons Regional Council. NIWA Client Report CHC2006-154, NIWA Project ELF07202/HZLC22.

ii. The total allocation from a catchment on the date that the standards comes into force less any resource consents surrendered, lapsed, cancelled or not replaced.

99. The proposed NES specifies that for larger rivers with a mean flow greater than 5 m^3/s, the minimum flow shall be equal to 80% of the seven-day MALF and the allocation limit shall be set the greater of:

i. 50% of the seven-day MALF.

ii. The total allocation from a catchment on the date that the standards come into force less any resource consents surrendered, lapsed, cancelled or not replaced.

100. Horizons' historic flow-based method for setting minimum flows uses the one-day MALF statistic. There are a range of reasons why the one-day MALF is used rather than the seven-day MALF, including:

i. Horizons allocates on a maximum daily rate basis and manages water allocation on a daily basis.

ii. Rivers in Horizons' Region change on a daily basis.

iii. Horizons' data archives are capable of using a one-day MALF for calculation of flow statistics. NB: Some hydrologists prefer the seven-day MALF as it "smoothes" the discrepancies that can occur in flow records.

4.9.3 Comparing the one-day MALF with the seven-day MALF

101. The proposed NES approach uses the seven-day MALF statistic in contrast to the one-day MALF used by Horizons. The seven-day MALF is higher than the one-day MALF, meaning the frequency of occurrence of a seven-day MALF is higher than for the one-day MALF, ie. the seven-day MALF occurs more often than a one-day MALF. To investigate the relationship between the one-day MALF and the seven-day MALF within Horizons' Region, Horizons, through Envirolink, commissioned NIWA to assess the relationship and the cause of any variation in this relationship. The report (Henderson, 2008[50,51], Box 12) was prepared based on the same information used in the flow statistics project (Henderson & Diettrich, 2007). The results provided some indicative relationships and identified the importance of a localised assessment on a site-by-site basis.

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[50] REFERENCE TO TECHNICAL REPORT: Henderson (2008) Relationship between 1-day and 7 day MALF in the Horizons Region. NIWA client report CHC2008-140 prepared for Horizons Regional Council.

[51] CLARIFICATION ON MY ROLE: I initiated and project managed this project for Horizons.

Box 12: Technical project summary – comparing the one-day and seven-day MALFs

To investigate the relationship between the one-day MALF and the seven-day MALF within Horizons' Region, Horizons, through Envirolink, commissioned NIWA to assess the relationship and the cause of any variation in this relationship. The report (Henderson, 2008) was prepared based on the same information used in the flow statistics project (Henderson & Diettrich, 2007).

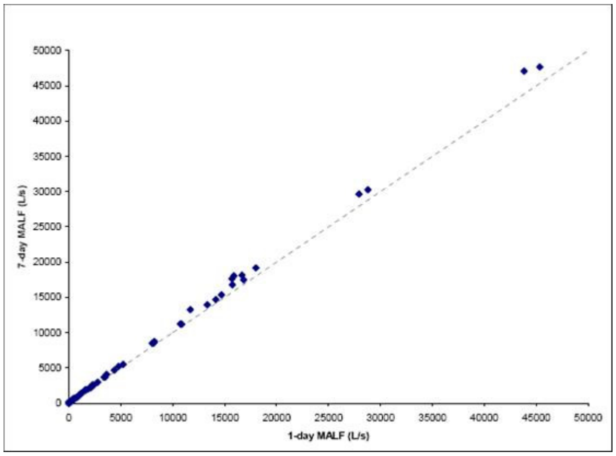


Figure A. 1 day MALF as a predictor of the 7-day MALF. The dashed line indicates a 1:1 ratio

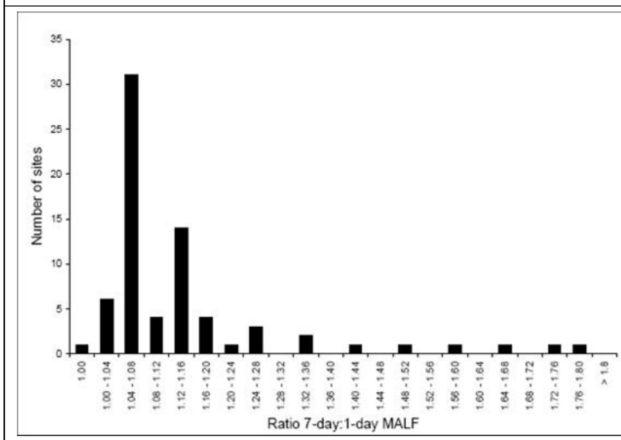


Figure B. Histogram of 7-day:1-day MALF ratios

The executive summary of Henderson (2008) states: "*An analysis of the relationships between the 7-day MALF and the 1-day MALF shows that the ratio ranges from 1.0 to more than 1.7. More than 80% of catchments have a ratio of less than 1.2, and the median ratio is 1.08. Most of the catchments with a low ratio are large (catchment area > 400 km^2) and/or high yielding at low flow (MALF > 10 L/s/km^2). Small low yielding catchments have greater values of the ratio 7-day/1-day MALF, and there is also greater variability of that ratio (from 1.0 to more than 1.7).*

The site-by-site assessment shows the range of effects, some of which can be explained by variations in climate, geology and catchment size. To assess the impact of a change in MALF statistic on any particular consent in the Horizons region, it is therefore necessary to examine the difference in MALF statistics at the flow recorder to which the consent conditions are linked."

4.9.4 Comparing the NES approach to the frequency of low flows with Horizons' approach

102. When comparing allocation limits and minimum flows recommended by the proposed approaches of Horizons and the NES, the minimum flows are more similar than the allocation limits. The NES default allocations of 30% and 50% of the seven-day MALF are greater than those proposed by Horizons. Horizons has set allocation limits based on how often minimum flows are likely to occur, using the historical flow records and modelling of the minimum flow and allocation limits. Allocation limits from Horizons' approach generally range from 5% to 30% of the one-day MALF. As would be expected, the amount of time the minimum flows are predicted to occur under the NES

approach is much higher than that under Horizons' approach. The evidence of Ms Hurndell provides comparisons between these approaches at specific sites where this could (and has) been modelled[52].

4.10 Monitoring of water take volumes

103. Relates to key provisions in the Proposed One Plan as notified:

- Policy 6-16: Core water allocation and minimum flows
- Policy 6-19: Apportioning, restricting and suspending takes in times of low flow
- Policy 13-2: Monitoring requirements of consent holders
- Policy 15-4: Monitoring requirements of consent holders
- Policy 15-6: Transfer of water permits
- Policy 6-13: Efficient use of water

4.10.1 Concepts and linkages

104. The monitoring of water take volumes is currently being addressed nationally via a proposed National Environmental Standard (NES) on measurement of water use[53]. The proposal has been notified and submissions provided, though it is currently unclear exactly where this NES may be heading. The Implementation Taskforce for the Proposed Measurement of Water Takes Standards has been provided an indication from MfE staff that Section 330 of the RMA may be utilised in place of the proposed NES. Horizons' current monitoring programme predates the development of the proposed NES and has been used by the NES Taskforce as one of the case studies for best practice around water use measurement. Horizons' requirements for water use measurement meet or exceed the proposed standards for water use measurement of the NES. The one exception to this may be in relation to small takes for agricultural use.

105. Monitoring of water take volumes is an essential component of managing the water resource to ensure:

i. Information to characterise the resource is available for future water allocation decisions, eg. the ability to naturalise flows.
ii. The framework implemented by decision makers is complied with, providing equity between users (ie. users who comply are not disadvantaged by those who do not comply), ensuring transparency for stakeholders that decisions are being

[52] LINK TO FURTHER EVIDENCE: The evidence of Raelene Hurndell includes comparisons between the NES approach and Horizons' approach to using historical flow records to set minimum flows.

[53] CLARIFICATION ON MY ROLE: I am a member of Implementation Taskforce for the Proposed Measurement of Water Takes Standards and have led a work stream for this group on case studies.

complied with, and ensuring the environmental protection provided by the framework.

106. Horizons' historical water use monitoring programme is overviewed in Box 13. In summary, Horizons has typically required consent holders to submit water-use records via manually collected readings from water meters to Horizons on a monthly or annual basis. This has had limited success in terms of characterising overall use of water in the Region. One issue has been obtaining the records for consent holders. This could be further resolved via increased prompting from Horizons about the requirements to provide records. However, the major issues for manual records are accuracy, timeliness and the time taken to obtain and process the information. Further, manual records do not overcome issues in relation to accuracy of meters and whether they are functioning. With manually supplied records, this information is not obtained until well after critical periods of use. For some large takes, these types of mechanical metering issues have led to large gaps in information required to inform consent decisions.

107. Horizons have trialled data loggers, which provide an alternative to daily collection of manual records. The data loggers require regular downloads of information and if they are not downloaded then information can be lost. Information from data loggers is likely to be submitted on a monthly or similar basis. The processing of the data and its entry into databases then requires some level of technical effort. If issues are found (eg. information is not recorded or there are potential non compliances) the ability to follow these up is delayed as a result of the time between submission of records.

108. Horizons have established a water-use monitoring programme with emphasis on automatic provision of water-use records to Horizons' databases on a daily basis. This provides high quality water-use records to enable the calculation of the natural flows of the Regions water bodies. The automatic provision of water-use records in a timely manner has the advantage of enabling early detection of any issues with the metering or compliance with consent conditions. Horizons' WaterMatters[54] system (Box 14), which processes this information, provides automatic daily reports for Horizons, consent holders and stakeholders that highlight issues identified in the data.

[54] CLARIFICATION ON MY ROLE: I conceptualised and built the first prototype of the WaterMatters system. I have led and managed the project to produce WaterMatters in its current form and manage the associated water metering programme.

Box 13: Horizons' historical approach to water-use provision, and examples of effectiveness

Since the late 1990s, Horizons has typically required water use records for the majority of consented water takes. Up until about 2004, these records were generally required to be recorded daily and forwarded to Horizons regularly (eg. once a month). A number of consents still operate in this manner and consents continue to be granted with similar requirements in some cases. Attempts to process and use records as part of water resource assessments have shown the ineffectiveness of manually supplied daily records as a mechanism to determine water use in a catchment. The Rangitikei River Water Resource Assessment (WRA), (Roygard & Carlyon, 2004; pp 100-105) and the upper Manawatu catchment WRA (Roygard *et al*., 2006; pp 86-97) both contain sections on water-use records and document the poor state of water-use records for these catchments.

The following quote from the Rangitikei River WRA sums up the analysis for water-use records in this catchment in 2004: "*Analysis of surface water abstraction consents for the Rangitikei Catchment (riparian and surface abstractions) showed that 26 of a total of 51 consent holders are required to collect records and make them available to Horizons Regional Council. Of these 26 consents, four consent holders are required to make these water-use records available upon request. Twenty-two are required to provide the records regularly, eg. quarterly, or within 10 days of the end of each calendar month. From the 22 consents required to provide records, 13 consent holders have provided records. Several of the 22 consents are relatively new consents and may not yet be operating. From the 13 consents that provided water-use records, one consent registered no abstraction, two water-use records had questionable units, one had only one water meter reading and a further consent had three days of actual water use listed. The remaining eight water-use records* [are] *available…*".

109. Timely provision of accurate information about water take volumes enables effective management of the resource. The POP has several monitoring requirements in relation to installation of water meters and automatic data transfer systems on water abstraction takes (Policy 15-4) and discharges to water (Policy 13-2). This monitoring not only enables calculation of natural flows for setting core allocation limits and minimum flows (Policy 6-16a) but it also provides a mechanism to check compliance with these. Further, the monitoring provides a mechanism to monitor compliance with consent requirements in relation to Policy 6-19 (apportioning, restricting and suspending takes in times of low flow). Accurate monitoring also enables assessment of the efficiency of use of water (Policy 6-13). The water abstraction monitoring programme also provides the monitoring network that could be used to monitor compliance of consented volumes transferred under Policy 15-6. While the focus of the programme is the automated transfer of records, manually collected water-use records are required in some situations.

Box 14: Technical Project Summary – Horizons' WaterMatters System

Horizons' WaterMatters system is a custom-built piece of software. Its key function is to provide accurate, up-to- date information to water resource managers, including consent holders (water users), stakeholders and Horizons staff. The system reduces time spent analysing information and enables users to act on the available information. The goal of the system is improved water management. The software processes information from the monitoring network. which includes measurement of more than 50% of the Region's consented surface water volume; More than 25% of consented ground water volume, and more than 65 flow recording sites. The software analyses the information and updates users, stakeholders and Horizons staff via automatic reporting that includes:

i. Daily emails listing areas with water take restrictions and the consents influenced by these.

ii. Daily maps on the website showing areas experiencing water take restrictions (Figure A).

iii. Daily emails identifying potential errors in the data, eg. gaps, missing data, part days of data, late installations of telemetry equipment, etc.

iv. Daily summaries of totals of actual water use in relation to consented volumes by: Water Management Zone (Figure B), by Sub-zone (Figure B) and by consent (Figure C).

v. Daily maps of consents status in terms of compliance and potential non compliance (Figure B).

vi. Daily emails to compliance officers highlighting any potential non-compliances.

vii. Daily summary of information for consent holders that relates to their specific consents (Figure C & Figure D).

The website component of the programme is located at: www.horizons.govt.nz/watermatters

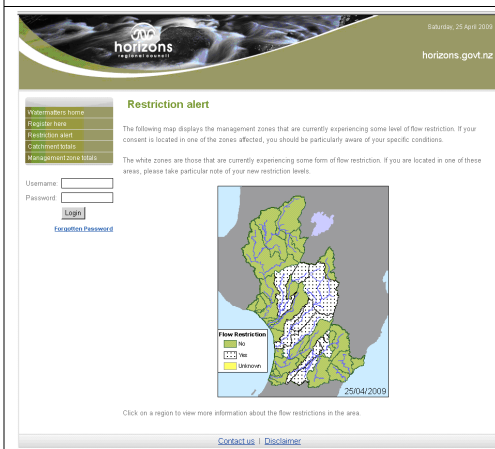


Figure A. Zones with water use restrictions (in white)

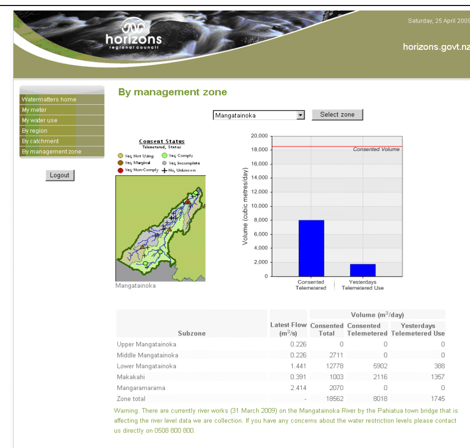


Figure B. Management zone maps and totals.

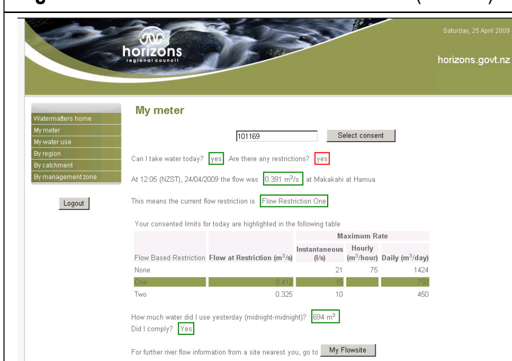


Figure C. User-specific daily summary information

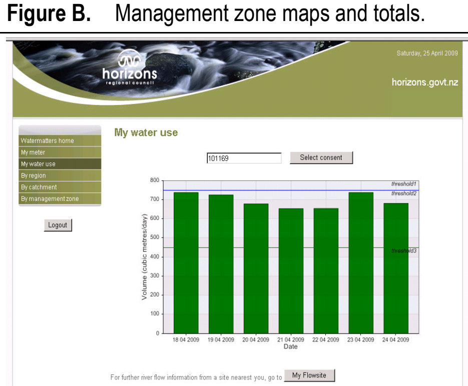
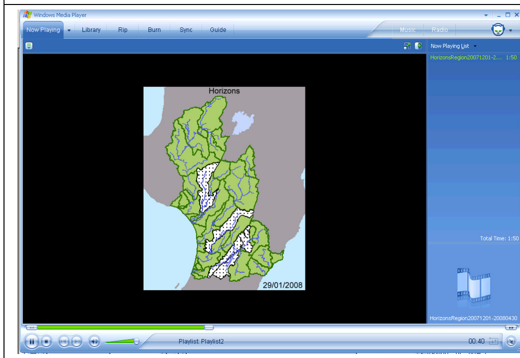


Figure D. User-specific summary of historic use

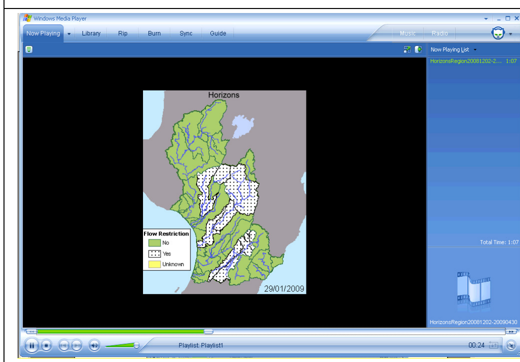
4.10.2 WaterMatters Videos

110. Maps from the WaterMatters website can be merged into a video clip to provide seasonal information. Three videos are appended to this evidence to demonstrate how many Water Management Zones change from day to day in the Region (see Box 15).

Box 15: WaterMatters videos



Video 1. WMZ restrictions during the 2007-2008 summer



Video 2. WMZ restrictions during the 2008-2009 summer

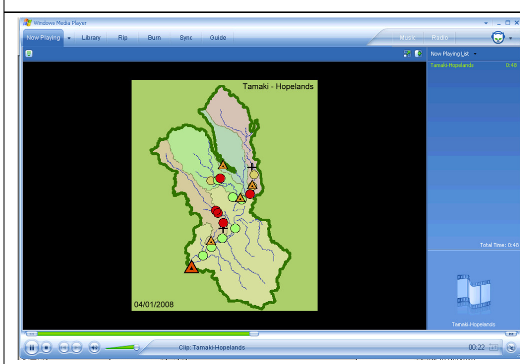
Video 1 and Video 2 each present daily information on Water Management Zones experiencing some form of restriction during two different summers (ie. irrigation seasons).

NB: the white areas indicate locations where some form of water use restriction is in place for one or more consents.

These restrictions do not necessarily apply to all users in the zone and WaterMatters provides daily emails to notify which users in these zones are required to reduce take volumes due to flow conditions in the river. Some minimum flows occur relatively frequently, reflecting reductions in consented volumes at half median flow.

Some restrictions reflect step reductions in consents, eg. in accordance with consent conditions to reduce takes by 50% when flows are below the Mean Annual Low Flow.

Each consent is analysed in accordance with its individual consent conditions. At present, minimum flows for various consents can vary between consent holders within the same Water Management Zone or Sub-zone.



Video 3. WMZ experiencing restrictions during 2007-2008 season

Video 3 presents daily information for the Tamaki to Hopelands Water Management Zone during 2007-2008, the first year in which the WaterMatters website was used to detect non-compliance with consent conditions. The red dots identify potential non-compliances for that day. Triangles show the location of flow recorders and markers in circles indicate water takes. The key is below.

4.10.3 Determining thresholds for Policy 15-4 for the Proposed One Plan

111. The proposed technical thresholds[55] that generally require telemetry in Policy 15-4 were greater than 750 m^3/day for surface water and riparian takes, and greater than 4,000 m^3/day for groundwater takes. Horizons has been implementing requirements for water metering and telemetry in accordance with these thresholds since 2004 and has also typically funded the installation and operation of telemetry units in accordance with these thresholds since 2004. These values were calculated in 2004 and sought to achieve:
    i. Automated management of 95% of the consented volume for surface and riparian takes. At that time this was calculated to require telemetry on 140 consents.
    ii. Automated management of 50% of the consented volume for groundwater takes. At that time this was calculated to require telemetry on 30 consents.

4.10.4 Technical amendments

112. Analysis of the consented volumes in 2009 shows these thresholds would provide for:
    i. 95.9% of the consented surface water volume being automatically monitored, potentially requiring 160 of the 294 surface water consents to have telemetry.
    ii. 53% of the groundwater allocation being automatically monitored, potentially requiring 39 of the 347 groundwater consents to have telemetry.

113. Based on the 2009 analysis, if the same threshold of 750 m^3/day was utilised for groundwater and surface water, this would provide for 90% of the consented groundwater volume being automatically monitored. This would potentially require 140 of the 347 groundwater consents to have telemetry. This level of monitoring is feasible and would provide significantly better information on water use in the Region. A threshold of 750 m^3/day for groundwater takes is recommended. For context, the volume of 750 m^3/day (8.7 l/s) provides sufficient water to irrigate 19 hectares at a rate of 4 mm/day.

4.10.5 Determining thresholds for Policy 13-2 for the Proposed One Plan

114. The proposed technical thresholds in Policy 13-2 provide for installation of pulse- count capable water meters on discharges to water that have maximum daily volumes greater than 100 m^3/day. As outlined in the section on flow statistics (section 4.6.2.5), measurement of discharge volumes is important to get an accurate calculation of the

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[55] CLARIFICATION ON MY ROLE: I calculated these thresholds for surface water consents in 2004 and completed the updated analysis for surface takes, groundwater takes and discharges in 2009.

flow that would have occurred had there not been any takes or discharges. Knowledge of discharge volumes also informs assessments of the relative impacts of a discharge to the quality of receiving water.[56] At present, there is little information available on the volumes of discharges within the Region. Of the 340 consented discharges to water, 224 or 65% have specified consented volumes. Of the 224 consents, 12 major discharge to water consents that have maximum daily volumes greater than 42,000 m^3/day for hydroelectricity, construction etc. Excluding these larger takes that would likely require open channel flow measurement (see below), the proposed threshold of 100 m^3/day would require metering for 51 of the 224 consents with specified discharge volumes. This accounts for 99% of the cumulative discharge volumes from these 224 consents. The policy specifies automated transfer of information from these water meters to Horizons for discharges greater than 300 m^3/day. The analysis calculates that this would apply to 32 of the 224 discharges, capturing 97% of the cumulative discharge volume of these 224 consents. Adopting a similar threshold for this to the 750 m^3/day for surface water allocation would potentially require 25 of the 224 consents to have automated transfer of discharge volumes to Horizons, capturing 90% of the cumulative consented maximum daily discharge volumes for these 224 consents.

115. It is noted that the 224 consents do not represent the full data set. The majority of the other consents (without specified volumes in the full list of 340 consents) are for non-building / construction (60 consents) and water supply, sewage and drainage services (32 consents).

116. There are many reasons for monitoring discharge volumes including naturalising flows. One major reason for monitoring these volumes is to enable the impact of a discharge on water quality to be quantified. Its is for this reason that a threshold of 100 m^3/day for monitoring discharges to water, with full automation of records transfer, is recommended.

4.10.6 Measurement of open channels

117. Policy 6-13(e) provides for installing water metering and telemetry to monitor water use. Policy 15-4 provides that generally, the installation of a pulse count-capable water meter shall be required for resource consents for water takes. There are some notable exceptions where open channel measurement will be the preferred measurement technique, eg. some of the hydroelectricity takes and diversions. In practice, consent conditions relating to open channel measurement typically require open channel monitoring to be done in accordance with the ISO standard, and records to be provided

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56 REFER TO: A later section of this report further discusses the monitoring of discharges and Policy 13-2 (Section 6.18.3).

to Horizons on at least a daily, and preferably hourly, basis. Any open channel monitoring should be done in a manner that is ±8% more than 95% of the time with information automatically transferred to Horizons on at least a daily basis. Mr Brent Watson will provide further detail on the ISO standard for open channel measurement[57].

4.10.7 Recommendation to the Hearing Panel

118. **I recommend that the Hearing Panel adopt the changes to Policy 15-4 and Policy 13-2 as recommended in the planning report of Clare Barton.**

4.11 Reasonable and justifiable use of water

Relates to key provisions of the Proposed One Plan:

- **Rule 6-12: Reasonable and justifiable use of water**
- **Rule 6-13: Efficient use of water**
- **Rule 6-19: Apportioning, restricting and suspending takes in times of low flow**

4.11.1 Concepts and linkages

119. Assessing the reasonable and justifiable use of water provides a mechanism for maximising the efficiency of allocation of water. The Water Allocation Framework contains defined limits for the maximum amount of core allocation that can be allocated. These policies provide a check on whether the water being requested for an activity is required to efficiently meet the purpose of that activity. Ensuring efficiency of allocation is a key mechanism to ensure that, in the first-in, first-served allocation regime, the first users do not "lock out" further potential users of the resource.

120. Locking up allocation by consents has increasingly become an issue in Horizons' Region, as consented use has increased and core allocation limits have been set. Examples of locking up allocation include: 1) water that is consented and not used; 2) consented water not being fully used; and 3) consented water being fully utilised in an inefficient manner, eg. excessive irrigation or large losses of water in the course of consented use.

[57] LINK TO FURTHER EVIDENCE: Brent Watson provides further detail on the ISO standard for open channel flow measurement.

121. Locking up of water has resulted in some catchments of the Region being considered fully allocated, meaning new users are unable to access water. This has included some cases where the consented user's infrastructure was unable to use the consented volumes and/or did not require the volumes consented, and other cases where there was no infrastructure for some consents. In practice, assessing reasonable and justifiable use of consents at the time of consent application for "renewal" or review has proved a useful mechanism to address this issue. Recent consents have included use of "lapse" conditions, requiring use of consented volumes within two years. The specification of two years is less than the five years specified in the RMA.

122. Horizons' policy team has sought technical advice on defined limits that are able to be calculated with available information and tools. The aim of this is to reduce the need for ongoing debate around efficiency criteria on a consent-by-consent basis. Information in relation to the technical work is overviewed in the following sections in relation to: 1) use for irrigation (Section 4.12); 2) use for stock drinking water (Section 4.13); 3) use for public water supply (Section 4.14); and 4) use for industrial purposes (Section 4.14).

4.12 Reasonable and justifiable use for irrigation

Relates to key provisions in the Proposed One Plan:

- **Policy 6-12 (a): Reasonable and justifiable need for water – for irrigation**

4.12.1 Concepts and linkages

123. Applying reasonable and justifiable needs for water criteria to irrigation supplies provides for efficiency of use of allocation. After hydroelectricity generation, irrigation is the largest use of water in the Region and makes up the majority of the agricultural water use category identified in the sections on consented water use (Section 4.3).

124. Allocating irrigation water efficiently can make a large difference to the number of hectares in the catchment that is irrigable with the limited amount of water available. Advantages of efficient use of water for irrigation can include: 1) power savings through not having to pump water that is not needed; 2) reduced nutrient losses; and 3) lower frequency of occurrence of minimum flows.

4.12.2 Technical work in relation to reasonable and justifiable use for irrigation

125. Reasonable and justifiable use of water for irrigation is currently assessed as part of standard technical reporting for consents. The Soil Plant Atmosphere System Model (SPASMO) decision support tool is the primary tool used. A brief overview of the model is provided in Box 16. This model for calculating irrigation requirements was originally developed by HortResearch for Horizons in 2001 and was upgraded with further weather, climate and soil data in 2004 to provide improved coverage of the Region. The report of Green *et al*. (2004[58]) provides the detailed documentation of the model and the upgrade in 2004, and includes the recommendation for use by Horizons[59]. Dr Brent Clothier[60] provides a summary of this information in his evidence. The Green *et al*. (2004) report includes a sensitivity analysis to determine how various assumptions impact on the outputs of the model. The appendices of the report document the calculations within the model and the sources of data for the model.

Box 16 -Technical project summary – Determining irrigation needs using SPASMO-IR

The SPASMO-IR model calculates crop water use requirements on an annual and monthly basis.

The model operates on a daily time step and completes a soil water balance based on rainfall, irrigation and crop water use.

The model uses 30-year data sets for climate data (including rainfall data) and information on soils from the New Zealand Soils databases (Landcare Research).

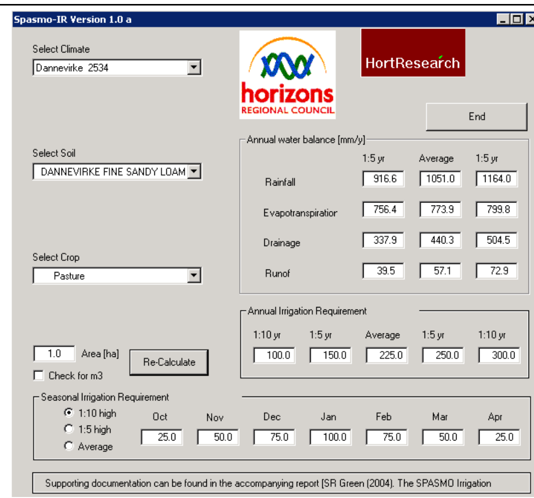

Figure 1. Example screenshot from the SPASMO-IR model.

4.12.3 Determining water use requirements using the SPASMO-IR Model

126. Use of the decision support tool is simple and requires selection of the climate station, soil type and crop from a series of boxes. There is wide coverage of climate and soils

58 REFERENCE TO TECHNICAL REPORT: Green S.R., Laurenson M.L., van den Dijssel C. and Clothier B.E. (2004). Expansion of SPASMO for determining reasonable water use for irrigation throughout the Wanganui – Manawatu Region. Research report commissioned by HortResearch and the Manawatu-Wanganui Regional Council, HortResearch Client Report No. 13472/2005.

59 CLARIFICATION ON MY ROLE: I commissioned and project-managed this work for Horizons.

60 LINK TO FURTHER EVIDENCE: Brent Clothier provides evidence in relation the reasonable and justifiable use of water for irrigation.

within the Region. Pasture is the only crop currently selectable for this model, reflecting pasture being the primary crop irrigated in the Region. Subsequent versions of SPASMO-IR produced for other Regional Councils have included other crops.

127. In determining the annual crop requirements for water use, the SPAMSO recommendation to meet crop needs for 9 out of 10 years is used (Table 4). As the SPASMO model assumes 100% of the applied irrigation water enters the soil root zone and an adjustment of 20% is added to this allocation to provide for reasonable inefficiencies in irrigation application, eg. evaporative losses and lack of irrigation uniformity. This adjustment is consistent with the provisions of POP Policy 6-12(a)(ii). With this adjustment for irrigation efficiency, there is opportunity for the crop needs for all years to be met within the volume allocated. This can be achieved through irrigation system efficiency.

Table 4. Annual irrigation requirements calculated by SPASMO for the Dannevirke climate data and four soil types. The 1:5 and 1:10 year highs represent the 80 and 90 percentile years respectively.

	Annual Irrigation Requirements					
	(mm)			Days of irrigation /year @ 5 mm /day		
Soil Type	Average	1:5 year high	1:10 year high	Average	1:5 year high	1:10 year high
Kairanga silt loam	225	275	300	45	55	60
Manawatu fine sandy loam	200	250	250	40	50	50
Dannevirke fine sandy loam	225	250	300	45	50	60
Kairanga silt loam	225	275	300	45	55	60

4.12.4 Efficiency of irrigation at the catchment level

128. Restricting irrigation to reasonable and justifiable use, and providing for efficiency of allocation, can make a difference to the area in the catchment that potentially can be irrigated. The example of the area of the upper Manawatu in Table 5 shows that if irrigation volumes are allocated to provide on average 7.0 mm/day (70 m^3/hectare/day) then the area that can be irrigated with the core allocation limit is 12,948 ha. If the average rate of irrigation is 3.0 mm/day then up to 30,211 ha may be irrigable (assuming all of the allocation is used for irrigation). Using the peak monthly requirements from the SPASMO calculations, it can be estimated that a reasonable and justifiable use for irrigation rate in this area is 3.9 mm/day (

Allocation limit	Allocation limit	Irrigation rate	Area able to be irrigated
m3/s	m3/day	mm/day	ha
1.049	90,634	7.0	12,948
1.049	90,634	6.0	15,106
1.049	90,634	5.0	18,127
1.049	90,634	4.0	22,659
1.049	90,634	3.0	30,211

129. Table 6). At this rate of daily irrigation, the allocation limit of 90,634 m^3/day (1.049 m^3/s) could potentially irrigate 23,414 ha.

Table 5. Relationship between maximum daily rate, allocation limits and number of potentially irrigable hectares for the upper Manawatu catchment.

Allocation limit	Allocation limit	Irrigation rate	Area able to be irrigated
m^3/s	m^3/day	mm/day	ha
1.049	90,634	7.0	12,948
1.049	90,634	6.0	15,106
1.049	90,634	5.0	18,127
1.049	90,634	4.0	22,659
1.049	90,634	3.0	30,211

Table 6. Calculating peak daily irrigation demand for water using the seasonal irrigation outputs[a] from SPASMO-IR and relating this to the area that is potentially irrigable, based on the allocation limits

Peak irrigation requirement	Days per month	Crop demand	Allowance for efficiency	Maximum daily rate + extra for efficiency	Allocation limit	Allocation limit	Number of hectares potentially irrigated
mm/month	days	mm/day	%	mm/day	m^3/s	m^3/day	ha
100	31	3.2	20%	3.9	1.049	90,634	23,414

[a] Calculated from peak monthly demand in a 1:10 year high (as shown in screenshot in Box 16).

4.12.5 Technical Amendments

130. There are no recommended technical amendments to the reasonable and justifiable use provision of the POP.

4.12.6 Recommendation to the Hearing Panel

131. **I recommend that the Hearing Panel adopt the recommendation in the planning report of Clare Barton in relation to reasonable and justifiable use for irrigation.**

4.13 Reasonable and justifiable use for public water supplies

Relates to key provisions in the Proposed One Plan:

- **Policy 6-12 (c): Reasonable and justifiable need for water – for public water supplies**
- **Policy 6-19: Apportioning, restricting and suspending takes in times of low flows**

4.13.1 Concepts and linkages

132. Applying reasonable and justifiable needs for water criteria to public water supplies relates to providing for efficient use of allocation. Recognition that these takes will likely continue to abstract at flows below minimum flow as a part of the essential use takes component is part of the POP approach to reasonable and justifiable use for public water supplies in relation to surface takes. To approach this, the technical team were tasked with defining efficiency criteria for two situations:

    i. When flows are in the 'normal range' ie. above minimum flow.

    ii. When flows are below minimum flow.

133. In setting these criteria, consideration was to be given to defining a higher level of efficiency below minimum flows when abstraction is likely to compromise the values of the water body. A further consideration for efficiency at low flows was the equity of other abstractors who are required to completely cease their takes below minimum flow. The consented volumes analysis earlier in this report identified 98 public water supply takes, with a total consented use of approximately 284,000 m^3/day. This is approximately 25% of the total consented water use for agriculture, industry and water supply.

134. Assessments of reasonable and justifiable use for public water supplies are a standard part of technical reporting for consent applications, "renewals" and reviews. In some cases, this has been subject to debate and has been a subject addressed at consents hearings. Significant reductions in consented water use for public water supply have occurred in the Region over recent years.

135. In some cases, public water supplies have locked up considerable allocation in catchments, thus preventing other users from obtaining access to water. Box 17 provides an example of this. A further issue for public water supplies occurs where a town supply has access to water from both surface water and groundwater. In these

cases, use of the groundwater supply can result in significant volumes of potentially usable surface water allocation not being used. Box 18 provides an example of this.

136. Efficiency of use for a township applies to the combined maximum take from all sources. Flexibility can be provided for the source of water by linking potential maximum daily takes from various sources to an overall maximum daily take for all consents, which links to efficiency of use criteria.

Box 17: Consented volumes and consented use for the Levin public water supply

The figures below identify water use for the Levin water supply which has had consent for a maximum take volume of up to 24,000 m³/day (Figure A). This is the equivalent of the total allocable volume for the Ohau River as identified by Horizons in the Ohau Water Resource Assessment (Horizons, 2003[61]) Following the review of this consent in 2007, the consented volume was reduced to 16,000 m³/day.

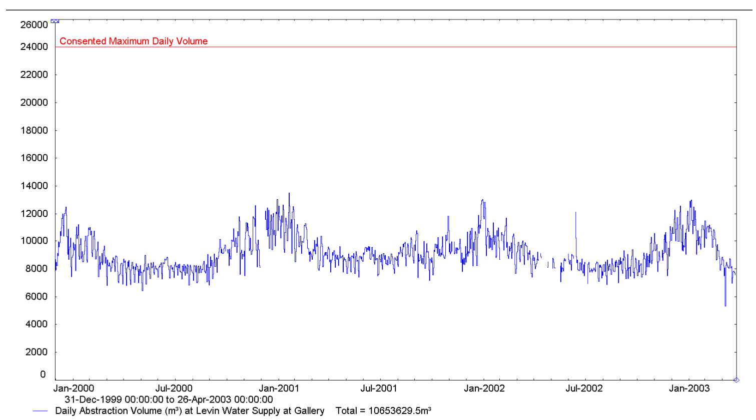

Figure A. Water-use records for Levin water supply for the period December 1999 to April 2003.

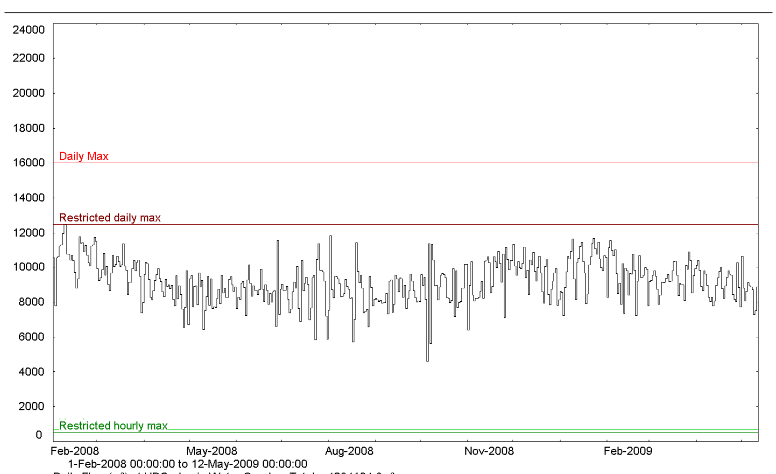

Figure B. Water-use records for Levin water supply for the period February 2008 to May 2009.

61 REFERENCE TO TECHNICAL REPORT: Horizons (2005). Water allocation project Ohau River, Water resource assessment, allocation limits and minimum flows - Technical report to support policy development. Horizons Report 2003/EXT/575

Box 18: Consented volumes and consented use for Feilding public water supply.

Feilding water supply has historically utilised nearly the full allocation from the surface water take for the township (9,000 m³/day, Figure A). The water-use records from 2007 indicate that use has reduced significantly (Figure B). This is likely related to the use of the alternative supply from groundwater. The Oroua Catchment is considered fully allocated under the current Regional Plan.

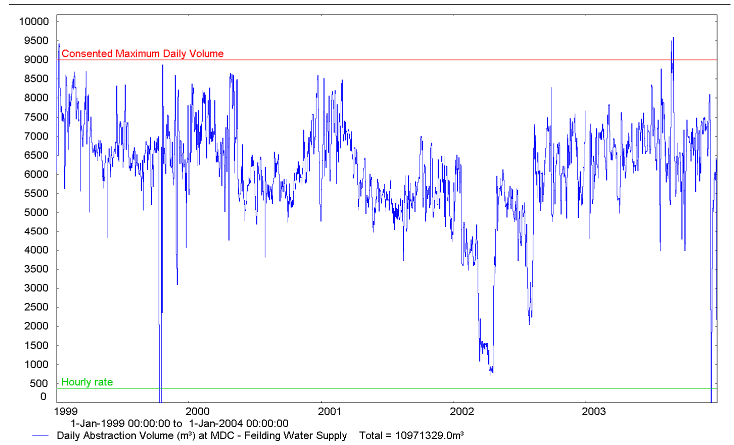

Figure A. Water-use records for Feilding water supply for the period January 1999 to January 2004.

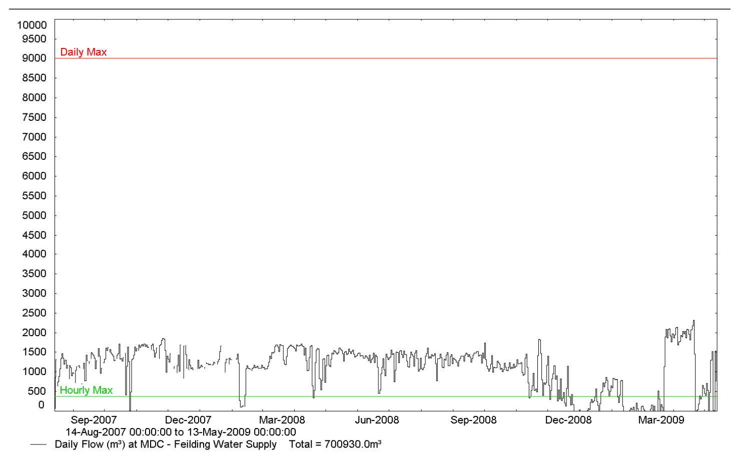

Figure B. Water-use records for Feilding water supply for the period August 2007 to May 2009.

4.13.2 Technical work in relation to reasonable and justifiable use for public water supplies

137. Horizons' assessments of reasonable and justifiable use of water for town water supplies has evolved from the simple per capita per day type assessment that was applied in the Ohau Water Resource Assessment (Horizons, 2003) and several other assessments for historical consents. In 2004, Horizons commissioned a report[62] on water allocation issues including determination of reasonable water use. The report, by

[62] CLARIFICATION ON MY ROLE: I participated in Horizons' project team in relation to this report.

Aqualinc (2004[63]), included an assessment of water use by communities in the Region and a section on determining the reasonable needs of townships.

4.13.3 Assessment of per capita use for public water supplies

138. Aqualinc (2004) identified 57 towns and communities within the Region that are on the Ministry of Health register. Approximately 90% of the Region's population was estimated to live in these towns and communities, with the majority receiving water from these supplies. The report completed a summary of current use by townships as determined by water-use records and published District Council figures (Table 7). The table shows that per capita use, including use for all purposes, varies widely between towns. Average Daily Demand (ADD) varied from close to 400 litres/head/day (l/h/day) to 900 l/h/day. Peak Daily Demand (PDD) varied from approximately 400 l/h/day to 1,300 l/h/day.

Table 7. Summary of water-use information in relation to town supply networks, expressed as per capita use. Industrial users are also identified. Modified from Aqualinc 2004.

		Supply (ℓ/h/d)		Industrial use (1)	
Town	Population	Average Daily Demand	Peak Daily Demand	Number	Percentage of overall use
Bulls	1,800	611	833	1	50
Dannevirke	6,000	983	1,300	2	11
Feilding	13,000	421	764	1	8
Foxton	2,700	556	778		
Hunterville	400	550	950		
Levin	20,000	415	675	3	NA
Mangaweka	250	640	800		
Marton	4,500	778	1,222		
Palmerston North	70,800	440	570	56	9
Ratana	450	289	411		
Shannon	1,500	523	683	1	NA
Taihape	2,200	682	955		
Tokomaru	545	378	446		
Wanganui	41,000	561	854	4	15

1 Industrial users based on metered users. There may also be a numbered of smaller non-metered users.

63 REFERENCE TO TECHNICAL REPORT: Aqualinc (2004). Water Allocation Project – Stage 1. Prepared for Horizons Regional Council. Aqualinc Client Report.

4.13.4 Recommended methodology for calculation of reasonable use

139. The Aqualinc (2004) report provided recommendations for a methodology to calculate reasonable use for townships (Box 19). In summary, the methodology provides a calculation method for five categories: Domestic use (ie. per capita consumption for personal and household requirements); Industrial use; Commercial use; Municipal use (ie. parks, sports clubs, swimming pools, etc.); and Unaccounted water (ie. fire-fighting and systems losses). Aqualinc (2004) reported that the recommended guidelines generate ADD and PDD values, excluding industrial demand of approximately 400 l/h/d and 415 l/h/d for urban centres and rural towns, respectively, when the resource was fully available (ie. above minimum flow). Aqualinc also recommended that use be reduced during low flow conditions (Box 19).

4.13.5 Recommended methodology for the Proposed One Plan

140. The methodology for calculating reasonable use for public water supplies has evolved through applying this methodology to town water supplies[64]. The main additions to this methodology are the inclusion of specific categories for agricultural water use and population growth. The methodologies notified POP reflect these amendments (as shown in Box 20).

141. The thresholds recommended for domestic needs reflect Ministry of Health (MoH) guidelines. The evidence of Mr Gordon Stewart[65] provides some further information in relation to these thresholds. Mr Stewart outlines the derivation of the 250 l/h/day and 300 l/h/day thresholds from the Ministry of Health (2004)[66] publication Household Water Supplies: The selection, operation and maintenance of individual household water supplies. While the MoH document focuses on on-site water systems, the household requirements noted are relevant for determining reasonable-need criteria purposes. The total of 300 l/h/d, consists of:

i. 5 litres for drinking, cooking, and food preparation.
ii. 100 litres for bathing, showering and cleaning.
iii. 145 litres for toilet flushing and clothes washing. ad
iv. 50 litres for general use (presumed to cover some outdoor/garden use).

The total of 250 l/h/day is derived from these numbers, less the 50 litres for general use.

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64 CLARIFICATION ON MY ROLE: I have been involved in the application of this methodology through a number of resource consent processes.

65 LINK TO FURTHER EVIDENCE: Gordon Stewart provides evidence in relation to the reasonable and justifiable use of water for public water supplies.

66 REFERENCE TO TECHNICAL REPORT: Ministry of Health (MoH), 2004. Household water supplies: The selection, operation and maintenance of individual household water supplies. Published by the Ministry of Health, Wellington, New Zealand.

Box 19: Summary of technical report - Aqualinc (2004) recommendations for determining reasonable use for public water supply

The following text provides a direct quote from the Aqualinc (2004) report in relation to recommendations for assessing reasonable use for public water supplies:

The key factors influencing demand on supply networks are:

- *Domestic use (ie. per capita consumption for personal and household requirements)*
- *Industrial use*
- *Commercial use*
- *Municipal use (ie. parks sports clubs, swimming pools etc.)*
- *Unaccounted water (ie. fire-fighting and systems losses)*

Ideally, in defining reasonable use, the key use elements should be identified in the supply network, particularly large industrial and commercial uses, so that realistic demand values can be assessed. However, there are often constraints in establishing assessment of reasonable demand, such as lack of use records and defining system losses.

As a basis to determining reasonable use for supply networks in the Manawatu-Wanganui region, the following is recommended:

- *Domestic demand – PDD based on 450 ℓ/h/d and ADD of 300 ℓ/h/d. The 300 ℓ/h/d value is consistent with the MoH guidelines for drinking water supplies in New Zealand and within reasonable values. The equivalent annual water use is 110 m^3/h/y.*
- *Commercial and municipal use – where available, based on metered water use; where not available, based on a percentage of domestic demand, with a differential between rural towns and larger urban centres of 20% and 15% (respectively). The differential allows for high proportion of water use in rural towns for agricultural service industries.*
- *Industrial – actual recorded values or calculated values from existing water use records. Industrial use is the most variable component of demand, and one which (for small towns) has a large impact on total demand. The water use ratio should also be comparable with the industry value (as listed below).*
- *Unaccounted water – assume a nominal value of 15% of total use (above) unless otherwise substantiated.*

The above recommendations generate ADD and PDD values, excluding industrial demand of approximately 400 ℓ/h/d and 415 ℓ/h/d for urban centres and rural towns, respectively. In the case of the latter, this value is considerably lower than values for some towns reported above. The difference in some cases may be due to industrial water use, while in others it will require further clarification.

The above approach is largely a pragmatic one that recognises the current constraints on information on water use within supply networks. Where detailed water use are available for the system as a whole and specific consumers (such as large industrial users), the approach can be further refined.

The above levels of demand are designed to meet reasonable use under full resource availability. During periods of constraints on resource availability (ie. drought), criteria may apply to reduce reasonable use to essential requirements." Aqualinc (2004).

- *Reduction in domestic demand allocations in incremental steps from 10 to 30%, based on the assumption that up to 30% of domestic use is for external uses. Most councils have water conservation programme that encourages water savings and limit water for gardening during droughts.*
- *Conservation guidelines for industrial and commercial users.*

Box 20: Methodologies for calculating reasonable use for public water supplies in the Proposed One Plan as notified

Policy 6-12: Reasonable and justifiable need for water

(c) For public water supplies, the following shall be considered to be reasonable:

- (i) an allocation of 300 litres per person per day for domestic needs, plus
- (ii) an allocation for commercial use equal to 20% of the total allocation for domestic needs, plus
- (iii) an allocation for industrial use calculated, where possible, in accordance with best management practices for water efficiency for that particular industry, plus
- (iv) any allocation necessary to cater for the reasonable needs of livestock or agricultural practices that are connected to the public water supply system, plus
- (v) an allocation necessary to cater for growth, where urban growth of the municipality is zoned and is reasonably forecast, plus
- (vi) an allocation for leakage equal to 15% of the total of subsections (i) to (v) above.

Where the existing allocation for a public water supply exceeds the allocation calculated in accordance with subsections (i) to (vi) above, the Regional Council will establish, in consultation with the relevant Territorial Authority, a timeframe by which the existing allocation shall be reduced to the calculated amount.

Policy 6-19: Apportioning, restricting and suspending takes in times of low flow

(b) public water supply takes shall be restricted to a total public water consumption calculated as follows:

- (i) an allocation of 250 litres per person per day for domestic needs, plus
- (ii) an allocation for commercial use equal to 20% of the total allocation for domestic needs, plus
- (iii) an allocation which meets the reasonable needs of those facilities and industries listed under subsections (b)(ii) and (b)(iii) where such facilities and industries are connected to the public water supply* system, plus
- (iv) any allocation necessary to cater for the reasonable needs of livestock that are connected to the public water supply* system, plus
- (v) an allocation for leakage equal to 15% of the total of subsections (A) to (D) above.

4.13.6 Testing the proposed methodology for determining reasonable use

142. In 2006, Horizons commissioned a report (Stewart, 2006a[67]) to compare the proposed efficiency criteria with other regions and to test the approach on five water supply schemes in Horizons' Region[68]. The report also addressed options to reduce water use in these schemes. In the evidence of Mr Stewart[69], this report is summarised as follows: "*Based on the study of the municipal water supply schemes, it can be said that:*

- *The proposed efficiency criteria/water-use guidelines appear suitable when compared to approaches in other regions.*
- *The guidelines seem reasonable and fair when assessed against typical water use around the region.*
- *Any gaps between high-season/peak day use and the restricted-flow guidelines can be addressed via appropriate demand management initiatives*".

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[67] REFERENCE TO TECHNICAL REPORT: Stewart G. (2006a). Assessment of proposed water-use guidelines for public water supplies. Prepared for Horizons Regional Council, Aquas Consultants Ltd.

[68] CLARIFICATION ON MY ROLE: I initiated and scoped this project with Helen Marr and project-managed this report.

[69] LINK TO FURTHER EVIDENCE: Gordon Stewart provides evidence in relation to reasonable and justifiable use for public water supplies.

143. It is noted that the report of Stewart (2006a) did use an earlier version of the reasonable use guidelines as outlined in the evidence of Mr Stewart. The earlier version did have minor variations in wording; however, these made little difference to the assessment. The major difference was the wording of the provision for unaccounted water under the low flow restriction. In the study, the level of unaccounted water below minimum flow was the same as that calculated for normal flows. In the policy, the level of unaccounted for water below low flow is reduced compared to the volumes provided for a normal flow.

144. The report of Stewart (2006a) compares a range of efficiency criteria approaches from seven other regions to the proposed approach of the POP. The evidence of Mr Stewart provides an update on this information, to summarise how some of the approaches have progressed. On the suitability of the guidelines, Mr Stewart concludes in his evidence: "*Compared to per capita water use targets in other Regions studied, HRC's proposed guidelines are in the middle of the range for domestic needs – more demanding than one guideline but less so than two others. The HRC guidelines of 300 l/p/d during normal times and 250 l/p/d during times of low flow are also consistent with the Ministry of Health household requirements (ie. 250 l/p/d as essential use and 50 litres in addition for general use). Finally, HRC guidelines for non-domestic use vary from the compared approach in Canterbury, but they do have similarities. Overall, the HRC guidelines can be considered suitable or fitting for their intended use.*".

145. The testing of the five water supplies was completed in close collaboration with the Region's District Councils. Overall results of the study are documented in Stewart (2006a). Separate reports were prepared for the participating District Councils, which were:

i. Horowhenua District Council – Levin water supply (Stewart, 2006b[70])
ii. Manawatu District Council – Feilding water supply (Stewart,2006c[71])
iii. Rangitikei District Council – Bulls and Hunterville water supplies (Stewart, 2006d[72])
iv. Tararua District Council – Eketahuna water supply (Stewart, 2006e[73])

146. The results of these studies are presented in the evidence of Mr Stewart. In summary, for each of the town water supplies studied, the average daily demand was less than the

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70 REFERENCE TO TECHNICAL REPORT: Stewart G. (2006b). Water demand management options for Horowhenua District Council. Prepared for Horizons Regional Council; Aquas Consultants Ltd.

71 REFERENCE TO TECHNICAL REPORT: Stewart G. (2006c). Water demand management options for Manawatu District Council. Prepared for Horizons Regional Council; Aquas Consultants Ltd.

72 REFERENCE TO TECHNICAL REPORT: Stewart G. (2006d). Water demand management options for Rangitikei District Council. Prepared for Horizons Regional Council; Aquas Consultants Ltd.

73 REFERENCE TO TECHNICAL REPORT: Stewart G. (2006e). Water demand management options for Tararua District Council. Prepared for Horizons Regional Council; Aquas Consultants Ltd.

reasonable use guideline (ie. being 72% to 94% of it). Comparing peak daily demand to the requirements below minimum flow showed peak requirements exceeded the restricted use requirements at low flows. The extra water use at peak daily demand was associated with residential outdoor garden watering and increased utilisation by processing industries. The evidence of Mr Stewart concluded that: "*Any gaps between high-season/PDD use and the restricted-flow guidelines can be addressed via appropriate demand management initiatives*".

4.13.7 Technical Amendments

147. There are no recommended technical amendments to the reasonable and justifiable use provisions of the POP in relation to public water supplies.

4.13.8 Recommendation to the Hearing Panel

148. **I recommend that the Hearing Panel adopt the recommendation in the planning report of Clare Barton in relation to reasonable and justifiable use for public water supplies.**

4.14 Reasonable and justifiable use for industry

Relates to key provisions in the Proposed One Plan:

- **Policy 6-12 (c): Reasonable and justifiable need for water – for Industry**
- **Policy 6-19: Apportioning, restricting and suspending takes in times of low flows**

4.14.1 Concepts and linkages

149. Applying reasonable and justifiable needs for water criteria to public water supplies relates to providing for efficiency of use of allocation. As with public water supplies, some industries may also be provided consented volumes below the minimum flow as a part of the "essential use" takes component. To approach this, efficiency criteria were sought for two situations:

i. When the flows are in the 'normal range' ie. above minimum flow.

ii. When flows are below minimum flow.

In setting these criteria, consideration was to be given to defining a higher level of efficiency below minimum flows when abstraction is likely to compromise the values of the water body. A further consideration for efficiency at low flows was the equity of other abstractors who are required to completely cease their takes below minimum flow.

4.14.2 Technical work in relation to reasonable and justifiable use for industrial use

150. Characterising the use of water by industries is difficult, given that many of these industries are provided water as part of public water supply schemes. The consented volumes analysis earlier in this report identified 108 industry takes that are independent of public water supplies with a total consented use of approximately 155,000 m^3/day. This is approximately 13% of the consented water use for agriculture, industry and water supply.

151. The report by Aqualinc (2004[74]), included an assessment of water use by industries in the Region and a section on determining the reasonable needs of industries. The report identified that more than 80% of the industrial use at that time was attributable to five main industries. These industries (with estimated cumulative percentages of the allocation to industry) were meat processing (40%), dairy processing (15%), quarries (12%) pulp and paper (9%), and brewing (7%).

152. Aqualinc (2004) proposed a water-use ratio approach be adopted to determine the reasonable water-use needs for industries. The POP has adopted a broader approach to defining water-use efficiency for industries, based on best practice.

4.14.3 Technical Amendments

153. There are no recommended technical amendments to the reasonable and justifiable use provisions of the POP in relation to industry.

4.14.4 Recommendation to the Hearing Panel

154. **I recommend that the Hearing Panel adopt the recommendation in the planning report of Clare Barton in relation to reasonable and justifiable use for Industries.**

[74] REFERENCE TO TECHNICAL REPORT: Aqualinc (2004). Water Allocation Project – Stage 1. Prepared for Horizons Regional Council. Aqualinc Client Report.

4.15 Reasonable and justifiable use for stock water requirements

155. Stock water use and use for farm dairy-shed requirements are commonly part of reticulation schemes for rural water supplies and public water supplies within the Region. To establish reasonable use criteria on which to base recommendations for these, Horizons commissioned some technical work beyond the original assessment by Aqualinc (2004). This further work (Stewart & Rout, 2007)[75, 76] was completed by AQUAS Consultants and Aqualinc Research. A summary of this technical work is provided in Box 21. Mr Stewart[77] provides evidence in relation to this report and reasonable stock water requirements.

156. In summary, a table for stock drinking water requirements was provided, along with advice on how to set limits in relation to Peak Daily Demand (PDD) or Average Daily Demand (ADD). In practice, Horizons has been using PDD figures from this table in setting consent conditions. The PDD relates to the maximum daily volume conditions for setting limits in consents.

157. Stewart & Rout (2007) compiled some information on reasonable use guidelines for dairy-shed requirements (Box 22). In summarising this information in his evidence, Mr Stewart concluded: "*Lincoln Environmental (2003) note that 50 l/h/d was adopted by Auckland Regional Council based on a 1999 study of wastewater on 20 farms in Franklin District. Fleming (2003), Aqualinc (2004) and NZFSA (2007) all cite a figure of 70 l/h/d. One Dexcel source suggests an average of 50 l/h/d, but notes that it could range from 30 to 100. Another Dexcel source suggests 70 l/h/d. This recurring 70 l/h/d figure is the amount generally accepted for water-use planning. This is the same as peak milk cooling requirements suggested by Lincoln Environmental (2003). Reuse of milk cooling water for plant and yard wash down is common, so absolute water use (ie. draw on supply) in the dairy-shed is driven by milk cooling volumes given that wash down volumes generally do not exceed milk cooling water use (as noted in the 'Water Use in the Dairy-shed' table in this report* [Box 22])". The references as cited in Mr Stewart's evidence and the report of Stewart & Rout (2007) are elaborated on in Box 22.

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75 REFERENCE TO TECHNICAL REPORT: Stewart & Rout (2007). Reasonable stock water requirements guidelines for resource consent applications. Technical Report prepared for Horizons Regional Council by Aquas consultants Ltd and Aqualinc Research Ltd.

76 CLARIFICATION ON MY ROLE: I initiated and scoped this report. Project management of this project was completed along with Raelene Hurndell.

77 LINK TO FURTHER EVIDENCE: Gordon Stewart provides evidence in relation to reasonable and justifiable use for stock water and farm dairy-shed water use.

Box 21 – Technical project summary – Reasonable needs for stock water requirements

The project by Stewart & Rout (2007) provided a table (Table A) of recommended values for Average Daily Demand (ADD) and Peak Daily Demand (PDD) in relation to various types and classes of stock in the Region and provided the following guidance in relation to setting limits for reasonable needs for stock water:

"*The ADD and PDD figures can be used as a basis for discussion when Council comes to set policy and standards for reasonable stock water use. Average day demand comes into play – and can serve as a good guide – in the case of groundwater use. On the other hand, peak day demand is a helpful guide for surface water sources, given that the greatest demand tends to come at times of natural low flow.*

For simplicity, it makes sense for Council to adopt a single standard (l/h/d) for each stock type/sub-type as in the table. A standard toward or at the top end of the range makes sense for a number of reasons. It accommodates peak demand periods (varying climatic conditions) and different feeding regimes. It should also be viewed as 'fair and reasonable' by farmers, which would help in the new consenting process gaining acceptance. A disadvantage of adopting a standard in the PDD range is that it 'locks up' water as 'allocated' but generally not used (given the difference between ADD and PDD figures). This may or may not be an issue – water for stock is essential and there are other water applications that could be restricted to accommodate peak demand periods. Council will want to weigh up these and other issues in order to set appropriate standards." Stewart & Rout (2007)

Table A. Average Daily Demand (ADD) and Peak Daily Demand (PDD) for a range of stock types

Farming Enterprise	Type of Animal	ADD (l/h/d)	PDD (l/h/d)
Dairy	Milking cows	45	70
	Dry stock	30	45
Beef	Mature cattle, herd replacement stock and bulls	30	55
Sheep	Ewes, hoggets and rams	3.0	4.5
Deer	Hinds and stags (all ages)	6.0	12.0
Horses	Working horses	55	70
	Grazing horses	35	50
Goats	Milking goats	5.0	10
	Dry goats	3.5	7.0
Pigs	Mature pigs	11	18
	Brood sows	22	35
	Pigs up to 120 kg	7.0	11
Poultry * *all figures are for l/100 birds/d*	Laying and breeder hens	30*	45*
	Non-laying hens and chickens	18	29
	Turkeys	55	100

Box 22 – Technical project summary – Water use in the farm dairy shed

The project by Stewart & Rout (2007) provided an assessment of water use in farm dairy sheds, as outlined in (Table A). In practice, Horizons has been using 70 l/h/day as the recommended volume for dairy-shed water use in resource consent processes.

Source	Water Requirements
Aqualinc (2004a)	65 l/h/d – shed and yard requirements
Aqualinc (2004b)	Total use: 70 l/h/d
Dexcel (2007a)	Wash down water *per cleaning event*: 50 l/h/d (150 in herd); 48 l/h/d (250 in herd); 43 l/h/d (500 in herd)
Dexcel (2007b)	50 l/h/d but could range from 30 to 100 l/h/day (2 wash downs/day)
Dexcel (2007c)	70 l/cow/day
NZSFA (2007)	70 l/h/d
Lincoln Environmental (2003)	*Estimates based on research/consultation:* Milk cooling: At upper ratio of cooling water to milk volume (3:1), peak cooling requirements approach 70 l/h/d. Average requirements are likely to be 40 to 50 l/p/d. Plant washing: 3.5 to 5.5 l/h/d Yard wash down: 50 l/h/d adopted by ARC based on 1999 study of wastewater on 20 farms in Franklin District. (Other research shows variability and range from 20 to 80 l/p/d.)
Fleming (2003)	70 l/h/d

The references in the table are as cited by Stewart & Rout (2007). These references are:

1. Aqualinc (2004). *Water Allocation Project – Stage 1.* Report for Horizons Regional Council (referred to as Aqualinc (2004a) in the table),
2. Aqualinc (2004b). Water demand forecasting; Part A North Auckland Region Report prepared for North Auckland Regional Council.
3. Dexcel (2007a). Minimising muck, Maximising money: Stand-off and Feed pads –Design and Management Guidelines (accessed 17 August 2007 at www.dexcel.co.nz/main.cfm?id =322&nid=97, pp 12 and 18).
4. Dexcel (2007b). A Guide to Managing Farm Dairy Effluent. Resource guide supported by Environment Waikato and Dairy InSight.
5. Dexcel (2007c). FarmFact: 3-24 Farm water – quantity and quality. Funded by Dairy InSight.
6. New Zealand Food Safety Authority (2007) NZCP1: Code of Practice for the Design and Operation of Farm Dairies, Version 5.
7. Lincoln Environmental (2003). Water Requirements for Dairy Farms. Report prepared for Auckland Regional Council.
8. Fleming, P [Editor] (2003). Farm Technical Manual. Lincoln University, Farm Management Group.

4.15.1 Technical Amendments

158. At present there are no reasonable and justifiable use criteria specified in the POP. If these are to be specified at the Plan level, then the limits as stated above are recommended.

4.15.2 Recommendation to the Hearing Panel

159. **I recommend that the Hearing Panel adopt the recommendation in the planning report of Clare Barton in relation to reasonable and justifiable use for stock water requirements.**

4.16 Permitted Takes

Relates to key provisions of the Proposed One Plan:

- **Rule 15-1: Minor takes and uses of surface water**
- **Rule 15-2: Minor takes and uses of groundwater**

4.16.1 Introduction

160. Rule 15-1 of the POP provides for take limits from surface water of 30 m^3/day (30,000 litres/day) per property, subject to conditions, where the water is required for an individual's reasonable domestic needs and/or the reasonable needs of an individual's animals for drinking water; or 15 m^3/day per property where the water is for any other use. Rule 15-2 of the POP provides for take limits from groundwater of 50 m^3/day per property, subject to conditions.

4.16.2 Determining what 15 m^3/Day, 30 50 m^3/Day and 50 m^3/Day provide for

161. A summary of the technical assessments of what these levels of allocation provide for is included in Box 23). In summary:

i. <u>For household drinking water</u> using an allowance of 300 l/h/day (50 l/h/day above the Ministry of Health guidelines of 250 l/h/day) the rates of 15, 30, and 50 m^3/day provide for 50, 100, and 166 people respectively;

ii. <u>For irrigation</u> using a typical irrigation rate of 5 mm/day the rates of 15, 30, and 50 m^3/day provide for irrigation of 0.3, 0.6, 1 hectare respectively;

iii. <u>For stock drinking water</u> using recommended standards for reasonable stock drinking water use from (Stewart and Rout, 2007)[78], [79] show the classes of stock with the highest peak daily demand are working horses and milking cows. At a peak daily demand of 70 litres/head/day (l/h/d) for these classes of stock, the rates of 15, 30, and 50 m^3/day provide for 214, 429, and 714 stock respectively;

[78] REFERENCE TO TECHNICAL REPORT: Stewart & Rout (2007). Reasonable stock water requirements guidelines for resource consent applications. Technical Report prepared for Horizons Regional Council by Aquas Consultants Ltd and Aqualinc Research Ltd.

[79] CLARIFICATION ON MY ROLE: I initiated and scoped this report. Project management was completed along with Raelene Hurndell.

iv. For stock drinking water and dairy-shed washdown at rates of 70 l/h/d for stock water peak daily demand of stock water and 70 l/h/day for dairy-shed washdown. The rates of 15, 30, and 50 m^3/day provide for 107, 214, and 357 stock respectively.

162. In recent years Horizons has placed considerable emphasis on legitimising small combined takes for dairy-shed washdown and stock water where these have exceeded the Permitted Take thresholds in the current plan. Water metering has been addressed as part of this exercise. In some cases, water running to waste has also been addressed. In practice, the existing thresholds of 15 m^3/day, 30 m^3/day and 50 m^3/day for surface water and groundwater have created some confusion where water is abstracted from shallow bores.

Box 23: Technical work summary – Determining the number of stock provided for by the proposed permitted take thresholds

Based on recommended standards for reasonable use for stock-drinking water requirements (Stewart & Rout, 2007), the proposed Permitted Take limits of 15 m^3/day, 30 m^3/day and 50 m^3/day provide stock water for various classes of animals as outlined in the table below.

Table A. The level of stock water requirements provided for by various Permitted Take limits in the POP as notified

		Requirements[1]		15 m^3/day		30 m^3/day		50 m^3/day	
		ADD[2]	PDD[3]	ADD[2]	PDD[3]	ADD[2]	PDD[3]	ADD[2]	PDD[3]
Farming Enterprise	Stock class	L/h/d[4]	L/h/d[4]	——number of stock provided for——					
Dairy	Milking cows	45	70	333	214	667	429	1,111	714
	Dry stock	30	45	500	333	1,000	667	1,667	1,111
	Washdown (WD) only	70	70	214	214	429	429	714	714
	Milking cows stock water + WD	115	140	130	107	261	214	435	357
Beef	Mature cattle, herd replacement stock & bulls	30	55	500	273	1,000	545	1667	909
Sheep	Ewes, hoggets and rams	3	4.5	5,000	3,333	10,000	6,667	16,667	11,111
Deer	Hinds and stags (all ages)	6	12	2,500	1250	5,000	2,500	8,333	4,167
Horses	Working horses	55	70	273	214	545	429	909	714
	Grazing horses	35	50	429	300	857	600	1,429	1,000
Goats	Milking goats	5	10	3,000	1,500	6,000	3,,000	10,000	5,000
	Dry Goats	0.5	7	30,000	2143	60,000	4,286	100,000	7,143
Pigs	Mature pigs	11	18	1,364	833	2,727	1,667	4,545	2,778
	Brood sows	22	35	682	429	1,364	857	2,273	1,429
	Pigs up to 120 kg	7	11	2,143	1,364	4,286	2,727	7,143	4,545
Poultry	laying and breeder hens[5]	30	45	500	333	1,000	667	1,667	1,111
	Non laying hens & chickens[5]	18	29	833	517	1,667	1,034	2,778	1,724
	Turkeys[5]	55	100	273	150	545	300	909	500

[1] **Stock water requirement sourced from Stewart & Rout (2007) [2]ADD = average daily demand, [3]PDD = peak daily demand, [4]L/h/d = litres/head/day. [5] All figures are for litres 100 birds/day.**

4.16.3 Technical Amendments

163. There are no recommended technical amendments to the permitted activity rules if the plan.

4.16.4 Recommendation to the Hearing Panel

164. **I recommend that the Hearing Panel adopt the recommendation in the planning report of Clare Barton in relation to permitted takes.**

5. GROUNDWATER ALLOCATION AND QUALITY

Relates to key provisions in the Proposed One Plan:

- **Objective 6-2: Water quality**
- **Objective 6-3: Water quantity and allocation**
- **Policy 6-21: Overall approach to bore management and groundwater allocation**

5.1 Chapter Theme Summary

165. **The Groundwater Management Framework uses Groundwater Water Management Zones that are consistent with the boundaries of the Surface Water Management Zones. The proposed framework for groundwater sets total limits for allocation of water for these zones. Groundwater-related provisions in the POP include requirements for reasonable and justifiable use of water as a mechanism to enable as much efficient use as possible of the resource available, within these defined limits. Resource availability is not the major issue for groundwater allocation. However, accessing and using this groundwater requires management in relation to effects on other users, surface water bodies, and saline intrusion (salt water from the coast being drawn into groundwater sources). Several technical projects in relation to groundwater have been completed since the POP was notified. These include a comprehensive assessment of previous technical work in relation to groundwater in Horizons' Region, and documentation of current understanding of the resource. Other technical work has analysed and reported on groundwater quality information in the Region. Further work in relation to groundwater has aimed to provide a greater level of certainty to the provisions of the POP in relation to groundwater management. This chapter provides a brief overview of the technical work and technical evidence in relation to groundwater management in the POP.**

5.2 Introduction

5.2.1 Concepts and Linkages

166. The proposed Groundwater Management Framework has considerable overlaps with the surface water allocation provisions and the water quality provisions of the POP. Aspects of groundwater management are presented in other chapters, including sections on:

   i. Groundwater Management Zones (see Section 3.3.3)
   ii. Reasonable and justifiable use of water (see Sections 4.11 to 4.15)
   iii. Permitted Takes (see Section 4.16)
   iv. Pressure on the resource from allocation (see section 4.3)

   Aspects of groundwater quality also relate to other provisions of the POP where groundwater interacts with surface water bodies such as rivers and lakes. Beyond the provisions that are introduced in other chapters (see above), the groundwater provisions primarily relate to bore construction, allocable volumes, effects of abstraction on other users, groundwater and surface water interaction, and saline intrusion.

167. The technical evidence in relation to groundwater provisions for the POP has been prepared by Mr Hisham Zarour [80] and Mr Peter Callander[81].

168. The evidence of Hisham Zarour documents the findings of two main technical projects[82], the report of Zarour (2008)[83] and the report of Daughney *et al.* (2009)[84].

169. Zarour (2008) presents the state of the groundwater resource based on the monitoring programme and the pressure on the resource. The report also documents some of the tools available to manage groundwater, and introduces some of the technical concepts that have fed into the POP for management of the groundwater resource. These include the Groundwater Management Zones and the associated allocation limits. A major component of the project was creating a single report on the current knowledge of groundwater. The report includes review of the past groundwater studies in the Region and the various conceptualisations of the groundwater resource that have been put

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80 LINK TO FURTHER EVIDENCE: Hisham Zarour provides evidence in relation to the groundwater resource of the Region and technical work in relation to the Proposed One Plan.

81 LINK TO FURTHER EVIDENCE: Peter Callander provides evidence in relation to the groundwater resource of the Region and work in relation to the Proposed One Plan provisions to add further certainty.

82 CLARIFICATION ON MY ROLE: I have been involved in the scoping, review and management of these projects with Hisham Zarour.

83 REFERENCE TO TECHNICAL REPORT: Zarour H. (2008). Groundwater resources in the Manawatu – Wanganui Region: Technical report to support policy development. Horizons Regional Council Report No. 2008/EXT/948.

84 REFERENCE TO TECHNICAL REPORT: Daughney, C., Meilhac, C. and Zarour, H. (2009). Spatial and temporal variations and trends in groundwater quality in the Manawatu-Wanganui Region. Prepared for Horizons Regional Council. GNS Science, Lower Hutt, New Zealand. GNS Science Report 2009/02.

forward over the years. The report also draws together past and current thinking on the hydrogeology of the Region and puts forward the conceptual model for the groundwater resource that has been developed in recent years. The Daughney *et al*. (2009) report provides a comprehensive assessment of the groundwater quality of the Region.

170. The evidence of Peter Callander provides a general overview of the groundwater resource and the management issues that arise from its use. The evidence also presents specific comments in relation to provisions of the POP. This work relates to the preparation of the technical report titled Groundwater Management Options for the Proposed One Plan (PDP, 2009) [85,86]. Further, Peter Callander provides information in relation to a project to produce pump test guidelines for Horizons' Region.

171. Given the comprehensive nature of the evidence of Hisham Zarour and Peter Callander, further summary of this information is not provided in this report.

6. SURFACE WATER QUALITY

Relates to key provisions in the Proposed One Plan:

- **Objective 6-2: Water Quality**

6.1 Chapter Theme Summary

172. **The proposed management framework for surface water quality uses the Water Management Zones (and Sub-zones) framework, and the values of these water bodies, as mechanisms to establish water quality standards in relation to these values. The spatial differences in water quality state and trends for various parameters require consideration of a range of scenarios for managing water quality. The spatial framework of the Water Management Zones, values and standards provides for this. Determining the relative contributions of various sources of contamination to water quality at various flows has been a focus of the technical work to provide guidance on approaches to the management of water quality. The provisions of the POP provide guidance on the management of water quality in relation to the state of the environment, the values identified, and the water quality standards within the spatial framework. Where thresholds have been defined, the aim has been to do so numerically rather than via a narrative**

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[85] REFERENCE TO TECHNICAL REPORT: Pattle Delamore Partners Ltd (2009). Groundwater management options for the Proposed One Plan. Report prepared for Horizons Regional Council (in prep). Pattle Delamore Partners Ltd, Christchurch, New Zealand.

[86] CLARIFICATION ON MY ROLE: I have been involved in the scoping, review and management of this projects with Hisham Zarour and Helen Marr.

approach. This aims to provide certainty in the policy document and to reduce the need for debate about appropriate thresholds on a case-by-case basis through individual consent processes. New work completed since notification of the POP has prompted amendments to some aspects of the proposed water quality framework, which primarily relate to the setting of water quality standards. This chapter overviews technical work in relation to pressure on, and state of, the resource, and the proposed Water Quality Management Framework. This includes a summary of the proposed amendments to this framework and linkages to the evidence being provided in relation to surface water quality. The next chapter addresses the approach to managing land use impacts on water quality.

6.2 Introduction

6.2.1 Concepts and Linkages

173. The proposed Surface Water Quality Framework is built on the Water Management Zones and values discussed in Chapter 3 of this report. Water quality is also linked to the amount of water in the water bodies, that can be impacted upon by water allocation (Chapter 4). Surface water quality varies throughout the Region, as would be expected given the large and diverse range of catchments and pressures water is subjected to. The spatial framework of the Water Management Zones and values has enabled the assessment of the state of water quality in these various areas in relation to thresholds that are related to the type of stream at the particular location. Water quality is assessed for a range of parameters for a range of reasons. It is possible for water quality to be suitable for one purpose and not for another that is measured by a different parameter. Similarly, for different purposes (or values), the threshold for suitability may vary for a single parameter. For some purposes, eg. swimming, some thresholds are also only appropriate at certain flows.

174. Where water quality is not meeting a specified threshold, it is important to identify the relative sources that contribute to this. Given the importance of flow on river water quality, it is important to be able to separate out the sources at a range of flows. This enables the appropriate source to be addressed at the right time to improve water quality. This type of approach equally applies to assessing the impact of new activities on water quality in relation to standards or other thresholds.

175. The water quality provisions of the POP use information from a range of technical reports and technical evidence. The framework also draws on the work of other

Regional Councils and research agencies in relation to water quality. The framework factors into account the state of water quality, contributions to that and previous decisions around water quality and experience in implementing these eg. resource consent decisions and previous Plans.

6.2.2 Chapter contents

176. This chapter is arranged in the following sections:

i. The pressure on the resource
   a. Consented discharges to land and water (Section 6.4)
   b. Land use in the Region (Section 6.5)

ii. Surface water quality state and trends
   a. State of surface water quality – Horizons' State of the Environment (SoE) Report 2005 (Section 6.7)
   b. Surface water quality trends (Section 6.8)
   c. Further analysis of water quality state and trends (Section 6.9)
   d. State and trends analysis of biomonitoring data (Section 6.10)

iii. Surface water quality response
   a. Setting water quality standards (Section 6.12)
   b. River water quality nutrient standards (Section 6.13)
   c. Relating the proposed river water quality nutrient standards to management of the river (Section 6.13)
   d. Relative contributions of non-point sources and point sources to nutrient loadings (Section 6.14)
   e. Options for discharge to land and water (section 0)
   f. Recommendations in relation to the flows at which the water quality standards should apply (Section 0)
   g. Update of the monitoring network to enable relative contributions of non-point source and point source inputs to be calculated (Section 0)
   h. Point source discharges to land (Section 0)
   i. Determining the relative contributions of various non-point sources to nitrogen loadings measured in the river (Section 0)
   j. Management scenarios for non-point source nitrogen inputs to water bodies Section 0)
   k. Determining the relative contributions of various non-point sources to phosphorus loadings measured in the river (Section 0)
   l. Summary of the nutrient-related aspects of this chapter (Section 0)

6.3 Pressure on the resource

6.3.1 Introduction

177. The pressures on water quality in the Region in relation to consented discharges to water and land, and land use in the Region are characterised in the sections below. For an overview of the water allocation pressure on the water resource, refer to Chapter 4 of this report. For both discharges to land and discharges to water, the number of consents is only an indicator of pressure. The impacts of these consented discharges on specific water quality parameters at a location provide a better measure of the pressure from the various types of consents. The relative inputs from consented activities, which include point source discharges to water, are further discussed in later sections of this report[87] and in the evidence of Kate McArthur[88].

6.4 Consented discharges to land and water

6.4.1 Introduction

178. Discharges to land and direct discharges to water are some of the pressures on water quality in the Region. Within the Region, 1,377 discharge to land consents and 340 discharge to water consents were identified in analysis from information collated in January 2007 (see Box 24).

179. Most of the 1,377 discharges to land are related to dairy farming (ie. 68% of consents). Another major category is septic tank consents. The consents database only identifies those in the Region, for which consent has been sought (see Box 24). The consents identified as other industry discharges are also a major category and include washwater from various sources (eg. vegetable washing, truck washing, gravel washing, etc), calcium magnesium acetate (which is applied to roads as a de-icing agent) and a range of industrial effluents (eg. dairy factory, brewery and timber treatment).

180. Of the 340 consented discharges to water, the majority of them are in the categories stormwater (30%) and temporary discharges, mostly in relation to construction (18%). The other major categories in terms of number of consents are other industry (14%), community effluent discharges (11%) and hydroelectricity (10%).

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87 REFER TO: Later sections of this chapter show methodologies for determining relative contributions from point source discharges to overall water quality loadings (Sections 6.14 and 6.15).

88 LINK TO FURTHER EVIDENCE: Kate McArthur provides evidence in relation to the contributions of point source discharges to water quality in the Water Management Zones of the Region.

181. Over the last 12 years, there has been a significant shift from direct discharge to water to discharges to land (see Box 25).

Box 24: Technical project summary – Determining consented discharges in the Region

An analysis of the number of consented discharges to water was completed based on information collated in January 2009. This information reflects numbers of consents where some of these consents provide for consented activities at more than one location. This analysis sums the number of consents and does not take into account the multiple locations that are consented within individual consents. The categories are simplified from the more detailed information available within the consents database.

Table A.. Number of consented discharges in the Region

Type of Discharge	Discharge to Land	Discharge to Water	Coastal Discharge permit	All Discharges
Septic Tank	140	3	0	143
Domestic Wastewater	43	38	3	84
Water Treatment	2	9	0	11
Stormwater	42	103	3	148
Cleanfill	9	0	0	9
Landfill	22	22	0	44
Dairy Farming	942	15	0	957
Chicken Industry	42	0	1	43
Piggery	25	1	0	26
Meat Processing	20	5	0	25
Hydroelectricity	1	35	0	36
Other Industry	84	48	6	138
Temporary Discharge	5	61	0	66
Total	**1,377**	**340**	**13**	**1,730**

Discharges to land

- Of the 1,377 consents 942 (68%) are related to dairy farming)
- The 140 identified septic tank consents represent septic tanks where consents have been sought due to exceeding volume thresholds in current Plans and it is likely to include some that were consented during transitional rules.

Discharges to water

Of the 340 consents the major categories are:

- 30% are for stormwater.
- 18% are temporary discharges (generally sediment or water in relation to construction).
- 14% are for other industry. This category includes wash water (including gravel and vegetable wash water), calcium magnesium acetate, leachate, cooling water and water).
- 11% are for domestic wastewater (treated sewage effluent from communities).
- 10% are for hydroelectricity.

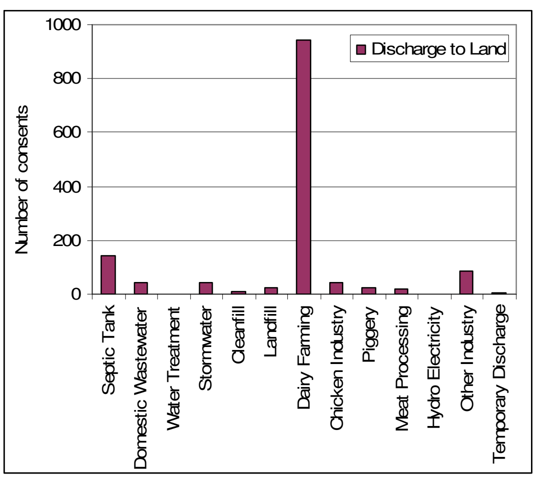


Figure A. Discharges to land of various types.

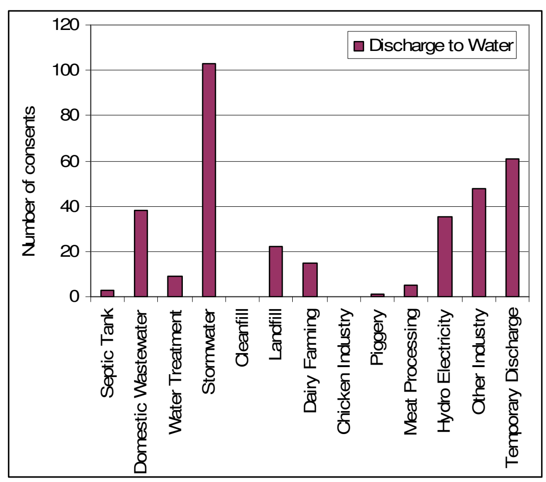


Figure B. Discharges to water of various types.

Box 25: Technical summary – Relative numbers of consented discharges to water and land

Horizons' policies have required a transition from discharges to water to discharges to land. The relative number of discharges to water and discharges to land have been analysed using the information from the State of the Environment Report (Horizons, 2005a) and the information collated in January 2009 (see Box 24 above). Two examples of the changes in numbers of consents are shown and discussed below.

Example 1: Discharges from livestock operations

- The discharges from livestock operations category includes discharge of poultry manure, dairy farm effluent and piggery effluent
- Figure A below shows the transition from 439 discharges to water in 1997 to 16 discharges to water 2009. During the same period, discharges to land increased by 193 consents.
- Numbers of consents for discharges to land have dropped slightly over the past five years. This likely reflects some consolidation of consented activities. For example, single consents for poultry manure spreading can cover many locations.

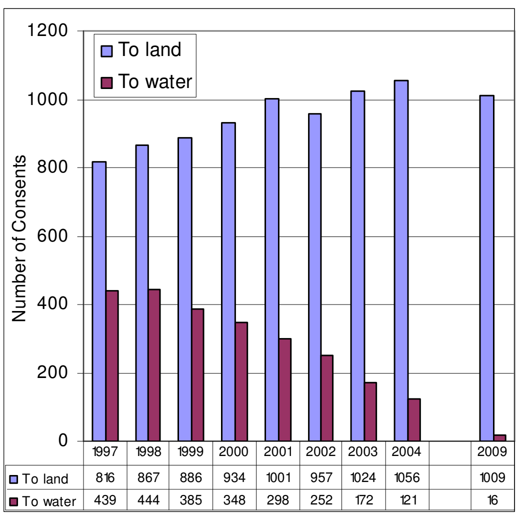


Figure A. Livestock operation discharges to land and water.

Example 2: Discharges of treated sewage effluent

- The treated sewage effluent category represents the discharges from town and community sewage systems following treatment.
- Figure B below shows the transition from very few discharges to land to the situation where discharges to land outnumber discharges to water; and an overall increase in the number of consents from 54 to 81.
- The increase in number of consents is likely contributed to by the discharges from the base of ponds being consented as part of overall consenting for these types of discharges upon "renewal". Previously, the discharge from the base of the pond had not been consented.

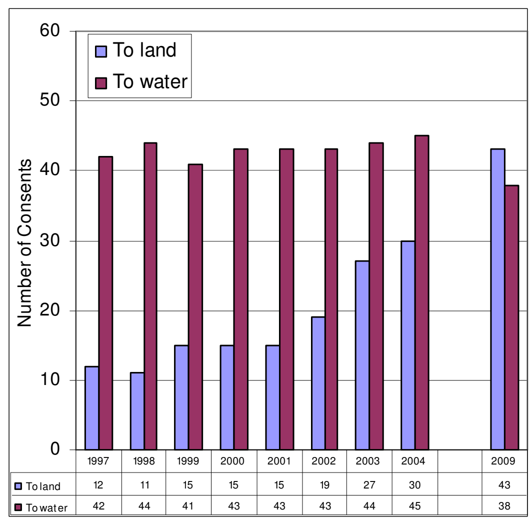
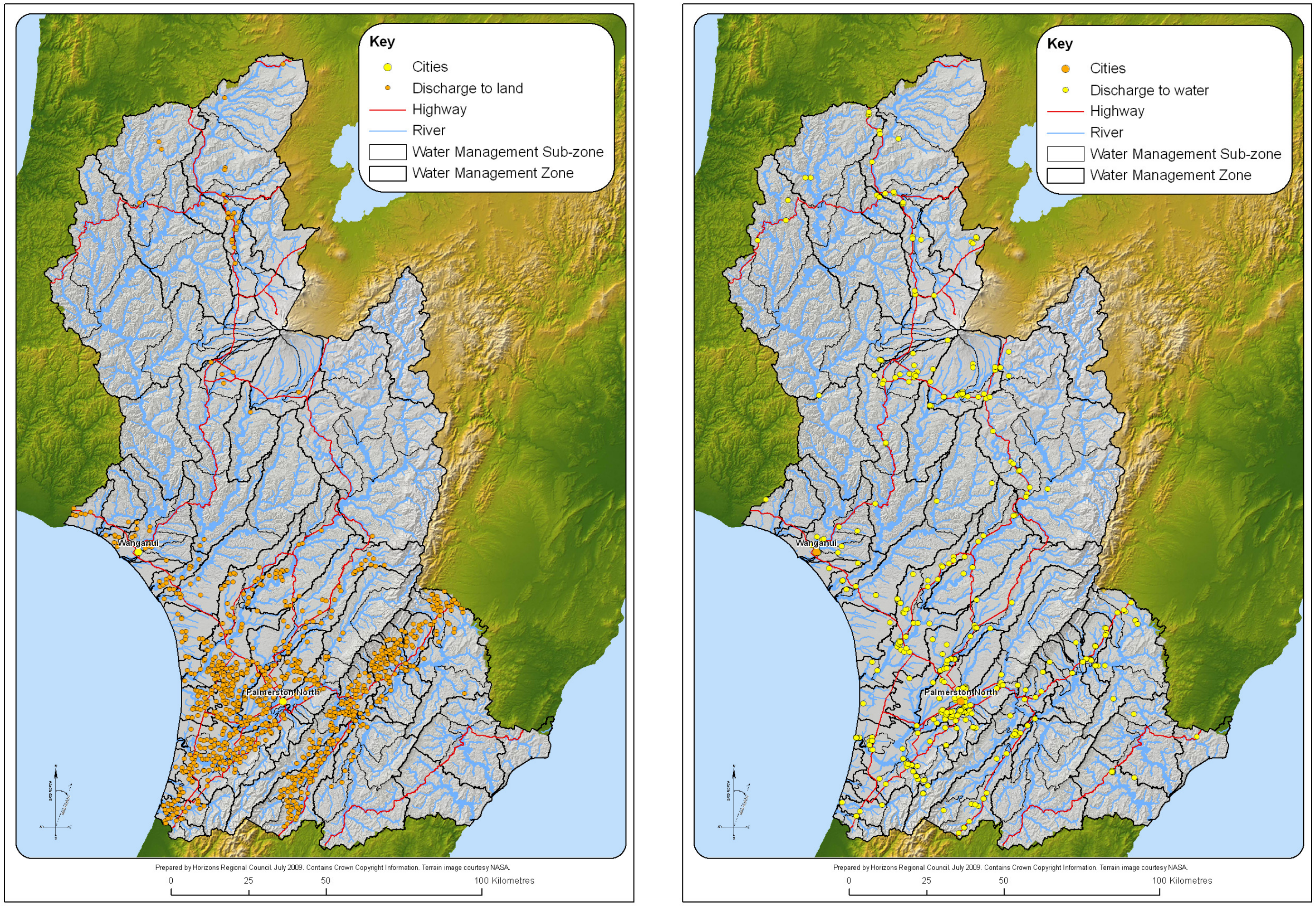


Figure B. Treated sewage effluent discharges to land and water.



Map 4. Locations of the consented discharges in the Region. Left: Consented discharges to land; Right: consented discharges to water.

6.5 Land use in the Region

6.5.1 Introduction

182. Land use provides one form of pressure on water quality in the Region. Land use has been characterised for the Region, using available databases, in the report of Clark & Roygard (2008)[89, 90]. The Region-scale analysis showed land use is predominately sheep and/or beef farming (51%) followed by native cover (31%) and exotic cover eg. forestry (7.5%). Dairy farming was the fourth biggest land use type by area at 6.7% (Box 26).

Box 26: Technical Project Summary – Land use and Land use capability in the Region

Clark and Roygard (2008) used a range of databases to get a land use layer for the Region. This layer represented the information available and may well be of limited accuracy for a range of reasons eg. gaps in information available, changes in land use and accuracy of some of the voluntary data supplied. However this layer does provide a mechanism to categorise land use within the Region at the broad level.

The Clark and Roygard (2008) report provides summaries of land use at the Regional level, Catchment level and Water Management Zone (and subzone) level. The summaries include Maps and Tables to enable some familiarisation with the local land use in a particular area. The analysis simplified land use into ten categories (Table A). The land use in these categories at the regional level is shown in Table B.

Table A. Simplified land use categories for regional analysis.

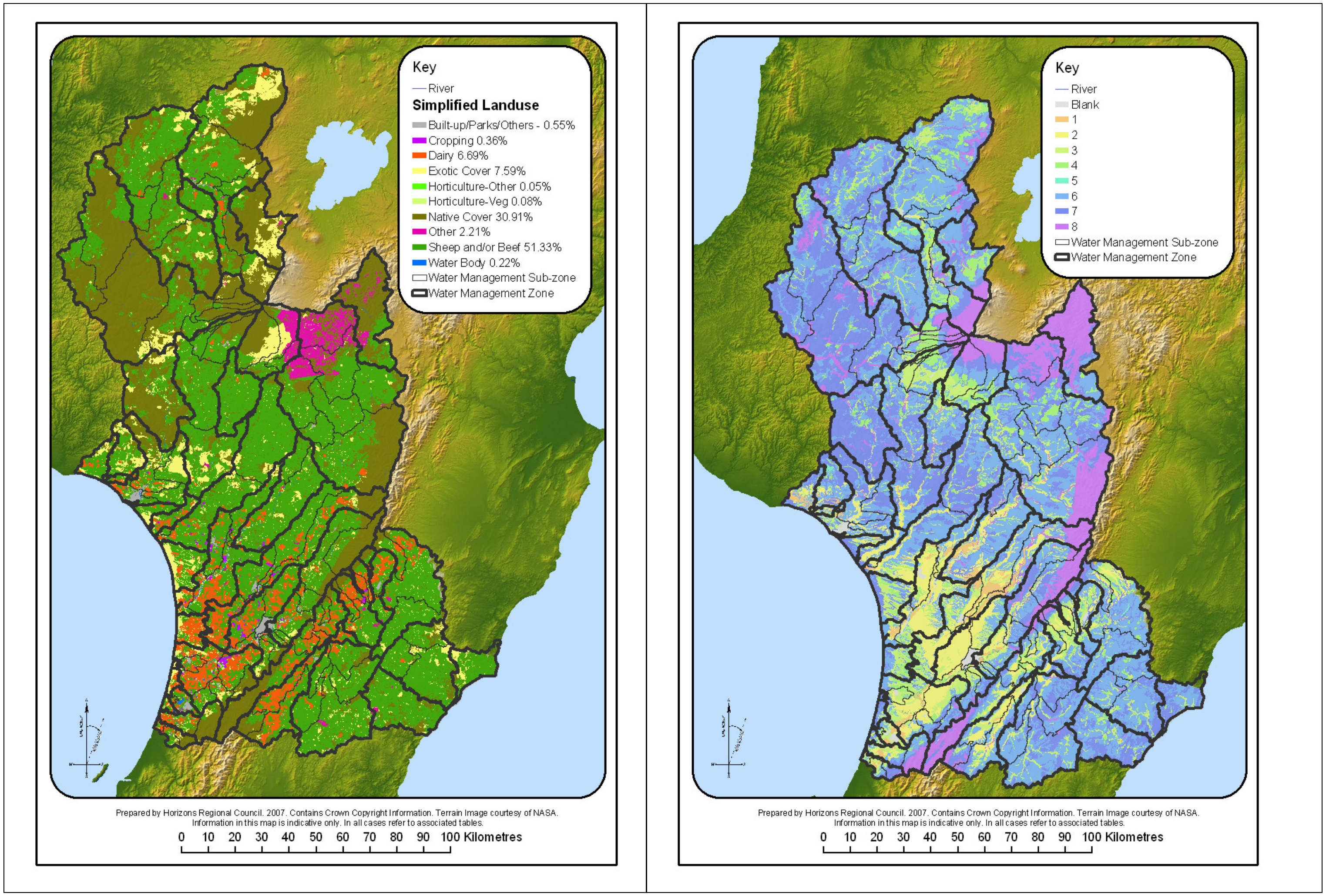
Simplified Land Use	Land Use Classification
Dairy	Dairy
Sheep and/or Beef	Sheep and/or Beef, Depleted Tussock Grassland, Low-Producing Grassland, High-Producing Grassland and Other Dry Stock
Horticulture-Other	Flowers, Fruit Growing, Nursery, Orchard/Crop, Other Planted, Viticulture
Horticulture-Veg	Vegetable Growing
Cropping	Cropping
Native Cover	Native Forest, Other Native Cover, Alpine Grass/Herbfield, Alpine Gravel and Rock, Coastal Sand and Gravel, Landslide, Permanent Snow and Ice, Tall Tussock Grassland
Exotic Cover	Exotic Forest, Major Shelterbelts, Other Exotic Cover, Forest Harvested
Built-up	Built-Up and Urban Parkland/Open Space, Dump, Tourism, Surface mine
Other	Other
Water Body	Estuarine Open Water, Water Body, River and Lakeshore Gravel

Table B. Simplified analysis of land use type in the Manawatu-Wanganui Region.

Simplified Land Use	Area (km^2)	Percentage of Region
Built-up/Parks/Others	123.0	0.55%
Cropping	79.5	0.36%
Dairy	1492.3	6.69%
Exotic Cover	1693.2	7.59%
Horticulture-Other	10.8	0.05%
Horticulture-Veg	17.5	0.08%
Native Cover	6894.2	30.91%
Other	491.9	2.21%
Sheep and/or Beef	11445.1	51.33%
Water Body	49.9	0.22%

89 REFERENCE TO TECHNICAL REPORT: Clark and Roygard 2008 Land Use and Land Use Capability in the Manawatu-Wanganui Region Internal Technical Report to Support Policy Development. Horizons Report number HRC/INT/616).

90 CLARIFICATION ON MY ROLE: I initiated, scoped and co-authored this report. Maree Clark completed the majority of the project.



Map 5. Left: Land use in the Manawatu-Wanganui region, Right: Land use capability in the Manawatu-Wanganui region.

6.5.2 Land use and Land Use Capability – Potential for intensification of Dairy Farming

183. Comparing the land use capability (LUC) with the current land use type estimations enables some broad comparison of current land use in the context of potential production in the Region. Grant Douglas[91] provides an overview of LUC in his evidence and further discussion of LUC is provided in later sections of this report. In terms of pressure on the Resource the LUC classification of the capability of land is used as a methodology to explore further land use scenarios.

184. The analysis of Table 8 (modified from Clark and Roygard, 2008) estimates that 78% of the regions dairy farming is on Class I to IV land and 22% is on areas greater than Class IV. It is noted that the Class I, II, and III land is in the order of over 60% sheep and/or beef and over 20% dairy (Table 8).

185. There is likely potential for dairy to displace some of the sheep and/or beef farming. Clothier *et al.* 2007)[92] run a scenario of dairy expanding onto all Class I to III land in the upper Manawatu Catchment[93]. Taking this type of assumption to the regional level there would be considerable room for expansion of the dairy sector within Horizons Region. Further analysis could be done on this to assess the limitations to dairy expansion (for example it may be that some of the subclasses of Class I to III are limiting to dairy).

186. Based on this broad level analysis, it seems reasonable that dairy farming may have room to more than double in area in the Region. The water allocation framework proposed in the One Plan indicates there is potential that in some areas, this expansion could occur where water is available for irrigation (eg. the coastal Rangitikei Water Management Zone).

187. The potential pressure on the catchments of this expansion can perhaps be demonstrated through the indication from Clothier *et al.* (2007). Clothier shows that each hectare of the upper Manawatu catchment converted from sheep/beef farming to dairy farming may result in a further 11.5 kg N/ha/year reaching the upper Manawatu River.

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[91] LINK TO FURTHER EVIDENCE: Grant Douglas provides an overview of the Land use capability system, how it was developed and ways it is used.

[92] REFERENCE TO TECHNICAL REPORT: Clothier B., Mackay A., Carran A., Gray R., Parfitt R., Francis G., Manning M., Duerer M and Green S. 2007. Farm strategies for contaminant management, A report by SLURI, The Sustainable Land Use Research Initiative for Horizons Regional Council. This report is further discussed in subsequent sections of this report (Section 6.24).

[93] LINK TO FURTHER EVIDENCE: Brent Clothier provides evidence in relation to the Clothier *et al.* 2007 report and the modeling in relation to dairy expansion in the upper Manawatu.

Table 8. Percentage of land use type by land use capability class in the Manawatu-Wanganui Region (modified from Clark and Roygard, 2008).

	I	II	III	IV	V	VI	VII	VIII	Total	Blank	Percentage[a] of land use type in	
	Percentage of Region										Class 1-IV	Class V-VIII
Built-up/Parks/Others	0.01	0.04	0.04	0.02	<0.01	0.02	0.02	<0.01	0.15	0.4	73	27
Cropping	0.06	0.21	0.06	0.01	0.00	0.01	<0.01	<0.01	0.35	<0.01	97	3
Dairy	0.37	2.38	1.81	0.65	0.01	1.18	0.26	0.03	6.69	0.01	78	22
Exotic Cover	0.04	0.17	0.46	0.65	<0.01	3.32	2.63	0.27	7.54	0.04	18	82
Horticulture - Other	0.01	0.02	0.00	<0.01	0.00	<0.01	<0.01	0.00	0.03	<0.01	100	0
Horticulture - Veg	0.02	0.04	0.01	<0.01	0.00	<0.01	0.00	0.00	0.07	<0.01	100	0
Native Cover	0.03	0.19	0.58	1.6	0.01	7.53	12.9	8.05	30.89	0.04	8	92
Other	0.01	0.03	0.04	0.16	<0.01	0.52	0.66	0.77	2.19	0.01	11	89
Sheep and/or beef	1.01	4.70	5.42	4.10	0.15	24.33	10.84	0.61	51.16	0.16	30	70
Water	0.01	0.03	0.03	0.02	<0.01	0.03	0.02	0.03	0.17	0.06	53	47
Total	1.57	7.81	8.45	7.21	0.17	36.94	27.33	9.76	99.24	0.72	25	75
	Percentage [a] of land use class in each land use type											
Built-up/Parks/Others	0.6	0.5	0.5	0.3	0.0	0.1	0.1	0.0	0.2			
Cropping	3.8	2.7	0.7	0.1	0.0	0.0	0.0	0.0	0.4			
Dairy	23.6	30.5	21.4	9.0	5.9	3.2	1.0	0.3	6.7			
Exotic Cover	2.5	2.2	5.4	9.0	0.0	9.0	9.6	2.8	7.6			
Horticulture - Other	0.6	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0			
Horticulture - Veg	1.3	0.5	0.1	0.0	0.0	0.0	0.0	0.0	0.1			
Native Cover	1.9	2.4	6.9	22.2	5.9	20.4	47.2	82.5	31.1			
Other	0.6	0.4	0.5	2.2	0.0	1.4	2.4	7.9	2.2			
Sheep and/or beef	64.3	60.2	64.1	56.9	88.2	65.9	39.7	6.3	51.6			
Water	0.6	0.4	0.4	0.3	0.0	0.1	0.1	0.3	0.2			
	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0			

[a] Where a category has <0.01 the value for the percentage analysis is assumed to be zero.

6.6 Surface Water Quality State and Trends

6.6.1 Introduction

188. The state and trends of water quality in the Region have been documented in a range of reports over many years. An overview of the state and trends of surface water quality is provided in the sections below. A further, more detailed, assessment of state and trends information is provided in the evidence of Kate McArthur[94]. The evidence of Barry Gilliland[95] provides some historical context for state of water quality and changes over the past 50 or so years. In summary, his evidence shows that some significant gains have been made in addressing a number of issues in relation to water quality, eg. removing large amounts of organic pollution from water bodies through addressing

[94] LINK TO FURTHER EVIDENCE: Kate McArthur details the state and trends of water quality analyses for the Region.
[95] LINK TO FURTHER EVIDENCE: Barry Gilliland provides an overview of the history of water quality in the Region.

inputs of wastes from industries such as meat processing plants and milk factories. The state of water quality in relation to a range of water quality parameters has improved in many locations, due to work addressing point source discharges. These issues are not entirely resolved in some locations.

6.7 State of surface water quality – Horizons State of the Environment Report (2005)

189. The State of the Environment (SoE) Report (Horizons 2005a[96]); and SoE technical report (Horizons 2005b[97]) completed a regional-scale analysis of the state of water quality based on the available information from a range of monitoring programmes including the SoE monitoring programme. Indicators[98] of water quality based on available information were used to display the water quality information for the period 1997-2004 in a spatial framework (Box 27).

Box 27: Technical Report Summary – State of the Environment Report 2005

The SoE Report (Horizons 2005a), and SoE technical report (Horizons 2005b) presented maps of indicators based on the percentage of time that a site meets a particular threshold when sampled. The SoE Report maps present summary indicators for particular issues, eg. a nutrient indicator that is a hybrid of the information for Dissolved Reactive Phosphorus (DRP) and nitrate (NO_3). The SoE technical report maps also present information on individual parameters, eg. a single map for each of DRP and NO_3. A further indicator, discussed in Table 4.2 of the SoE technical report, relates to the relative state of the water body, ie. how far away from the threshold the results for a particular parameter are, although this indicator is not presented in any of the SoE maps (as is indicated by the text). Threshold values used as part of the analyses are documented in the SoE technical report. Consistent values were used for the whole Region and these were generally determined from national guidelines.

190. The SoE report (Horizons, 2005a) identified that water quality issues in the Region break down to four main issues that relate to the values of water bodies. These main issues are:

   i. **Levels of sediment**, water clarity and turbidity that impact on aesthetic values, life supporting capacity (eg. the ability of fish to feed), and contact recreation values.

   ii. **Physiochemical characteristics** (eg. the presence of chemical conditions or toxic substances that compromise the life supporting capacity of the water body,

[96] REFERENCE TO TECHNICAL REPORT: Horizons (2005a). Horizons Regional Council state of environment report 2005. Horizons Report 2004/Ext/608. Chapter 4 & 6 relate to surface water quality and groundwater.

[97] REFERENCE TO TECHNICAL REPORT: Horizons (2005b). Horizons Regional Council State of Environment Technical Report 2005. Horizons Report 2004/Ext/609. Chapter 4 & 6 relate to surface water quality and groundwater.

[98] CLARIFICATION ON MY ROLE: I developed the indicators for the State of the Environment report and technical report in relation to water quality, including completing the numerical analysis for these. Maps were produced by other team members.

including parameters such as dissolved oxygen, temperature, pH (acidity or alkalinity of the water) and Biochemical Oxygen Demand (demand for oxygen for breakdown of organic material).

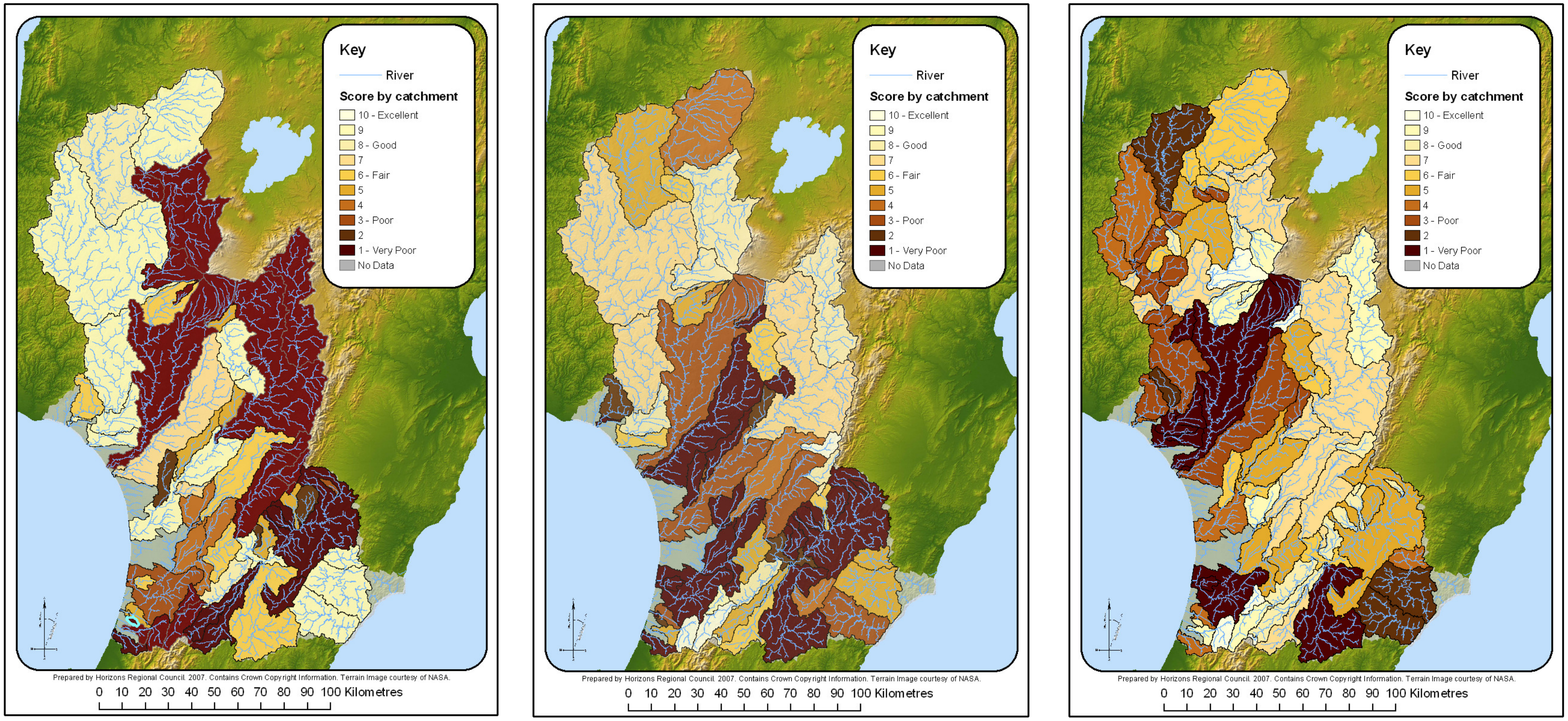
iii. **Bacterial and/or faecal contamination,** which can compromise the water's recreational quality, or suitability for human and/or stock drinking water.

iv. **Nutrient enrichment**, which can cause accelerated growth of nuisance plant material and can compromise recreational, consumptive use and life supporting capacity values.

191. In summary, the SoE report identified that parts of the Region have excellent water quality, particularly in headwaters that have extensive native vegetation or exotic forest cover. However, water quality typically declines moving downstream in a river. Horizons' Region is large and has a diverse range of catchments, each with varying geologies, flow regimes and pressures. The state of these water bodies can vary, with some sites meeting the standards for one parameter while being identified as not meeting the standards for a different parameter. Table 9 and the SoE indicator maps (eg. Map 6) provide context for the spatial distribution of sites identified as having particular water quality issues. The SoE report shows many catchments have a combination of issues.

Table 9. Main water quality issues by catchment. Significance of issues is indicated as: (+++) major, (++) moderate, (+) minor, and (-) not significant issue for each catchment. Sourced from Horizons (2005a)

Catchment	Contact Recreation	Nutrient Enrichment	Stressors	Turbidity (sediments)
Whanganui	++	-		**+++**
Rangitikei		++		++
Manawatu	++	**+++**		++
Whangaehu	+	-	+++	+++
Turakina	++	+		+++
Akitio	+	-		+++
Owahanga	++	-		+++
Ohau	-	-		-
Hokio (Lake Horowhenua)	+++	+++		
Kai Iwi, Mowhanau	+++	+		+
Waikawa	++	+++		+



Map 6. State of the Environment maps for, Left: Nitrate; Middle: Dissolved Reactive Phosphorus; and Right: Turbidity.

6.8 Surface water quality trends

192. Horizons' State of the Environment report (2005) provided information on the state of water quality in the Region's water bodies. A key question to follow this is whether the state is getting better or worse. To investigate this, Horizons undertook an analysis of water quality trends in 2006 producing the water quality trends report (Gibbard *et al.*, 2006[99,100]).

> **Box 28: Technical project summary – Horizons Water Quality Trends Report - methods**
>
> The project of Gibbard *et al*. (2006) used available water quality data for nitrate, dissolved reactive phosphorus and turbidity for 22 sites in Horizons' Region. Bacterial indicators were not selected because Horizons changed the monitoring parameter from *Enterococci* to *E. coli*, following guidance from the Ministry for the Environment. The physiochemical parameters (eg. dissolved oxygen and temperature) were not tested for trends as the continuous records for these parameters were the preferred measurement over the spot measurements from the SoE monitoring data.
>
> This report was completed in consultation with a range of scientists very experienced at water quality trends analysis. A minimum of 60 samples (ie. five years of monthly samples) have been identified as being needed for meaningful trends analysis. The periods analysed were dependent on data availability; some sites were analysed from the period 1989-2004 and a number were analysed for 1997-2004. Some sites were tidally influenced and the results from these are likely questionable because of this. Gibbard *et al.* (2006) provide two measures of the water quality trends; the first is non flow-adjusted whereas the second is flow-adjusted. Flow adjusting aims to remove the influence of flow events on the analysis.

6.8.1 Results of the trends analysis

193. The results of the study (Box 29) show the Manawatu catchment has the highest number of sites with increasing trends (ie. degrading water quality). It is noted that the Manawatu catchment made up 10 of the 22 sites in the study. Of the study catchments, the Manawatu was the only one to show trends for increased nitrate concentrations with five sites showing increasing trends in each of the non-flow adjusted and flow adjusted analyses. Although the five sites differed between these two analyses.

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99 REFERENCE TO TECHNICAL REPORT: Gibbard R., Roygard J., Ausseil O. and Fung L. (2006). Water Quality Trends in the Manawatu-Wanganui Region 1989-2004. Horizons Regional Council Report 2006/EXT/702.

100 CLARIFICATION ON MY ROLE: I was a co-author of this report and project-managed the project for Horizons. The lead author, Ron Gibbard, completed the analysis of trends.

194. When the trends data is combined with the State of the Environment data, sites like Manawatu at Hopelands and Mangatainoka at SH2 show poor state and degrading water quality (increasing trends) for some parameters.

Box 29: Technical project summary – Horizons' Water Quality Trends Report - Results

The results of the Gibbard *et al.*, 2006 water quality trends study (Table A) showed:

i. Nitrate, Dissolved Reactive Phosphorus (DRP) and turbidity had significant trends showing degrading water quality a number of Manawatu catchment sites.

ii. The Rangitikei catchment showed a significant increase in DRP concentration at one site near the headwaters, but this was not observed at other sites.

iii. The Whanganui catchment showed differing trends depending on the use of flow adjusted data or non-flow adjusted data. For non flow-adjusted data, DRP concentrations increased at two sites (middle and lower reaches) and there was increasing turbidity at the tidal site. When data is flow-adjusted only the lower river site (Kaiwhaiki) had highly significant increasing trends for both DRP and turbidity. It is noted that this site may be under tidal influence.

iv. In both tests, the Whangaehu catchment has an increasing trend for DRP near the headwaters, for flow-adjusted data, and a decrease in turbidity at the same site.

Table A. Summary of water quality trend results from Gibbard *et al.* 2006

SOE site	Non flow-adjusted			Flow-adjusted		
	DRP	NO_3	TURB	DRP	NO_3	TURB
Rangitikei Catchment						
Rangitikei at River Valley	↑			↑		
Hautapu upstream at Rangitikei						
Rangitikei at Mangaweka						
Rangitikei at Vinegar Hill						
Rangitikei at Kakariki						
Rangitikei at Scotts Ferry*						
Manawatu Catchment						
Mangatera at Timber Bay	↓↓↓	↑↑				
Makakahi at Konini		↑↑		↑↑	↑↑↑	↑↑
Mangatainoka at SH2		↑↑↑			↑↑↑	
Manawatu at Hopelands	↑↑↑	↑↑↑	↑↑	↑↑↑	↑↑↑	
Manawatu at Ashhurst Domain						
Oroua at Nelson Street	↑↑		↑↑	↑↑↑	↑↑↑	↑↑
Oroua at Awahuri Bridge				↑↑↑		↑
Manawatu at Maxwell's Line					↑↑	↑↑↑
Manawatu at 42 Mile						
Manawatu 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.						

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

1. Some flow data has been supplied by Genesis Energy and NIWA.
2. 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).
3. ↑/↓ 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%)

6.9 Further analysis of surface water quality state and trends

6.9.1 Prior to notification of POP

195. The State of the Environment Report was produced early in the One Plan process. Further analyses of the state of water quality have been completed both nationally and as a part of technical work for the POP. The water quality standards report by Ausseil & Clark (2007c)[101] completed an analysis of whether the water quality met the water quality standards they proposed in Table 27 of their report. This analysis indicated that many sites did not meet the recommended standards. Further detail in relation to this analysis is presented in the evidence of Ms McArthur[102].

6.9.2 After POP notification

196. The National State of the Environment Report[103] was released in December 2007. The technical work on which this report was based was completed by NIWA for MfE. The findings of this report were consistent with those of Horizons SoE report. Conclusions for Horizons Region in the National SoE Report were based on the seven (NIWA) water quality monitoring sites in the Region. The National SoE Report, and its underpinning technical work, are further discussed in the evidence of Ms McArthur. Subsequent to this a further National state and trends report has been prepared by NIWA for MfE report (Ballantine & Davies-Colley, 2009a[104]).

197. Subsequent to the National SoE report, Horizons pooled its water quality monitoring information with NIWA's information to produce an updated analysis to inform the POP hearings[105]. Ballantine & Davies-Colley (2009b) were commissioned to update the water quality trends analysis for the Horizons' Region and to compare the state and trends for the Region with updated information for NIWA's national network of water quality monitoring sites. Dr Davies-Colley[106] and Ms McArthur provide further evidence in

[101] REFERENCE TO TECHNICAL REPORT: Ausseil & Clark (2007c). Recommended water quality standards for the Manawatu-Wanganui Region. Technical report to support policy development. Horizons Report 2007/ext/806

[102] LINK TO FURTHER EVIDENCE: Kate McArthur provides further information in relation to state and trends of water quality in Horizons Region including work completed by NIWA for MfE (2007), the analysis of Ausseil & Clark (2007c), and Ballantine & Davies-Colley (2009).

[103] REFERENCE TO TECHNICAL REPORT: MfE (2007). Environment New Zealand. MfE Report ME847. This report is New Zealand's second State of the Environment report and was produced in December 2007.

[104] REFERENCE TO TECHNICAL REPORT: Ballantine & Davies-Colley (2009a). Water quality at National water quality network sites for 1989-2007. Prepared for the Ministry for the Environment. NIWA Client Report HAM2009-026.

[105] CLARIFICATION ON MY ROLE: I initiated this project. The project management was carried out by Kate McArthur on behalf of Horizons Regional Council.

[106] LINK TO FURTHER EVIDENCE: Rob Davies-Colley provides further information in relation to state and trends of water quality in Horizons' Region, including comparison to the NIWA national network data.

relation to this report (Ballantine & Davies-Colley, 2009b[107]). An overview of the project is provided in Box 30. There are some positive messages from the shorter-term trends analysis completed as a part of this project which indicate improvement in water quality for a range of water quality standards. Further work is underway to determine the potential influence on the short-term trends analysis by the very high flows of the 2004 storm event (and throughout the 2004 year) at the start of these records. These short-term trends results also have a "drought" year close to the end of the record. It is unclear as to the degree that these climatic conditions influenced the short-term trends analysis.

Box 30: Technical project summary – Water Quality State and Trends - 2009

Ballantine & Davies-Colley (2009b) were requested to:

1. Analyse formal time trends of Horizons' water quality data at 25 State of the Environment monitoring sites (16 current and 7 historic), with an emphasis on nutrients and visual clarity (also including *E. coli* and turbidity).
2. Comment on the state and trends in Horizons' Region, including at National River Quality Network (NRWQN) sites in the Region (7 sites), and compare them with the national picture (70 sites outside of the Region.

The following quote from the executive summary of that report sums up the main findings and conclusions of the report. Further detail is provided in the evidence of Dr Davies Colley:

"*Water quality in the Horizon's region is rather poor, as can be seen when water quality data from Horizon's region is compared with guideline and trigger values and national data (inferred from the National Rivers Water Quality Network: NRWQN). In the Manawatu catchment median nutrient concentrations (DRP and SIN) are among the highest* [note 1] *in the country. Visual clarity is low* [note 2] *at many sites and turbidity is correspondingly high* [note 1]*. Faecal microbial pollution is also often high* [Note 1]*. Water quality in the Whanganui and Rangitikei is generally better; nutrient concentrations are mostly lower than trigger values but there are a few "hotspots" where nutrient concentrations are high eg.. DRP concentrations in the Hautapu upstream of the Rangitikei and especially in the Whanganui River, where visual clarity ranks among the lowest nationally* [note 1]*. This is most likely a consequence of the high loads of fine sediment which are the product of easily erodible soils and soft sedimentary rocks that dominate in the region. These soils and rocks weather to produce fine particles that are intensely light-scattering and so strongly reduce visual clarity* [note 2].

There are few significant trends in water quality across the region. Trend analysis of 2001-2008 water quality data revealed no significant trends in DRP concentrations (either increasing or decreasing), 6 meaningful decreasing trends in SIN concentrations [note 1]*, 4 meaningful decreasing trends in E. coli* [note 1] *and 4 meaningful decreasing trends in turbidity* [note 1]*. These trends are in sharp contrast to the longer term trends (1989 to 2007) for the NRWQN sites where meaningful increases were observed for NO_x-N at the 3 NRWQN sites on the Manawatu* [note 1]*. This suggests the longer term (19-yr) trend of worsening water quality in the Manawatu has been slowing or even reversing more recently (ie., water quality has been improving).*"

Note 1: Higher values for this indicator indicate poorer water quality.

Note 2: Lower values for this indicator indicate poorer water quality.

[107] REFERENCE TO TECHNICAL REPORT: Ballantine & Davies-Colley (2009b). Water quality state and trends in Horizons' Region. Prepared for Horizons Regional Council. NIWA Client Report HAM2009-090.

6.10 State and trend analysis of biomonitoring data

6.10.1 Introduction

198. Biomonitoring indicators provide measures of ecosystem health that incorporate the overall conditions within a river system over a period of time. Horizons' biomonitoring programmes include sampling of macroinvertebrate communities, periphyton and fish populations. The macroinvertebrate and periphyton monitoring programmes are briefly overviewed below. For more detail on the history of these programmes and the information they are providing, refer to the evidence of Ms McArthur[108].

6.10.2 Macroinvertebrate monitoring

199. Horizons' biomonitoring programme has largely been based on an annual invertebrate monitoring programme that has been operational for more than 10 years. The invertebrate monitoring information was analysed for state and trends at the end of its ninth year by Dr John Stark (Stark, 2008[109]) and at the end of the programme's 10th year by Pohangina Environmental Consulting (PEC, Death, 2009[110]). At the broad level, the findings of the Stark (2008) report and the Death (2009) report largely agree in relation to trends in the invertebrate indices.

200. The Death (2009) report summarised for the Macroinvertebrate Community Index (MCI) that the scores for the 83 sites sampled between 1999 and 2008 showed:

   i. 6 sites (7%) classed as having good water quality.
   ii. 33 sites (40%) classed as mildly polluted.
   iii. 33 sites (40%) classed as moderately polluted.
   iv. 11 sites (13%) classed as severely polluted.

201. In terms of trends, the Death (2009) report also showed that of the sites monitored annually from 1999 to 2008:

   i. Two sites (Makakahi River at Konini and Whanganui River at Pipiriki) appear to have improved in water quality over eight and 10 years of sampling, respectively.

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[108] LINK TO FURTHER EVIDENCE: Kate McArthur provides evidence in relation to Horizons' biomonitoring programmes including an overview of the fish monitoring programme.

[109] REFERENCE TO TECHNICAL REPORT: Stark J.D. (2008). Trends in river health of the Manawatu-Wanganui region 2008 with comments on the SoE biomonitoring programme. Prepared for Horizons Regional Council. Stark Environmental Report No. 2008-07.

[110] REFERENCE TO TECHNICAL REPORT: Death, F. (2009). State of the environment report 1999 to 2008 Invertebrate and Periphyton communities. Prepared for Horizons Regional Council by Pohangina Environmental Consulting (PEC)

ii. The water quality of the Manawatu River at Maxwells Line/Teachers College, Rangitikei River at Pukeokahu (River Valley Lodge) and Whanganui River at Cherry Grove appears to have declined over the 10 years.

iii. The remaining nine sites monitored annually do not appear to have changed significantly in water quality over the 10-year period of biomonitoring.

6.10.3 Upgrade to the monitoring programme

202. In 2007, a review of the invertebrate monitoring programme was completed by Ms McArthur in consultation with a range of scientists within and external to Horizons[111]. The Stark (2008) report and Death (2009) report both provided recommendations in relation to the future monitoring programme. This review, which was completed over a long period, resulted in a number of changes to the invertebrate monitoring programme being implemented. These changes include using different methodologies to align with national protocols utilised by other Regional Councils. These methods have also provided for further sites to be monitored annually.

203. Horizons' new invertebrate monitoring programme, initiated in 2008-09, covers 48 sites per year compared to the previous programme which had a maximum of 33 sites per year with some sites only being sampled once every three years. The sites for the new programme are consistent with the sites of other SoE monitoring (ie. water quality, quantity, periphyton and fish monitoring). The reason all SoE monitoring sites are not sampled is that some of the sites are physically unsuitable (eg. due to size of river or type of substrate). Monitoring is now completed by Horizons staff and improvements in data management have been implemented.

6.10.4 Periphyton monitoring

204. Horizons' periphyton monitoring programme has largely been completed alongside the annual invertebrate monitoring. This programme has been operational since 1999. A history of the monitoring programme, and the variations in methodologies compiled by Horizons staff, is included in the report of Stark (2008)[112].

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111 CLARIFICATION ON MY ROLE: Kate McArthur and I initiated this review for Horizons and I was a part of the team that then implemented the changes to the monitoring programme.

112 REFERENCE TO TECHNICAL REPORT: Stark J.D. (2008). Trends in river health of the Manawatu-Wanganui region 2008 with comments on the SoE biomonitoring programme. Prepared for Horizons Regional Council. Stark Environmental Report No. 2008-07.

205. The evidence of Ms McArthur[113] provides a summary of this information, collated as follows: "*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:*

- *For the Manawatu catchment most sites were rarely above aesthetic guideline standards (120 mg/m^2) with the exception of the Manawatu 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.*[Note: this Nelson street site is upstream of Feildings treated sewage discharge and the Afco Freezing works discharge]
- *Three of the four sites in the Rangitikei catchment were always below the 50 mg/m^2 benthic biodiversity guideline. However, the Hautapu River upstream of the Rangitikei 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.* [Note this site is downstream of the Taihape STP treated sewage effluent discharge].
- *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 exceeding this guideline 56% of the time.*"

206. Single measurements of periphyton on an annual basis are less than optimal for describing the condition of periphyton in the Region's rivers. Further, the historic use of an acetone-based method to extract chlorophyll *a* has not aligned with the nationally accepted approach of using ethanol. Horizons have completed a review[114] of this monitoring programme, as documented in the report of Kilroy *et al*. (2008)[115]. A new monitoring programme samples 48 sites in alignment with the SoE and discharge monitoring programmes. The programme collects visual cover, chlorophyll *a* and ash-free dry weight (AFDW) data on a monthly basis.

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113 LINK TO FURTHER EVIDENCE: Kate McArthur provides evidence in relation to Horizons' periphyton monitoring programme.

114 CLARIFICATION ON MY ROLE: Kate McArthur and I initiated this review for Horizons and I was a part of team that then implemented the changes to the monitoring programme.

115 REFERENCE TO TECHNICAL REPORT: Kilroy C., Biggs B. and Death R.G. (2008). A periphyton monitoring plan for the Manawatu-Wanganui region. Prepared for Horizons Regional Council. NIWA Client Report: CHC2008-03.

6.11 Surface water quality response

6.11.1 Introduction

207. The pressure and state of the resource provide context for the water quality issues in the Region. The following sections overview the technical work in relation to the POP.

6.12 Setting water quality standards

Relates to key provisions in the Proposed One Plan:

- **Policy 6-2: Water quality standards**
- **Policy 6-3: Ongoing compliance where water quality standards are met**
- **Policy 6-4: Enhancement where water quality standards are not met**
- **Policy 6-5: Management of activities in areas where existing water quality is unknown**
- **Policy 6-8: Point source discharges to water**

6.12.1 Introduction

208. The water quality standards approach for the Proposed One Plan aims to define the appropriate thresholds for managing water resources in relation to the values of that water body. The development of water quality standards builds on the Water Management Zones and values framework for integrated catchment management. The technical brief for this project from Horizons' policy team was to define the standards specifically and numerically. The aim was to provide in the POP clear thresholds to protect the values of the water body and to provide certainty for all involved in the management of the resource. As a result of further work, there are some recommended amendments to the standards as notified in the POP. Ms McArthur provides a detailed summary of these recommended amendments in her evidence. The following sections provide an overview of the technical material in relation to the determination of the proposed standards, and linkages to the evidence of others.

6.12.2 Technical work in relation to water quality standards

209. A range of technical reports provide background information on the development of the water quality standards for the POP. The water quality standards report by Ausseil &

Clark (2007c[116]) was the original technical report that summarised the development of the proposed water quality standards for the POP as notified. An overview of the project is provided in Box 31. The project used information from a range of sources and had input from a range of scientists from around New Zealand, including using information from national guidelines and research agencies.

Box 31: Technical project summary – Water Quality Standards Report

Water quality standards were developed to provide for the water body values in the Water Management Zones of the Region. Numerical standards were developed for seven of the proposed water body values. These were: Life-Supporting Capacity (LSC), Contact Recreation (CR), Aesthetic (Ae), Trout Fishery (TF), Trout Spawning (TS), Shellfish Gathering (SG) and Livestock Drinking Water (SW). Standards for the other values were considered in other ways by the POP.

In determining standards for a particular value, the recommended water quality standards provide for a state of water quality that does not compromise the value. The recommended standards cover a range of water quality parameters that can be categorised into four groups:

1. **Physicochemical parameters** to ensure conditions are adequate for aquatic life and water users. These include: pH, dissolved oxygen, temperature, water clarity, biochemical oxygen demand (BOD), particulate organic matter (POM), and toxicants.
2. **Recreational use parameters** relating to the recreational use of the water bodies and the protection of public health. These include indicators of faecal contamination, water clarity, and algal biomass and cover.
3. **Biological parameters** directly linked with the integrity of aquatic ecosystems. These include biomonitoring indicators such as the Macroinvertebrate Community Index (MCI) and periphyton biomass and cover.
4. **Nutrient parameters** to control algal growth that relates to some of the above categories. These include forms of nitrogen and phosphorus.

There is overlap between these categories in terms of the parameters involved. The categories align closely with the categories identified by Horizons SoE report (2005a). For many parameters, multiple standards were developed and these were applied in relation to the differing water body characteristics and values. The current state of water quality in comparison to the recommended standards was also documented as a part of the report where sufficient data was available.

[116] REFERENCE TO TECHNICAL REPORT: Ausseil & Clark (2007c). Recommended Water Quality Standards for the Manawatu-Wanganui Region. Technical Report to Support Policy Development. Horizons Regional Council Report 2007/EXT/806

6.12.3 Technical evidence and recommended amendments to the water quality standards

210. Section 42 reports for the Water Hearing include technical evidence in relation to water quality standards. Table 10 provides an overview of the authors providing information in relation to specific standards/parameters in relation to the values. Ms McArthur[117] provides an overview of evidence related to water quality standards including a detailed summary of the recommended changes to these standards. Table 10 summarises who is providing evidence in relation to the various parameters, in the environments where the standards are proposed to apply. Some further information on the development of the river water quality nutrient standards is provided in the sections below, reflecting my involvement in some aspects of this work and the relevance of these aspects to subsequent sections of this report.

Table 10. Summary of evidence providers in relation to water quality standards in various environments. Kate McArthur provides an overview of water quality parameters and recommended standards.

Water Quality parameter	Environment		
	Rivers	Coast /Estuaries	Lakes
	Evidence provider		
pH	Dr Bob Wilcock	Dr John Zeldis	Max Gibbs
Temperature	Dr John Quinn	Dr John Zeldis	Max Gibbs
Dissolved Oxygen (DO) % of saturation	Dr John Quinn and Dr Roger Young	Dr John Zeldis	Max Gibbs
Biochemical Oxygen Demand (BOD)	Dr John Quinn	Dr John Zeldis	Max Gibbs
Particulate Organic Matter (POM)	Dr John Quinn	Dr John Zeldis	Max Gibbs
Periphyton and Phytoplankton	Dr Barry Biggs	Dr John Zeldis	Max Gibbs
DRP	Dr Barry Biggs	Dr John Zeldis	
SIN	Dr Barry Biggs	Dr John Zeldis	
Total P		Dr John Zeldis	Max Gibbs
Total N		Dr John Zeldis	Max Gibbs
QMCI	Dr John Quinn		
Ammoniacal Nitrogen	Dr Bob Wilcock	Dr John Zeldis	Max Gibbs
Toxicity	Dr Bob Wilcock	Dr John Zeldis	Max Gibbs
Turbidity / Clarity	Dr Rob Davies-Colley	Dr John Zeldis and Dr Rob Davies-Colley	Max Gibbs and Dr Rob Davies-Colley
Euphotic Depth		Dr John Zeldis and Dr Rob Davies-Colley	Max Gibbs and Dr Rob Davies-Colley
Faecal Indicator Bacteria (*E. coli*)	Dr Bob Wilcock and Dr Rob Davies-Colley	Dr John Zeldis and Dr Rob Davies-Colley	Max Gibbs and Dr Rob Davies-Colley
Cyanobacterial toxins			Max Gibbs

[117] LINK TO FURTHER EVIDENCE: Kate McArthur provides an overview of the evidence related to water quality standards and also provides a detailed summary of the recommended changes to these standards.

6.13 River water quality nutrient standards

Relates to key policies in the POP:

- **Policy 6-2: Water quality standards**
- **Policy 6-3: Ongoing compliance where water quality standards are met**
- **Policy 6-4: Enhancement where water quality standards are not met**
- **Policy 6-5: Management of activities in areas where existing water quality is unknown**
- **Policy 6.7: Land use activities affecting surface water quality**
- **Policy 6-8: Point source discharges to water**

6.13.1 Introduction

211. Ausseil & Clark (2007c) recommended water quality standards for nitrogen and phosphorus in water bodies year round, at flows below the three times median flow, ie. at times when the river wasn't in high flows (approximately 80% of the time). These recommendations are quite different to those of previous Plans for Horizons' Region. The Manawatu Catchment Water Quality Regional Plan (MCWQRP) (1997) did not have any standards for nitrogen though it did include phosphorus standards that applied below the half-median flow, ie. approximately 25% of the time. The following sections outline further technical information in relation to nutrient in water bodies, and the recommendations for these river water quality nutrient standards.

6.13.2 Nutrient cycling and the need to manage nutrient in rivers

Relates to:

- **Hearing Chairperson's Minute #6, Question 5.3: What problems do elevated nutrients cause in rivers and lakes? For rivers do such problems affect the Schedule D values for rivers?**

212. Nutrient cycling, and why there is a need to manage nutrient in water bodies, is briefly covered in the water quality framework report by Roygard and McArthur (2008)[118]. The link between Schedule D values and nutrient enrichment, and the setting of nutrient standards to provide for Schedule D values, are addressed in the evidence of Ms

[118] REFERENCE TO TECHNICAL REPORT: Roygard J. & McArthur. K. (2008). A framework for managing non-point source and point source nutrient contributions to water quality. Technical report to support policy development. Horizons Regional Council Report 2008/EXT/792; pages 23-25 include a section on nutrient cycling.

McArthur[119], Dr Bob Wilcock[120], Dr John Quinn[121] and Dr Barry Biggs[122]. Their evidence explains a link between nutrient and periphyton, describes why periphyton is an issue, and ties this back to the values framework.

213. Nutrient cycling in water bodies is a natural process that occurs as part of the ecology of river systems. The issue with nutrients in water ways develops when nutrient concentrations elevate to a level that causes nuisance growths of algae or periphyton that in turn impact on the values of a water body. For example, the life-supporting capacity and aquatic biodiversity value of rivers and streams can be decreased by smothering of the substrate by periphyton. Excess growth (ie. proliferations) of periphyton reduces the aesthetic and recreational appeal of water bodies and can negatively impact on many values. Consumptive uses can also be impacted through reduction of the potability of water for stock and human water supply, or the clogging of irrigation and water supply intakes with biomass.

6.13.3 Limiting nutrients for controlling undesirable periphyton growth

214. As part of the process of determining the approach to nutrient standards, Horizons hosted a workshop of scientific experts to obtain advice on control of undesirable periphyton growth. This workshop was held as a part of a joint Envirolink project with Hawkes Bay Regional Council. The attendees included Horizons water quality scientists, NIWA scientists, Russell Death from Massey University, and a scientist from Hawkes Bay Regional Council who was previously a water quality scientist at Horizons Regional Council (John Phillips). A key question addressed at the workshop, and in the subsequent report (Wilcock *et al*., 2007[123]) was, what are the appropriate mechanisms to control periphyton growth? The key recommendations from this report are detailed in Box 32. These can be summarised as the need to control both N and P year round at flows below flood flow. Bob Wilcock[124] will provide further evidence in relation this project and its findings and conclusions.

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[119] LINK TO FURTHER EVIDENCE: The evidence of Kate McArthur provides further information in relation to nutrient enrichment and the values of Schedule D, and the setting of water quality standards to provide for Schedule D values.

[120] LINK TO FURTHER EVIDENCE: The evidence of Bob Wilcock provides further information in relation to nutrient enrichment and the values of Schedule D, and the setting of water quality standards to provide for Schedule D values.

[121] LINK TO FURTHER EVIDENCE: The evidence of John Quinn provides further information in relation to nutrient enrichment and the values of Schedule D, and the setting of water quality standards to provide for Schedule D values.

[122] LINK TO FURTHER EVIDENCE: The evidence of Barry Biggs provides further information in relation to nutrient enrichment and the values of Schedule D, and the setting of water quality standards to provide for Schedule D values.

[123] REFERENCE TO TECHNICAL REPORT: Wilcock B., Biggs B., Death R., Hickey C., Larned S. and Quinn J. (2007). Limiting nutrients for controlling undesirable periphyton growth. Prepared for Horizons Regional Council; NIWA Client Report HAM2007-006, NIWA Project ELF07202.

[124] LINK TO FURTHER EVIDENCE: The evidence of Bob Wilcock provides further information in relation to limiting nutrients for controlling undesirable periphyton growth project (Wilcock *et al*., 2007)

Box 32: Technical project summary - Limiting nutrients for controlling undesirable periphyton growth

As part of the process of determining the approach to nutrient standards, Horizons hosted a workshop of scientific experts to obtain advice on control of undesirable periphyton growth. This workshop was held as a part of a joint Envirolink project with Hawkes Bay Regional Council. The conclusions of the subsequent report by Wilcock *et al*. (2007) were:

1. Both nitrogen (N) and phosphorus (P) need to be managed, because of the interconnectivity of water bodies (where different nutrients might be limiting in the same stream network).
2. A high background concentration of a 'non-limiting' nutrient can contribute to periphyton blooms if control of the 'limiting' nutrient fails.
3. 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.
4. 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 reduce nutrient pools within sediments and provide for downstream reaches with hard substrates or estuarine/coastal waters.
5. Controls on nutrient levels in water bodies should apply at all flows, with the exception of flood flows where these are defined as flows greater than the flow that is three times the median flow.

6.13.4 Horizons studies of limiting nutrients

215. Prior to the report by Wilcock *et al.* (2007), Horizons had completed nutrient limitation investigations in the Rangitikei Catchment via two methods:

i. The investigation of historic water quality data as part of the Rangitikei Water Resource Assessment had concluded[125] that the river was likely nitrate limited (Roygard & Carlyon, 2004[126], page 52).

ii. Using sampling via the use of nutrient diffusing substrates containing a range of nutrient concentrations to determine the relative rates of periphyton growth. Based on these measurements, the investigation concluded that the Rangitikei River was nitrogen limited during the time of the study. These types of surveys are only representative of the conditions in the river for the duration of the experimental equipment being deployed in the river. *Death et al.*, 2007[127] documents this study.

[125] CLARIFICATION ON MY ROLE: I completed this analysis and the subsequent write up.

[126] REFERENCE TO TECHNICAL REPORT: Roygard & Carlyon (2004). Water allocation project Rangitikei River, Water resource assessment, allocation limits and minimum flows - Technical report to support policy development. Horizons report 2004/Ext/606. Rangitikei Water Resource assessment.

[127] REFERENCE TO TECHNICAL DOCUMENT: Death R.G., Death F., and Ausseil O.M.N., 2007. Nutrient limitation of periphyton growth in tributaries and the mainstem of a central North Island river, New Zealand. *New Zealand Journal of Marine and Freshwater Research 2007, Vol. **41**:273-281.*

216. Since completion of the report by Wilcock *et al*. (2007), Horizons has completed some further work on nutrient limitation in the Regions rivers. These studies have confirmed some statements in the Wilcock *et al*. (2007) report, particularly the statement that both N and P should be managed because of the interconnectivity of water bodies (where different nutrients might be limiting in the same stream network), on any given day a catchment may contain areas that are:

i. Nitrogen limited.

ii. Phosphorus limited.

iii. Co-limited (limited by Nitrogen and Phosphorus).

iv. Not limited by nutrient.

That these conditions all exist in the same catchment on the same day is shown by two detailed water resource investigations carried out by Horizons[128]. The first study was completed in the upper Manawatu, with sampling in January and February 2007 (Box 33). The second study was completed in the Mangatainoka catchment in February 2008 (Box 34).

[128] CLARIFICATION ON MY ROLE: I initiated and scoped these investigations and conceptualised the indicator maps; mapping was completed by Maree Clark.

Box 33: Technical project summary – upper Manawatu low flow investigations

The water resource investigations in the upper Manawatu catchment (January and February 2007) monitored a range of water quality parameters at 27 sites. The upper Manawatu Catchment is defined (for the purposes of this study) as the Manawatu Catchment upstream of the Tiraumea River confluence with the Manawatu River. The results are documented in more detail in Roygard and McArthur (2008; pp 35-46). The maps below show the results for the two low flow sampling runs (at the 89th and 96th percentile flows[129],). On both sampling events, areas of the catchment were representative of the range of nutrient limitation possibilities[130], ie. some were soluble inorganic nitrogen (SIN) limited, some were dissolved reactive phosphorus (DRP) limited, others were both SIN and DRP limited, and some areas were not limited at all. It is also noted that some areas changed their status between the sampling events. These changes included:

I. Areas that were not limited by nutrient changing to an N limited state (Manawatu at Weber Road and Mangatera Confluence at Timber Bay).

II. An area that was not limited by nutrient changing to a P limited state (Kumeti at upstream Manawatu River Confluence).

III. An area that was limited by both nutrients changing to a P limited state only (Oruakeretaki at Fairbrother Road).

IV. An area that was N limited changing to a co-limited state (Tamaki at Stephensons).

Limitation has been determined for these indicators based on the recommended POP concentration standards and the original recommended (more stringent standards) of Barry Biggs.

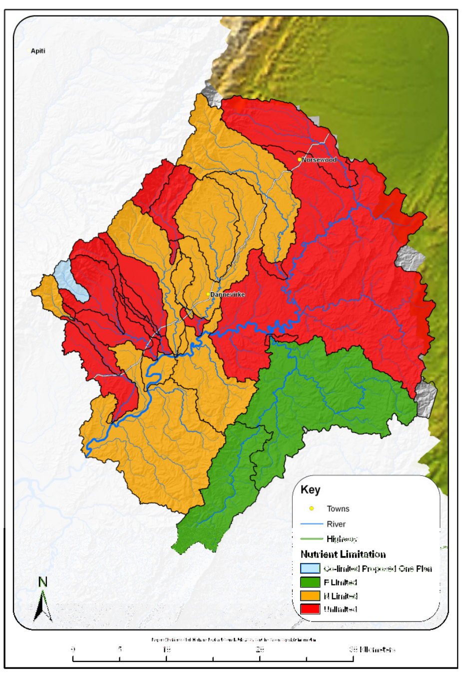

Figure A. Sampling in January 2007 at the 89th percentile, ie. the flow that is exceeded 89% of the time.

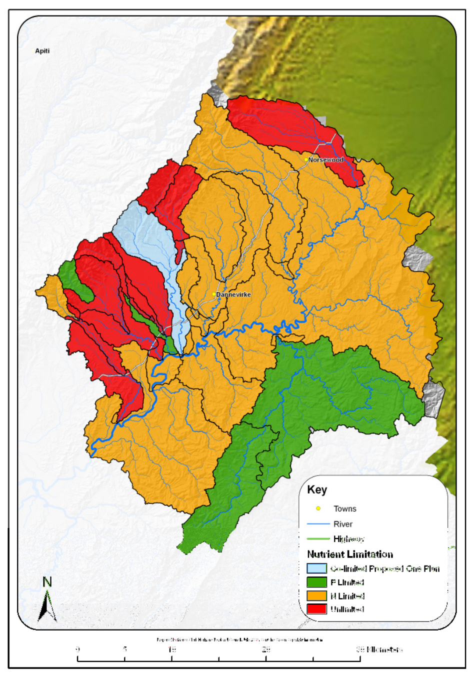

Figure B. Sampling in February 2007 at the 96th percentile, ie. the flow that is exceeded 96% of the time.

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129 REFER TO: Appendix 1 provides more information on flow distributions and percentile flows.

130 REFER TO: Roygard and McArthur 2008 provides more detail on the thresholds used to determine nutrient limitation including further context on the more stringent standards originally recommended by Barry Biggs. Section 6.13 provides some further information on nutrient standards.

Box 34: Technical project summary – Mangatainoka low flow investigations

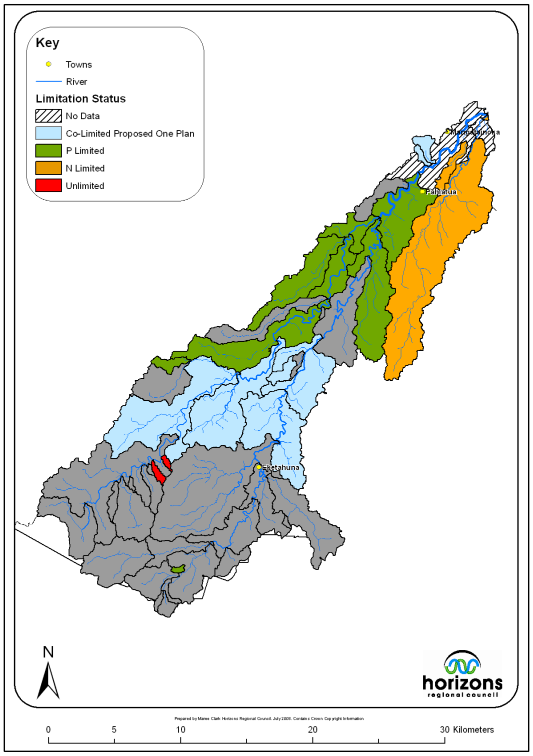


Figure A:. Sampling in February 2008 at the 99th percentile, ie. the flow that is exceeded 99% of the time.

The water resource investigation in the Mangatainoka River was carried out at a flow of less than the 99% percentile flow, ie. about as low as the flow gets in the Mangatainoka River. On this sampling occasion, a range of limitations were observed, including:

I. Co-limitation based on the original standards recommended by Dr Barry Biggs (24 sites).

II. Co-limitation based on the less stringent nitrogen standard proposed in the POP (seven sites plus the 24 sites that were co-limited according to Dr Barry Biggs' standards).

III. Phosphorus limited (seven sites).

IV. Nitrogen limited (two sites - it is noted the nitrogen limited sub-catchment is the Mangaramarama).

V. Not N or P limited (two sites)

Limitation has been determined for these indicators based on the recommended POP concentration standards and the original recommended (more stringent standards) of Barry Biggs.

217. A further key finding is that nutrient limitation at a site can change. The graphs in Box 35 show limiting nutrient status can change at a site when absolute concentrations are used to indicate limiting nutrient status. These graphs also show an alternate method (based on the Redfield ratios) to determine limiting nutrient status based on the ratio of nitrogen (N) to phosphorus (P). Using this method with a simple N:P ratio of 7:1 (by weight) ratio predicts phosphorus to be limiting more often that using the absolute concentrations of N and P in relation to the standards. Wilcock *et al.* (2007) note that Redfield ratios are averages that are subject to change depending on future levels of nutrient availability and competition between species.

218. Further analysis of nutrient limitations determined by absolute concentrations shows that the limiting nutrient status has some relationship with flows for the Manawatu River at Hopelands site (Box 36). Few samples taken above median flow show any nutrient limitation. Below median flow, the proportion of sampling occasions where either SIN or DRP are limiting increases. Sampling at the lowest of flows eg. below the 80th percentile flow (that represents the flows that occur less than 20% of the time) shows the greatest

proportion of nitrogen limited samples. This likely relates to the sources of nitrogen to water bodies at low flows, which are likely limited to direct inputs from point source discharges, stock access to water bodies, stock crossings, etc. At low flows, phosphorus may also be available from the sediments in the bed of the river. APPENDIX 1 provides further detail in relation to flow distributions and exceedance percentiles[131].

Box 35: Technical concept: Nutrient limitation at a site can change

The figures below, sourced from Roygard and McArthur (2008) show the concentration of nitrogen and phosphorus at sampling events for four sites. The background shading provides context for the limiting nutrient at the sampling events. At each site, the shading indicates that the limiting nutrient based on concentrations alone varies for all sites.

Another way to consider nutrient limitation is via the ratio of SIN and DRP (Wilcock *et al.*, 2007; p 2). To view how this differs from using the absolute concentrations, the dashed line in the figures below shows a simple N:P ratio of 7:1 as recommended by Wilcock *et al.* (2007). As would be expected, this method predicts a greater number of sites to be DRP limited than using absolute concentrations as an indicator. Using the ratio method, observations below the line are considered DRP limited and the observations above the line are considered SIN limited.

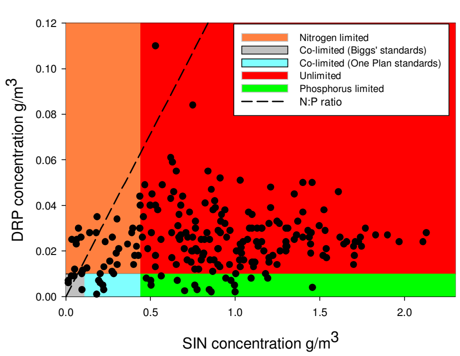


Figure A. Manawatu at Hopelands.

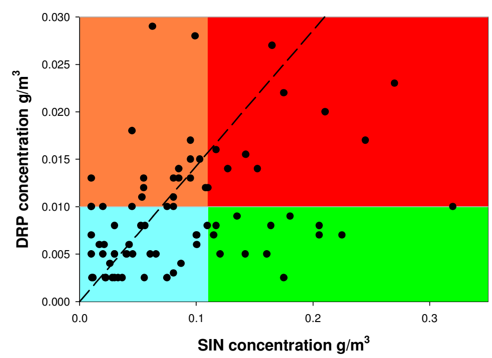


Figure B. Rangitikei at Mangaweka

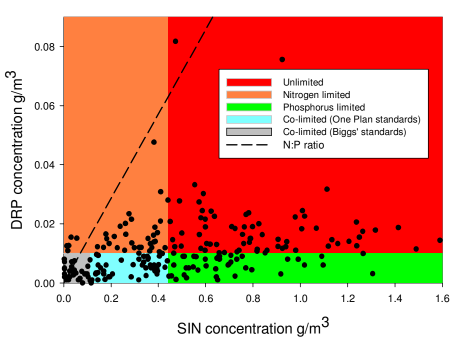


Figure C. Manawatu at Weber Road

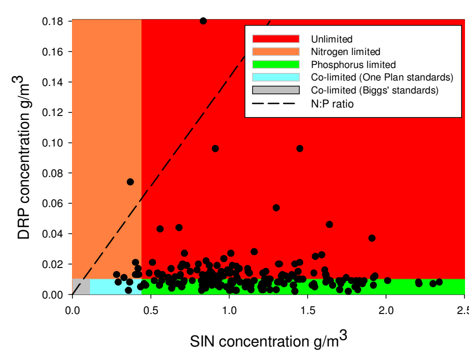


Figure D. Mangatainoka at Suspension Bridge.

[131] REFER TO: Appendix 1 provides some further information on flow exceedance percentiles.

Box 36: Technical concept: Nutrient limitation at a site can change with flow

The figures below, sourced from Roygard and McArthur (2008) show the relationship between limiting nutrient status and flows for the Manawatu at Hopelands site. The graphs show that a higher proportion of the sampling occasions show nitrogen limitation at flows below median flow, with a greater level of nitrogen limitation occurring at the lowest 20% of flows . At the lowest 20% of flows, the majority of samples show some limitation is occurring, either SIN or DRP or both. In the next flow category, between low flows and median flow, there are a greater number of samples that do not show limitation. Above median flows, few samples show any limitation.

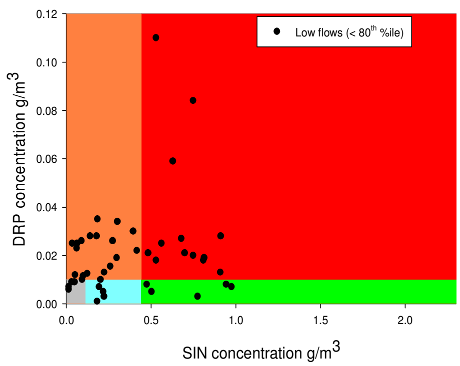


Figure A. Samples at flows below the 80th percentile flow ie. the lowest 20% of flows.

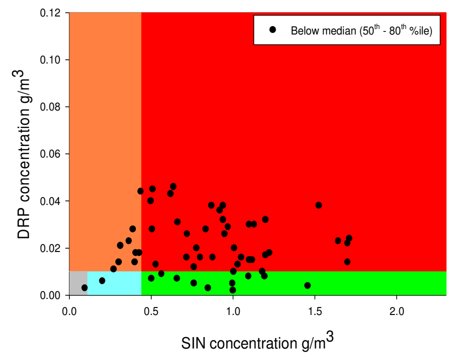


Figure B. Samples at flows below the median flow and greater than the 80th percentile flow.

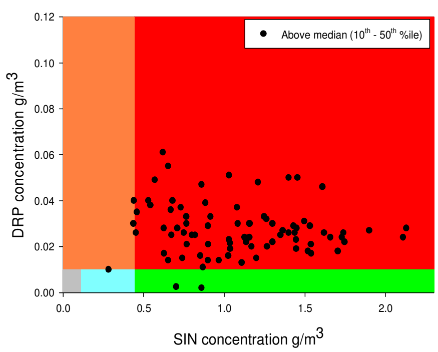


Figure C. Samples at flows above the median flow and greater than the 20th percentile flow.

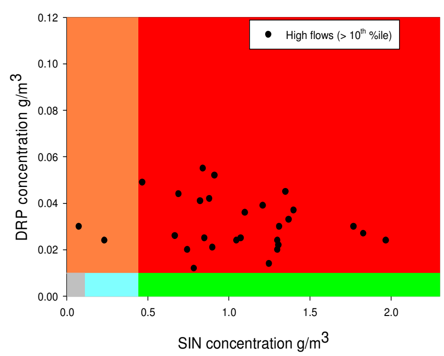


Figure D. Samples at flows above the 20th percentile flow ie. collected within the highest 20% of flows.

6.13.5 Setting nutrient standards

219. The approach to setting surface water quality nutrient standards for the POP is outlined in Ausseil & Clark (2007c). Further evidence on this approach, including the questions defined for the various other standards in the sections above, are addressed in the evidence of Ms McArthur[132], Dr Wilcock[133] and Dr Biggs[134]. In summary, the proposed

[132] LINK TO FURTHER EVIDENCE: The evidence of Kate McArthur provides further information in relation to the setting of river water quality nutrient standards to provide for Schedule D values.

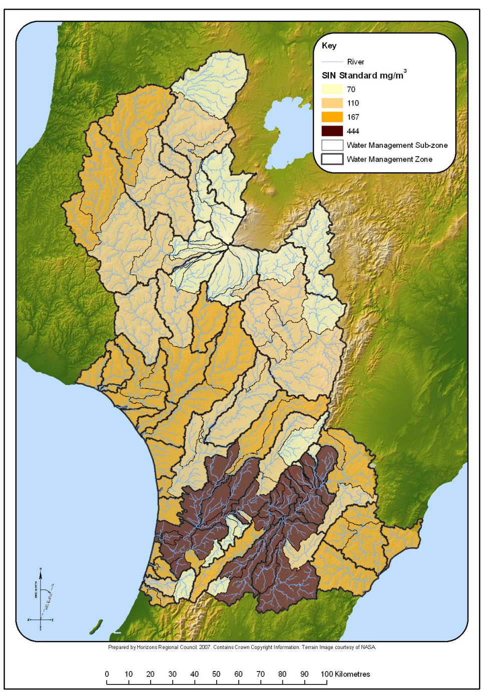
standards are set for both SIN and DRP, all year round, at flows less than the three times median flow. The POP standards were set at four levels for SIN: 0.070, 0.110, 0.167 and 0.444 g SIN/m^3 and three levels for DRP: 0.006, 0.010 and 0.015 g DRP/m^3 (Box 37).

6.13.6 Technical amendments

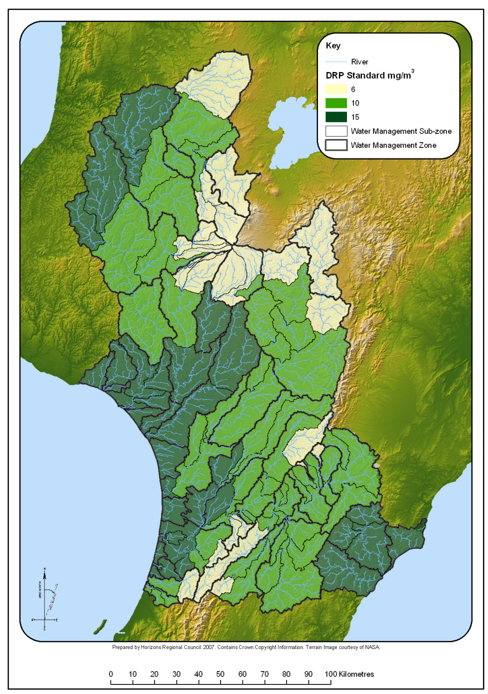
220. Further work on the water quality standards since the notification of the POP has resulted in some changes in these recommendations. In summary, the revised recommended standards are set for both SIN and DRP, all year round, at flows less than the 20th percentile flow (ie. approximately 80% of the time). Some changes have been proposed standards for the headwaters catchments to allow for the originally proposed standards for these headwater sites to be exceeded naturally.

Box 37: Applying the proposed river water quality standards via the Water Management Zones and values framework

The proposed water quality standards were applied to the Water Management Zones and values framework, as outlined in the maps below.



Map A. Proposed nitrogen standards



Map B. Proposed phosphorus standards

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[133] LINK TO FURTHER EVIDENCE: The evidence of Bob Wilcock provides further information in relation to the setting of river water quality standards nutrient to provide for Schedule D values.

[134] LINK TO FURTHER EVIDENCE: The evidence of Barry Biggs provides further information in relation to the setting of river water quality standards to provide for Schedule D values.

6.13.7 Recommendation to the Hearing Panel

221. **I recommend that the Hearing Panel adopt the recommendation in the planning report of Clare Barton in relation to water quality standards**

6.14 Relating the proposed river water quality nutrient standards to management of rivers

Relates to key policies in the Proposed One Plan:

- **Policy 6-2: Water quality standards**
- **Policy 6-3: Ongoing compliance where water quality standards are met**
- **Policy 6-4: Enhancement where water quality standards are not met**
- **Policy 6-5: Management of activities in areas where existing water quality is unknown**
- **Policy 6.7: Land use activities affecting surface water quality**
- **Policy 6-8: Point source discharges to water**

6.14.1 Introduction

222. The setting of the concentration-based standards, year round at flows below the three times median flow, as proposed in the POP, provides the limits within which to manage the river. Initial assessment of whether these standards are being met or not can be provided by indicators such as those used in Horizons' SoE report. To relate the proposed standards to requirements for management of the river, eg. management of inputs from point sources and non-point sources, requires an understanding of how these inputs relate to concentration-based standards on the daily and annual basis that they are managed. For example, nutrient management models such as OVERSEER® document nitrogen losses on a yearly basis (long-term average annual load). However, inputs from point sources could be managed on a daily basis.

223. The water quality framework report[135] (Roygard and McArthur, 2008[136]) addressed this using two example catchments: the Manawatu River upstream of Hopelands and the Mangatainoka River upstream of State Highway 2 (SH2). This work and the key findings are summarised in the following sections, including:

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[135] REFERENCE TO TECHNICAL REPORT: Roygard J. & McArthur. K. (2008). A framework for managing non-point source and point source nutrient contributions to water quality. Technical report to support policy development. Horizons Regional Council report 2008/ext/792; pp 23-25 include a section on nutrient cycling.

[136] CLARIFICATION ON MY ROLE: I initiated and scoped this project, including conceptualising the calculation methodologies. Kate McArthur is a co-author of this work.

i. The conversion of the concentration based standards to standards on an average daily, annual, and long-term average basis to enable comparison with current loads and the setting of catchment targets (Section 6.11.1).
ii. The reduction in annual loads due to the water quality standards not applying at all flows (Section 6.11.2)..
iii. The current loads of nutrient in the water body in comparison to the standards (Section 6.11.3)..
iv. The relative contribution of point source and non-point sources ((Section 6.12)..
v. The relative contributions of point source and non-point sources at various flows (Section 6.12.3)..

6.14.2 Converting the concentration-based standards to loading standards to enable comparison with current loads and the setting of catchment targets

224. The conversion of the concentration-based standards to daily and annual loads enables current loads from point sources and non-point sources to be compared with the concentration-based standards. This provides a mechanism to compare losses predicted by nutrient models such as OVERSEER, which provide numbers in relation to losses from farms on a long-term annual average basis. This conversion is based on the concept that the load of a particular contaminant that a river can receive, and still remain within a concentration standard, depends on the flow in the river. When the river is at higher flow, it takes a greater quantity of nutrient to make the river reach the defined concentration threshold (Box 38).

225. There is high variation in the standards when converted from instantaneous concentration-based standards to an annual load for each year (Box 39).

- For the Manawatu at Hopelands site, the long-term mean annual loading calculated from the concentration standard was 358 tonnes SIN/Year and 8.1 tonnes DRP/year. When calculated for the individual years, the standard loads ranged from 198 to 553 tonnes SIN/year, ie. approximately 50% higher and lower than the mean standard load.

226. It is concluded that this annual variation should be a consideration when setting any catchment target loads (as is done by the proposed Rule 13.1). For example, if the mean standard of 358 tonnes was achieved at the Hopelands site every year, then the standard would not be met in seven out of the 15 years analysed.

Box 38: Technical concept – Relating concentration based standards to flows

The POP SIN standard for Manawatu at Hopelands is 0.444 g/m^3. To be within this nutrient standard at a flow of 1 m^3/s, the loading input of SIN to a river has to be less than 0.444 g/s (1 m^3/s * 0.444 g SIN/m^3). This equates to a maximum limit of 38.4 kg SIN/day if the flow remains at 1 m^3/s and the SIN contribution is assumed to be constant. The table below shows how the loading input of SIN changes as river flow increases from the minimum to the maximum recorded flow for the Manawatu at Hopelands site, assuming no biological assimilation or nutrient uptake.

Table A. Theoretical SIN loads (kg/day) at different river flow statistics to meet the concentration-based water quality standard of 0.444g SIN/m^3 in the Manawatu River at Hopelands.

Flow Statistic	Flow m^3/s	SIN load kg/day
	1.000	38.4
Minimum	2.005	77
MALF	3.700	142
Median	15.400	591
Maximum	1669.642	64050

Box 39: Converting concentration-based standards to nutrient loads on an annual basis

A simple way to calculate the annual load standard for a given year is to multiply the mean flow for the year by the concentration-based standard.

Another method, which generates the same result, is to sum the volume of water flowing past a recorder site for every 15-minute recording interval over a year. This cumulative flow volume is multiplied by the concentration standard (g/m^3) to reach the maximum allowable annual contaminant load, or standard load limit. To calculate the long-term average in tonnes/year, each of the 15-minute interval loadings can be summed for an annual total for each year and then averaged over the period of record. More detail on this method is provided in Roygard and McArthur (2008; pp 57-80).

Example calculations using this approach are presented for the Manawatu at Hopelands site to show the annual variability in the conversion of the concentration-based standard to a standard load limit.

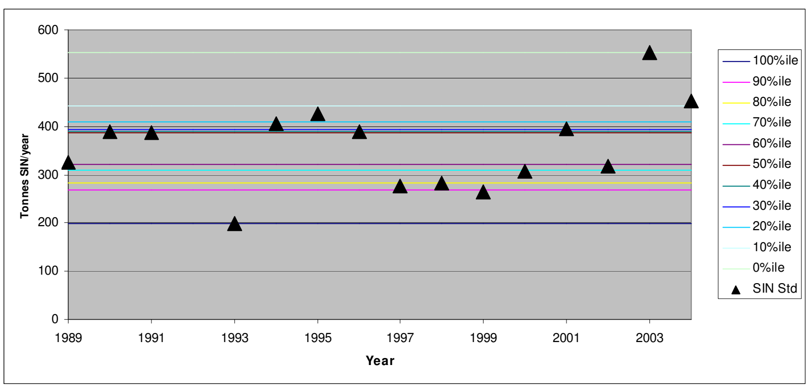


Figure A. Annual variation in the standard load limit for SIN at the Hopelands site showing the exceedance percentiles (%ile) of the standard loads.

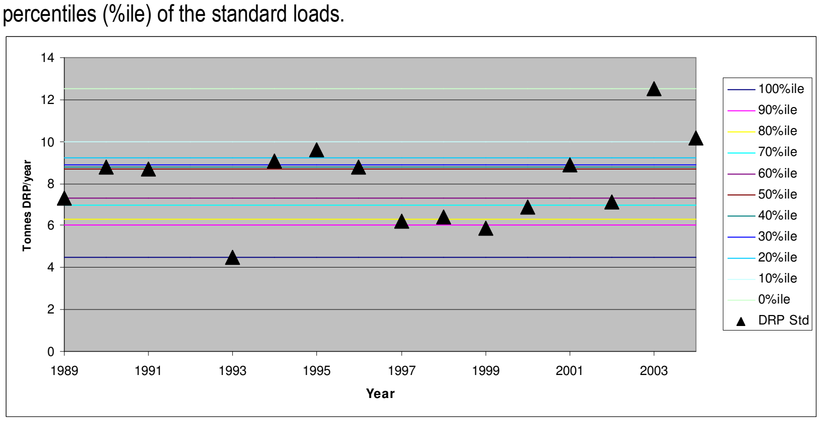


Figure B. Annual variation in the standard load limit for DRP at the Hopelands site showing the exceedance percentiles (%ile) of the standard loads.

6.14.3 Reductions in annual loads due to the water quality standards not applying at all flows

227. The reduction in annual loads due to the water quality standards not applying above three times median flow is an important consideration when setting target loads for a catchment (as is done in the proposed Rule 13.1).

228. For the Manawatu at Hopelands site, the three times median flow is equivalent to the flow that is only exceeded 12% of the time in the flow record (ie. the 12th percentile flow). APPENDIX 1 provides further detail in relation to flow distributions and exceedance percentiles[137]. The average annual loadings for the Manawatu at Hopelands site were recalculated excluding any flows above the 10th percentile flow. The average annual standard load reduced from 358 to 211 tonnes (ie. reduced by 41%). This reduction can only be due to flow and the implication is that 41% of the flow occurs in the highest flows that occur above the 10th percentile flow (41% of the river volume flows past the recorder station in 10% of the time).

229. Similar results were found for the Managatainoka site. The average annual standard load reduced from 266 to 166 tonnes (ie. reduced by 38%, meaning 38% of the river volume flows past the recorder station in 10% of the time).

6.14.4 The Measured loads of nutrient in the water body in comparison to the standards

230. Comparing the Measured loads to the standard loads identifies the size of the issue for the catchment. The methodology used to calculate the Measured loads in the catchments is documented in the water quality framework report (Roygard and McArthur, 2008). A flow stratification method was used that grouped the recorded water quality information via the flow deciles[138] at which the measurements were taken. Values for these flow deciles were used to calculate long-term loads, which were expressed in terms of tonnes of nutrient per year. Using this method enabled the relative contributions of non-point sources and point sources to nutrient loadings to be calculated (see below). APPENDIX 2[139] provides an overview of the comparison of this method with some other possible alternative methods, and explains why this was the selected as the methodology for load calculation for the POP technical work. The results show that the Measured loads (ie. annual average) for these catchments are in excess

137 REFER TO: Appendix 1 provides some further information on flow percentiles and flow exceedance percentiles.

138 DEFINITION OF TECHNICAL TERM: Flow deciles were 10 percentile bins of flows, eg. the 0 to 10th flow percentiles made up one of the 10 flow decile bins (see Roygard and McArthur, 2008; p 69 for more details).

139 REFER TO: Appendix 2 provides a comparison of the loading calculation methodology to alternate methods.

of the standard loads for these catchments (Box 40). Further, the proportional difference between the loads when all flows are included and the loads for only the flows where the standards apply can be calculated.

Box 40: Assessing the Measured nutrient loads in relation to water quality standards

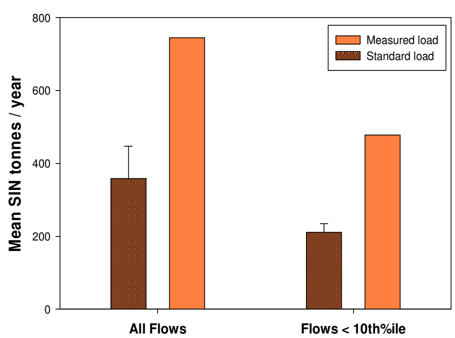
Example 1: Manawatu at Hopelands (1989-2005)

SIN – all flows

- The Measured SIN load (the sum of the annual averages for each flow decile category) for the Manawatu at Hopelands site had a value of 745 tonnes/year for all flows. This load was slightly more than twice the average Standard load of 358 tonnes SIN/year.

SIN – excluding flows above the 10 percentile

- The average Measured load reduces to 478 tonnes SIN/year. Again, the Measured load is more than twice the Standard load limit of 211 tonnes SIN/year at flows <10th percentile.

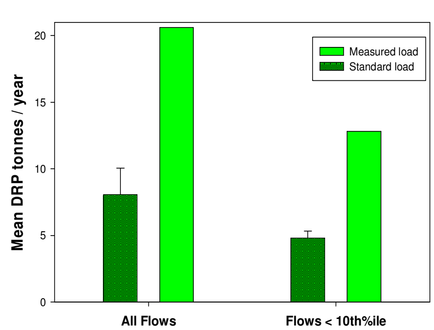


DRP – all flows

- The Measured DRP load at the Hopelands site had an average value of 21 tonnes/year for all flows, more than 2.5 times the Standard load limit (8.1 tonnes DRP/year).

DRP – excluding flows above the 10 percentile

- The average Measured load was 13.0 tonnes DRP/year, more than 2.5 times the Standard load limit. (4.3 tonnes/year at flows <10th percentile).)



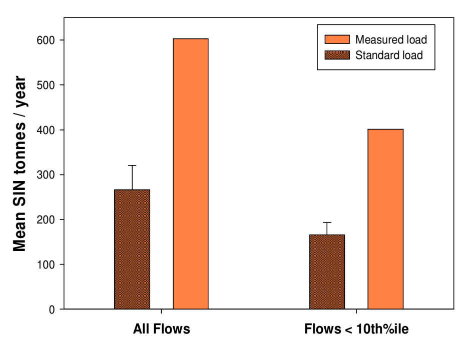
Example 2: Mangatainoka at SH2 (1993-2005)

SIN – all flows

- The Measured SIN load for the Mangatainoka at SH2 site had an average value of 603 tonnes/year for all flows. This load was more than twice the average Standard load limit of 266 tonnes SIN/year.

SIN – excluding flows above the 10 percentile

- The average Measured load reduces to 401 tonnes SIN/year. Again, the Measured load is approximately 2.5 times the Standard load limit (166 tonnes SIN/year at flows <10th percentile).

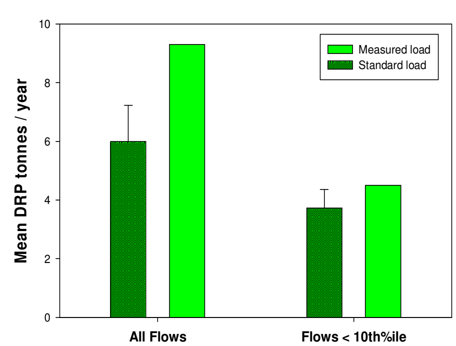


DRP – all flows

- The Measured DRP load at the SH2 site had an average value of 9.3 tonnes/year for all flows, approximately 1.5 times the Standard load limit (6.0 tonnes DRP/year).

DRP – excluding flows above the 10 percentile

- The average Measured load reduced to 4.5 tonnes DRP/year, approximately 1.2 times the Standard load limit (3.7 tonnes/year at flows <10th percentile).



6.15 The relative contribution of nutrient from point sources and non-point sources

231. Calculating the relative contribution of point source and non-point sources enables identification of how these two sources of nutrient contribute to water quality in comparison with the standards.

6.15.1 Relative contribution from point sources

232. The methodology for the calculation of point source inputs at various flows is documented in Roygard and McArthur (2008). These methods relied on available information for point sources in the study areas and methodologies that worked with the available information were employed[140]. The analysis in Box 41 calculates that removing the farm dairy-shed effluent discharges may have removed approximately 2% of the nitrogen load from the Manawatu at Hopelands site and the Mangatainoka at SH2 site. For DRP this number is estimated to be 10% of the load for Manawatu at Hopelands and 25% in the Mangatainoka River. For both catchments the overall amounts of SIN removed are about the same. For DRP a greater reduction was calculated in the Mangatainoka. This may reflect the smaller catchment size of the Mangatainoka relative to the number of discharges from dairy.

233. Farm dairy-shed effluent contributions are identified as a part of the estimation of the point source loads. However, for reporting in this report and in Roygard and McArthur (2008) they are considered separate to the point source load. This reflects the large shift away from point source discharges to water from farm dairy-shed effluent as per the requirements of Horizons Regional Plans (as documented in earlier sections of this report). Contributions from farm dairy-shed effluent application to land are considered as a part of the non-point source contribution to water quality.

234. Contribution from other consented point sources were also assessed in terms of their relative inputs. The methodologies for completing these analyses are overviewed in Box 42. The only major point source[141] in the catchment upstream of Manawatu at Hopelands was considered to be Dannevirke sewage. In the catchment upstream of Mangatainoka at SH2, the Eketahuna and Pahiatua sewage were identified as the major discharges (in terms of overall nutrient loadings at the SH2 site[142]). The conclusions of these studies estimated the point source contribution to the loading at the Hopelands

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[140] CLARIFICATION ON MY ROLE: I determined the methodology for these calculations.
[141] Major discharge in terms of nutrient loading at the Manawatu at Hopelands site.
[142] DB Breweries DRP load (downstream of the monitoring site) was considered high in Roygard and McArthur (2008) but has since been significantly reduced

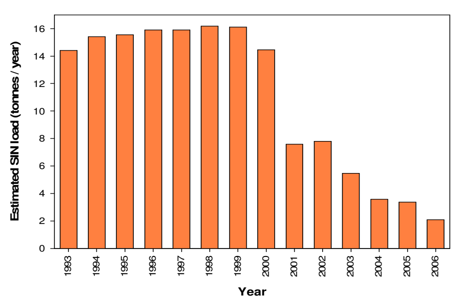
site from Dannevirke sewage totalled 2.1% for SIN and 20% for DRP. For the Mangatainoka the combined input from Eketahuna and Pahiatua was calculated to be 0.6% of the SIN load and 15.5% for DRP.

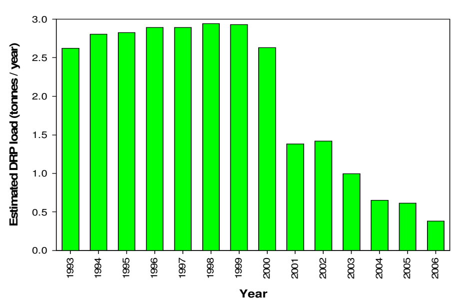
Box 41: Estimation of point source inputs from farm dairy effluent discharges to water

The water quality framework report (Roygard and McArthur, 2008) estimated the inputs from consented dairy-shed effluent to water for the study catchments, and compared these to the Measured loads for these catchments. The methods used consent information for numbers of consents and maximum daily volumes. This information was multiplied by typical dairy-shed effluent concentrations. The method is considered to likely overestimate contributions due to the use of maximum daily volumes, and the assumption that all consents were discharging. Some consent holders maintained dual consents while transitioning to discharges to land.

Example 1: Manawatu at Hopelands

- The number of dairy effluent discharge consents, and thereby volume and load estimates, peaked in 1998, totalling 16.2 tonnes SIN/year (t SIN/y) and 2.9 tonnes DRP/year (t DRP/y).
- By 2006, these estimates reduced to 2.1 t SIN/y and 0.4 t DRP/y, reflecting the decrease in dairy effluent discharges to water by this time.



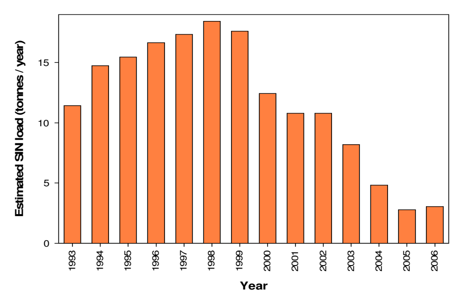


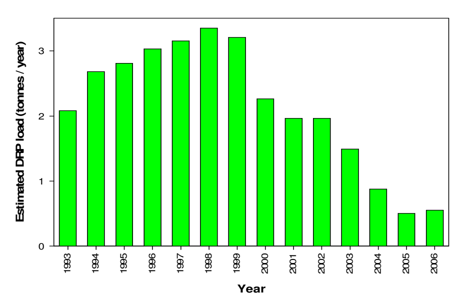
Compared to measured loads (1989-2005)

- As a proportion of the SIN load at Hopelands, the estimated dairy effluent load of 12.3 t SIN/y was 1.7% of the Measured SIN load (745 t SIN/y).
- As a proportion of the DRP load at Hopelands, the estimated dairy effluent load of 2.2 t DRP/y was 10% of the Measured DRP load (21 t DRP/y).

Example 2: Mangatainoka at SH2

- The number of dairy effluent discharge consents, and thereby volume and load estimates, peaked in 1998, totalling 18.4 tonnes SIN/year and 3.4 t DRP/y
- By 2005, these estimates reduced to 2.8 t SIN/year and 0.5 t DRP/y, reflecting the decrease in dairy effluent discharges to water by this time.





Compared to measured loads (1993-2005)

- As a proportion of the SIN load at the Mangatainoka site, the estimated dairy effluent load of 12.4 t SIN/y was 2.1% of the Measured SIN load (603 t SIN/y).
- As a proportion of the DRP load at the site, the estimated dairy effluent load of 2.3 t DRP/y was 25% of the Measured DRP load (9.3 t DRP/y).

Box 42 - Characterisation of effluent inputs from consented discharges

The methodologies for assessing the contributions from point source discharges included using:

i. The flow stratified method, calculating loading based on flow data and measurements of nutrient concentrations upstream and downstream of the discharges. This was completed for Dannevirke sewage.

ii. Daily discharge volumes and average effluent concentrations data (Dannevirke sewage alternate method).

iii. Average discharge volumes and average effluent concentrations data (Eketahuna sewage and Pahiatua sewage).

Example 1: Dannevirke sewage	**Example 2: Eketahuna & Pahiatua Sewage**
▪ Using the flow-stratified method, the annual average PS nutrient load from Dannevirke sewage treatment plant (STP) was estimated to be 17.1 tonnes SIN/year and 2.6 tonnes DRP/year at all flows. ▪ When compared to the average Measured load, Dannevirke STP contributed 2.3% of the Measured SIN load and 12.4% of the Measured DRP load. ▪ For flows less than the 10th percentile, Dannevirke STP contributions were 15.1 tonnes SIN/year and 2.3 tonnes DRP/year, making up 3.2% and 17.7% of the Measured SIN and DRP loads at Manawatu at Hopelands respectively.	▪ Effluent concentrations and average discharge volumes were used to estimate loads. ▪ 72 effluent concentration observations from compliance monitoring of Eketahuna STP. and 60 observations from monitoring of Pahiatua STP, collected between August 1989 and June 2008, were used with the estimated average discharge volumes to calculate SIN and DRP loads for Eketahuna and Pahiatua STP discharges.
▪ Effluent concentrations and daily discharge volumes were also used to estimate loads. ▪ 55 SIN and 61 DRP effluent concentration observations from December 1989 and June 2008, were used in a matrix with daily effluent volume data from between November 2004 and June 2007. ▪ Results showed Dannevirke STP annual average SIN load was 16 tonnes/year and the annual average DRP load was 4.2 tonnes/year. ▪ Compared to the average Measured load, Dannevirke STP contributed 2.1% of the SIN load and 20% of the DRP load at Hopelands.	▪ Results showed Eketahuna STP average SIN load was 0.42 tonnes/year and the annual average DRP load was 0.17 tonnes/year. ▪ Compared to the average Measured load, Eketahuna STP contributed 0.07% of the SIN load and 0.2% of the DRP load at the SH2 site. ▪ Results showed Pahiatua STP had an annual average SIN load of 3.39 tonnes SIN/year and 1.47 tonnes DRP/year. ▪ Compared to the average measured load Pahiatua STP contributed 0.6% of the SIN load and 15.8% of DRP load at the SH2.
▪ Using an estimation of soluble nutrient load from the Dannevirke STP, based on effluent discharge volume and nutrient concentration, produced an annual load slightly lower than the upstream minus downstream load calculation with respect to SIN, but a higher load with respect to DRP. This measurement is considered more accurate and is incorporated into estimates of Point source contributions	▪ If it is assumed all nutrient added to the river from the Eketahuna STP discharge travelled downstream approximately 35 km to the Mangatainoka at SH2 monitoring site, without any change to the total load along the way, the combined contribution of Eketahuna and Pahiatua STP discharges would account for 0.7% of the Measured SIN load and 16.0% of the DRP load.

6.15.2 Relative contributions of nutrient from non-point source inputs

235. Having calculated the relative contributions from the point sources, the non-point sources can be estimated by removing the point source estimates from the Measured loads. The results from this analysis are shown in Box 43. Overall, the results estimate that non-point source inputs contribute over 97% of SIN and approximately 80-85% of the DRP to the loadings at the study sites Manawatu at Hopelands and Mangatainoka at State Highway 2.

Box 43: Relative inputs from points source and non-point source inputs

Non-point source (NPS) loads to the catchment for the study catchments were estimated by subtracting the annual point source (PS) load from the Measured load.

Example 1: Manawatu at Hopelands	Example 2: Mangatainoka at SH2
▪ Removal of the PS load from the Measured load provides a NPS estimate of 729 tonnes SIN/year and 16.8 tonnes DRP/year (Figure A). ▪ This equates to a proportional NPS contribution of 97.9% to the Measured SIN load and 80% of the Measured DRP load.	▪ Removal of the PS load from the Measured load provides a NPS estimate of 600 tonnes SIN/year and 7.83 tonnes DRP/year (Figure B). ▪ This equates to a proportional NPS contribution of 99.4% to the Measured SIN load and 84.2% of the Measured DRP load.

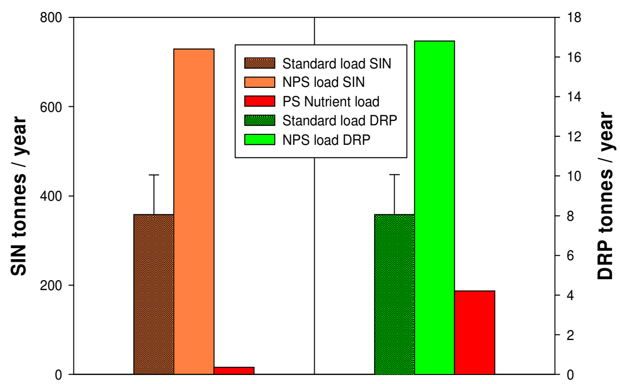


Figure A: Manawatu at Hopelands

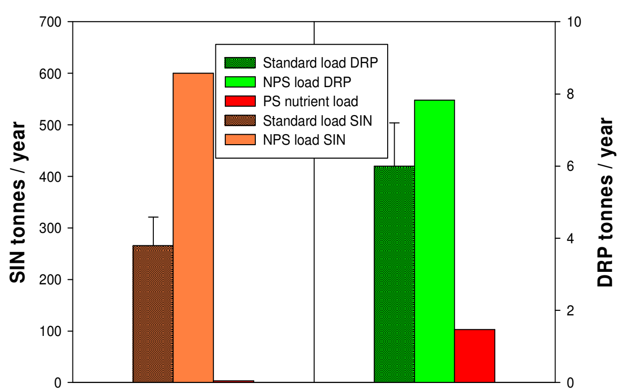


Figure B: Mangatainoka at SH2

6.15.3 The relative point source and non-point source nutrient contributions at various flows

236. The relative contributions from point source discharges and non-point source discharges are likely to vary with flow, given the mechanisms for nutrient input to rivers at various flows. A primary reason for adopting the flow-stratified approach to calculating loads was to enable calculation of the relative inputs from point sources and non-point sources at various flows[143].

237. To apply this method requires data from either daily discharges and related concentrations, or concentration and flow information upstream and downstream of the discharge over a range of flows. This type of data was not readily available for many major discharges at the time the water quality framework report was developed. The flow-stratified methodology was able to be applied to the Dannevirke sewage treatment plant discharge of treated sewage to water. The changes in the relative contribution of this point source to the overall load at different flows are estimated in Box 44.

238. In summary, a large change in the relative proportion of inputs can be observed, with point sources increasing in the proportional contribution at low flows (Box 44). For SIN, this example shows Dannevirke's contribution:

i. Averages 2.6% over all flows.
ii. Increases to 5.6% if only the flows less than median flow are considered.
iii. Increases to 10.6% for the lowest flow category that includes only the flows that occur less than 10% of the time.

239. These result shows a greater change for DRP where Dannevirke's contribution:

1. Averages 12.6% over all flows
2. Increases to 37.9% if only the flows less than median flow are considered.
3. Increases further to 66.7% for the lowest flow category that includes only the flows that occur less than 10% of the time.

[143] CLARIFICATION ON MY ROLE: I determined the methodology for the calculations of the dairy-shed effluent inputs and using the flow stratified methodology to determine relative contributions from point and non-point sources.

Box 44 – Relative contribution of point source and non-point sources at a range of flows

As outlined in previous sections, the flow-stratified method to calculate loadings of nutrients at various flows was applied to the discharge of treated sewage from Dannevirke sewage treatment plant to the catchment upstream of Manawatu at Hopelands. Using the numbers from this analysis, the relative contributions of point source (PS) and non-point source (NPS) loads can be determined at different flows. The results from this analysis (Table A) are calculated assuming no attenuation of the point source inputs from the discharge point to the monitoring site, so may overestimate. However, the numbers do show the relative size of the inputs from the discharge to the overall loadings recorded at the measuring sites over a range of flows (Figure A and Figure B). The relative contribution for the point sources to overall Measured loads increases considerably at low flows

For SIN - Assessed over all flows, the inputs are 2.3% of Measured loads; this increases to 5.6% for flows below median and 10.6% for the lowest flow decile, ie. for the lowest flows that occur only 10% of the time.

For DRP - Assessed over all flows the inputs are 12.6% of Measured loads; this increases to 37.9% for flows below median and 66.7% for the lowest flow decile.

Table A Relative contributions of NPS and PS to Measured loads at Hopelands at a range of flows.

		Flows that occur less than				
	All Flows	50% of the time	40% of the time	30% of the time	20% of the time	10% of the time
SIN						
Point source	17.1	6.3	4.4	2.2	1.8	0.5
Non-point source	727.6	105.6	61.6	33.8	15.3	4.2
Measured load	744.7	111.9	66	36	17.1	4.7
Point source contribution to total load	2.3%	5.6%	6.7%	6.1%	10.5%	10.6%
Non-point source contribution to total load	97.7%	94.4%	93.3%	93.9%	89.5%	89.4%
DRP						
Point source (tonnes/year)	2.6	1.1	0.9	0.6	0.4	0.2
Non-point source (tonnes/year)	18	1.8	1	0.5	0.2	0.1
Measured load (tonnes/year)	20.6	2.9	1.9	1.1	0.6	0.3
Point source contribution to total load	12.6%	37.9%	47.4%	54.5%	66.7%	66.7%
Non-point source contribution to total load	87.4%	62.1%	52.6%	45.5%	33.3%	33.3%

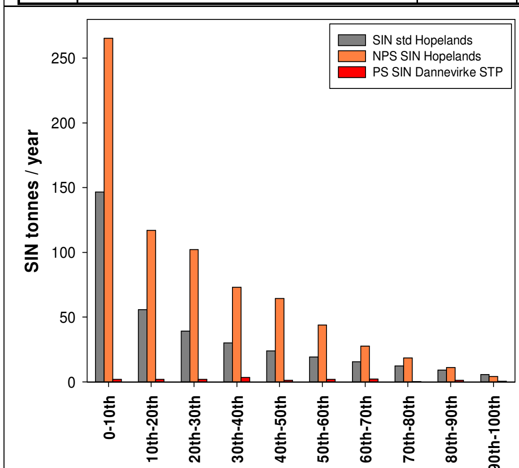


Figure A. NPS & PS contributions of SIN at various flows

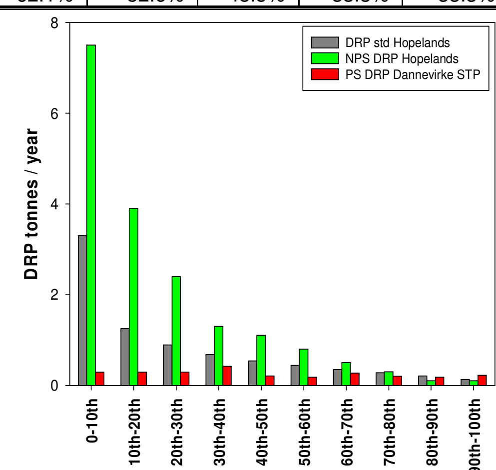


Figure B. NPS & PS contributions of DRP at various flows

240. The results of the analysis show that for DRP the relative contributions of Dannevirke sewage is about a tenth overall, but increases to about two-thirds at low flows. This highlights the importance of assessing contributions to water quality at different flows. This is particularly important when considering meeting the standard at low flows. Figure A and Figure B in Box 43 above show the relative non-point source and point source contributions to water quality in each of the flow decile categories in comparison to the standards. Figure B shows that removing Dannevirke sewage from the river below the 80th percentile flow (ie. at the lowest 20% of flows) would enable the river to meet the standard for phosphorus at these flows. The nitrogen standard is close to being met at flows below the 80th percentile flow, and removing Dannevirke sewage would improve the frequency of these N standards being met at low flows. These graphs represent overall summaries of the data at these lowest 20th percentile flows (ie. below the 80% percentile flow). The nutrient limitation graphs (Figure A of Box 36) at Manawatu at Hopelands site shows the scatter in the data at these flows. It is likely that for this scenario, the removal of Dannevirke sewage at low flows below the 80th percentile flow, would greatly increase the percentage of time when both the SIN and DRP standards would be met at low flow. However reduction of nutrients at flows above the 80th percentile flow will still be required to reduce the effects (ie. due to preceding nutrient conditions (Wilcock *et al.*, 2007)).

241. The data presented reflects a time period during which an upgrade of the Dannevirke plant has occurred and removal of some of the point source discharges to water from farm dairy effluent has also occurred (these are incorporated into the non-point source loadings in the example above). The example does show the importance of consideration of discharges at various flows in relation to the outcomes sought at those flows.

6.16 Options for discharges to surface water and land

Relates to key policies in the Proposed One Plan:

- **Policy 6-2: Water quality standards**
- **Policy 6-8: Point source discharges to water**
- **Policy 6-9: Point source discharges to land**
- **Policy 6-10: Options for discharges to surface water and land**

6.16.1 Concepts and linkages

242. As shown in the previous section, the relative contribution of point sources to overall water quality can change with flows. In the POP, Policy 6-10 identifies the opportunity to use a mix of options for a discharge, eg. withholding discharges of contaminants at some flows or applying different treatment options for discharges to different receiving environments or at different times. This policy provides for dual discharges, where at some times the discharge is to water and at others the discharge is withheld or discharged to land. The methodologies for optimising such practices in relation to the water quality outcome have been demonstrated in the water quality in sections above. Land treatment of effluent, can be a complementary approach to a discharge to water, especially when combined with some storage.

243. In terms of environmental outcome, the concept of land treatment, where the soil and crop system renovates or treats the effluent or sludge, is preferred to the approach of land disposal. Land disposal is more of a process where the effluent and sludge is applied to the land and very little treatment occurs. Land disposal systems, where the amount of water applied causes leaching or run-off and/or the nutrients applied are in excess of the amounts that a crop can uptake, can have considerable losses to the environment. Land disposal systems can cause direct run-off of nutrient through preferential flow (eg. direct flow through the large soil pores) and run-off. Care needs to be taken when assessing land treatment systems, and research into these, to ensure that land treatment and not land disposal was the initial goal. For example, trials have been known to apply approximately twice the amount of water required by the crop and report that little treatment occurred. Matching the water balance and nutrient balance in land treatment systems is a well understood science. There are some basic principles that need to be adhered to and many publications that are available to assist. An example is the New Zealand Guidelines for Utilisation of Sewage Effluent on Land (Tomer *et al.* 2000[144]).

244. Land treatment is a viable option for the treatment of effluent in Horizons' Region, particularly when the land treatment system is paired with a consent for discharge to water. These systems should primarily be complementary, ie. when the river is low, the conditions will likely be favourable for land treatment, whereas when the river is high, it is more likely to be able to accept the discharge to water at times when the land

[144] REFERENCE TO TECHNICAL REPORT: Tomer, M., A. Bruere, M. Rosen, J. Roygard, L. Schipper, and B. Clothier (2000). System management and monitoring. pp 121-150 In: (H. Wang, M. Tomer, and L. Whitehouse, ed.) New Zealand guidelines for utilisation of sewage effluent on land. Part 2: Issues for design and management. Joint publication of NZ Land Treatment Collective and New Zealand Forest Research Institute Ltd., Rotorua.

treatment system is unable to accept further effluent. There will be times where these two options do not line up and storage of effluent will be required. In such cases, the decision-making process as to irrigate to land, discharge to water or to store effluent on a given day can be designed and managed to achieve desired environmental outcomes. Further, during drier periods, the effluent generation from townships can be lower as is captured by statistics such as the dry weather flow through treatment systems.

245. Brent Clothier[145] provides some further references in relation to work on land treatment systems and the use of dual discharges.

6.17 Recommendations in relation to the flows at which standards should apply

Relates to key policies in the Proposed One Plan:

- **Policy 6-2: Water quality standards**

6.17.1 Introduction

246. In the Manawatu Catchment Water Quality Regional Plan (1998), the nutrient standard for DRP applied only at flows below half median flow. Wilcock *et al.* (2007) recommended that the standards for N and P should apply year round, below flood flows. The recommendation of the water quality standards report by Ausseil & Clark (2007c) for the POP was to have the nutrient standards apply at all flows, with the exception of flows above three times median flow. Flows that are three times the median flow are linked to the high likelihood of disturbance of periphyton by scouring/abrasion and movement of the river bed. An indicator of the frequency of disturbance, based on the number of events per year where the flow is greater than the three times median flow, has been developed. This indicator is referred to as the mean days of accrual (MDA). Further detail on this statistic is provided in flow statistics report (Henderson & Diettrich, 2007[146]) and in the evidence of Dr Barry Biggs[147].

6.17.2 Technical Amendments

247. The water quality framework report (Roygard and McArthur, 2008) discusses the use of a flow percentile as a surrogate flow disturbance measure above which nutrient

[145] LINK TO FURTHER EVIDENCE: The evidence of Brent Clothier provides further evidence and references in relation to land treatment and the use of dual discharges.
[146] REFERENCE TO TECHNICAL REPORT: Henderson R. & Diettrich J. (2007). Statistical analysis of river flow data in the Horizons Region. Prepared for Horizons Regional Council. NIWA client report CHC2006-154.
[147] LINK TO FURTHER EVIDENCE: The evidence of Dr Barry Biggs provides further information on the three times median flow indicator of the frequency of periphyton disturbance, and the concept of mean days of accrual.

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 to provide the flow threshold where standards apply. Flow percentiles provide an estimate of the frequency of the nutrient standards applying. Flow percentiles also provide a mechanism, with the calculation methods used in the water quality framework report, for determining the split between point and non-point source sources of nutrient.

6.17.3 Which flow percentile is recommended?

248. The water quality framework report compared what flow decile range (every 10th percentile range is considered a decile bin or decile category) the three times median flow lies within for 63 flow sites in rivers throughout the Region (Roygard and McArthur, 2008; Appendix 3). The three times median flows occurred within the 0-10th flow decile category at 30% of flow sites regionally, and within the 10th-20th decile category at 49% of the sites (Table 11).

249. The recommendation is to use a single threshold of the 20th percentile for all sites. Barry Biggs[148] and Kate McArthur[149] present further evidence in relation to the selection of this threshold.

Table 11. Proportion of flow sites at which the three times median flow lies within various flow percentile categories out of 63 flow recorder sites in Horizons' Region (statistics sourced from Henderson & Diettrich, 2007)

Flow percentile range	Percentage of sites with 3 time median flow within the flow percentile range
0 – 10th	30%
10th – 20th	49%
20th – 25th	11%
25th – 30th	3%
30th – 40th	5%
40th – 50th	2%

148 LINK TO FURTHER EVIDENCE: The evidence of Dr Barry Biggs provides further information on the recommendation of the use of the 20th percentile flow as a threshold below which the standards apply.

149 LINK TO FURTHER EVIDENCE: The evidence of Kate McArthur provides further information on the recommendation f the use of the 20th percentile flow as a threshold below which the standards apply.

6.18 Update of the monitoring network to enable relative non-point source and point source inputs

Relates to key policies in the Proposed One Plan:

- **Policy 6-2: Water quality standards**
- **Policy 6-3: Ongoing compliance where water quality standards are met**
- **Policy 6-4: Enhancement where water quality standards are not met**
- **Policy 6-5: Management of activities in areas where existing water quality is unknown**
- **Policy 6.7: Land use activities affecting surface water quality**
- **Policy 6-8: Point source discharges to water**
- **Policy 13-2: Monitoring requirements for discharges**

6.18.1 Concepts and linkages

250. The proposed policies of the POP require water quality information to determine where water quality standards are met (Policy 6-4), not met (Policy 6-4), or unknown (Policy 6-5). Further water quality information in relation to specific discharges and diffuse sources is also required to monitor the relative impacts. This information will likely be useful in assessments in relation to Policy 6-10 (Options for discharges to surface water and land) and is also useful for measuring State of the Environment and policy effectiveness monitoring (ie. the anticipated environmental results).

6.18.2 The SoE and discharge monitoring programme

251. Horizons State of the Environment (SoE) monitoring programme[150] is the primary water quality monitoring programme in the Region. NIWA monitors a further seven sites and various consent applicants and consent holders also collect water quality information. One of the issues with these different data sources is that they are often collected on different days or using different methods. To enable calculation of relative contributions for various point sources and non-point sources to water quality at the SoE monitoring sites, Horizons has upgraded its SoE monitoring programme to a combined SoE and discharge monitoring programme.

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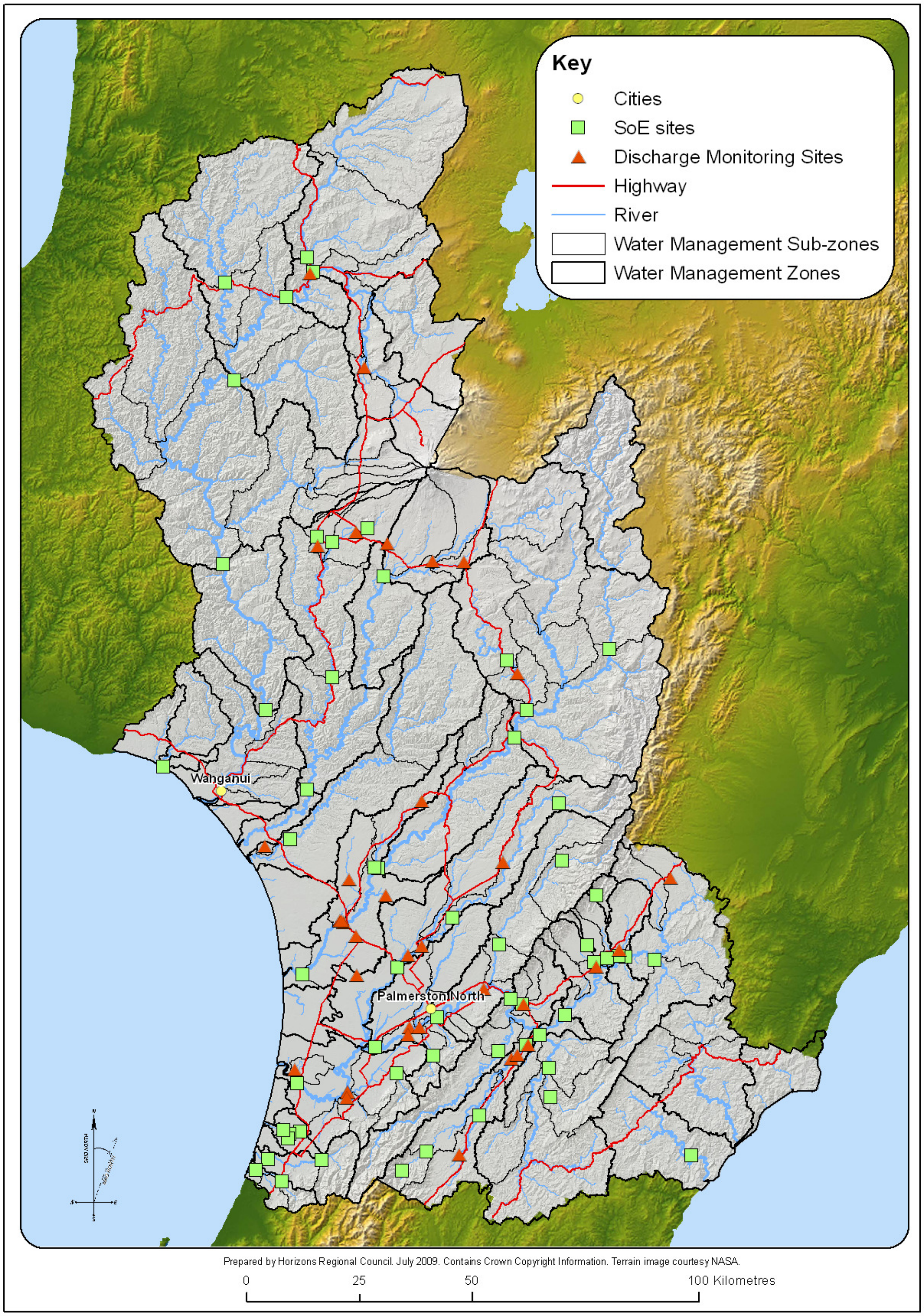
[150] CLARIFICATION ON MY ROLE: I lead and manage this programme and have initiated the upgrades of this programme. The establishment, design and implementation of this programme have been completed by a project team that included Kate McArthur and Maree Clark.

252. The combined SoE and discharge monitoring programme provides significant improvements over previous monitoring regimes. Previous monitoring did not typically measure the impact of the discharges on the same days as SoE monitoring, and generally discharges were monitored in the order of two or three times per year as a part of compliance monitoring. Some SoE sites had previously been located to capture the impact of various major discharges. The upgraded monitoring programme provides a snapshot of water quality and the point source contribution to it, once per month. This provides 12 assessments per year, across a range of flow and seasonal conditions.

253. The upgrading of the SoE monitoring programme to include discharge monitoring was initiated in the Manawatu, Owahanga, and Whangaehu catchments in 2007. The SoE programme for the Rangitikei catchment was implemented in July 2008. The Whanganui Catchment SoE programme was implemented in July 2009. The monitoring is carried out on a monthly basis with the sampling runs in each catchment starting at the headwaters and working toward the sea. Further information on the water quality monitoring programme, what it measures and where can be found in the evidence of Kate McArthur[151]. Monitoring at discharge points typically involves sampling of the effluent, water quality and flow upstream of the discharge, and water quality sampling downstream of the discharge, after reasonable mixing. The selection of the discharges to monitor has been restricted to the major discharges. The selection of SoE sites has focused on areas of pressure. Not all Water Management Zones or Sub-zones are monitored. Horizons combined monitoring programme monitors 60 SoE sites and 36 discharges to water (Map 7).

[151] LINK TO FURTHER EVIDENCE: Kate McArthur provides further evidence in relation to the SoE and Discharge Monitoring programme within Horizons' Region.



Map 7. Locations of the SoE and discharge monitoring sites throughout the Region

6.18.3 Monitoring requirements for consent holders

254. Policy 13-2 (Monitoring requirements for consent holders) proposes that holders of consents for discharges to water generally be required to monitor discharge volumes for consents greater than 100 m^3/day and report these to Horizons. These requirements are also addressed in Section 4.9.5 of this report[152]. Information of accurate daily discharge volume combined with water quality parameter data, eg. nutrient concentration, will enable characterisation of the inputs from the discharge. Combining this with upstream flow and water quality information, and downstream water quality information, will enable characterisation of the relative inputs of the discharge to the receiving water body and the overall water quality in the river. This type of information, collected in a coordinated, consistent manner with all information going to a single database, will provide for improved knowledge to inform decision-making.

255. Policy 13-2 also proposes requirements that shall generally apply in Policy 13-2 (d). Monitoring and reporting on the quality of discharge at the point of discharge and upstream and downstream (after reasonable mixing) may also be required. This will align with Horizons' environmental monitoring programme where practicable, to enable cumulative impacts to be measured.

256. In practice, this policy has the potential to streamline water quality monitoring in the Region, saving costs and producing a better data set to inform decision making. This could also provide further consistency in monitoring requirements for consented discharges to water. At present these requirements are variable. Another benefit of the aligned monitoring programme for discharges to water is the ability to automatically process the data collected to provide information in a timely manner, as outlined in the following section.

6.18.4 Recommendation to the Hearing Panel

257. **I recommend that the Hearing Panel adopt the changes to Policy 15-4 and Policy 13-2 as recommended in the planning report of Clare Barton.**

[152] REFER TO: Section 4.9.5 of this report provides further information in relation to discharge volume monitoring and Policy 13-2.

6.19 The WaterQualityMatters Website

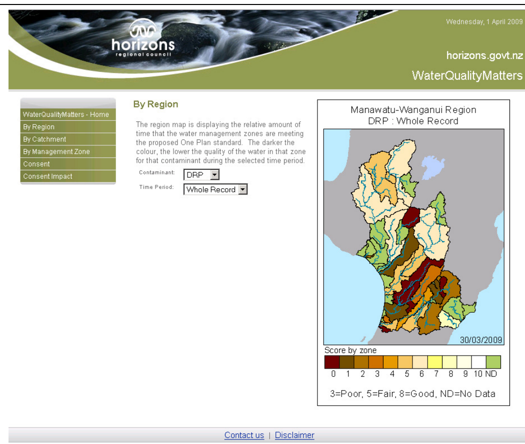
258. Horizons' WaterQualityMatters project is one of several interlinked projects to further improve the knowledge of water quality in the Region and to communicate this understanding to consent holders, the public and within Horizons.

259. The WaterQualityMatters software and the website are the mechanism by which Horizons initially analyses the data from the SoE and discharge monitoring programme, as it is collected. Prior to implementation of WaterQualityMatters, data was generally analysed when prompted by reason to look at the data eg. a science report, compliance check, or consent application. This was due to the considerable analysis that had to be completed in order to understand what the data was showing. With WaterQualityMatters, this analysis is automated and run daily to display the results for all to see. This provides up-to-date (daily) information, to inform decision-making around the management of the resource. The monitoring programme provides a level of understanding that was not previously available. Box 45 provides an overview of some of the information presented as a part of the WaterQualityMatters website. This SoE-type reporting component of the website is currently being tested and further developed. This test version of the website is functional (in a draft form) and available on Horizons' website at http://www.horizons.govt.nz/default.aspx?pageid=376.

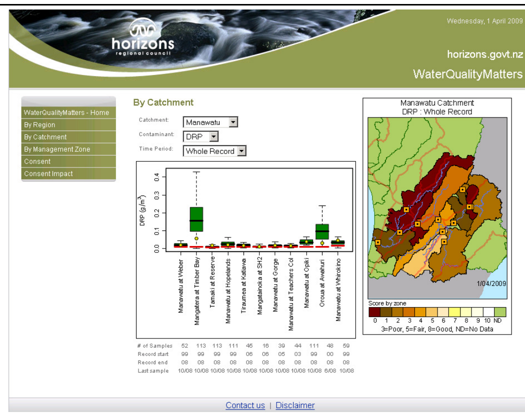
260. A further component of this software is the automated checking of compliance against consent conditions. This module of the programme, which is currently being developed, will summarise the compliance information onto the website and automatically report to Horizons' compliance team via emails. Through the development of the automated compliance checking module of this software, individual consent conditions for discharges to water have been entered into a database format to enable automatic testing. This process has shown the specificity of the individual consent conditions and the variability of requirements for various consents of a similar type. This tool has the ability to test for each specific condition in relation to water quality monitoring of the consent, as to whether the consent complies or not. When completed, the software will automatically notify the compliance team of any potential breaches of consent conditions that are detected through the discharge monitoring programme. A further component following this will provide notification of critical dates, eg. when reports required by consent conditions are due to be completed and provided to Horizons.

Box 45: Technical project summary - the WaterQualityMatters Website

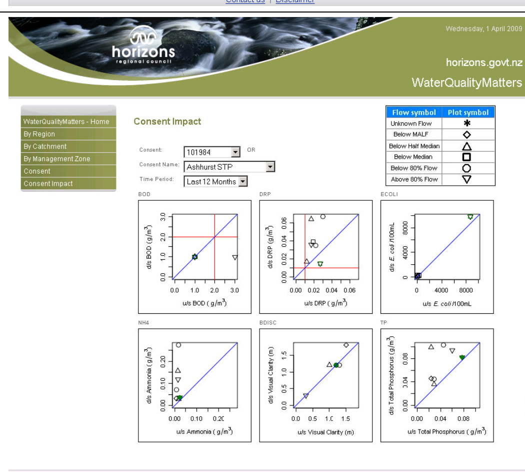
The WaterQualityMatters software has a range of functions in terms of SoE and policy effectiveness reporting at the regional, catchment, and Water Management Zone level. Reporting also contains specific information for consents for individual, major discharges to water, such as comparison of upstream and downstream monitoring results, as well showing these monitoring results in relation to the downstream state of environment monitoring site.



A screenshot of the test version of the website showing the "By Region" page. This page displays SoE indicator results for the percentage of time the water quality is less than the POP standard.



A screenshot of the test version of the website showing the "By Catchment" page, which maps the SoE indicator results for the percentage of time the water quality is less than the POP standard. This screen also shows the relative concentrations at the SoE monitoring sites throughout the catchment.



A screenshot of the test version of the website showing the "Consent Impact" page, which graphs the relative concentrations upstream and downstream of a single point source discharge, to demonstrate the impact of the discharge on various water quality parameters. The graphs provide a useful summary of the relative contribution of the discharge to water quality outcomes in relation to the POP standard. The plots also provide information on the relative impacts at various flows.

6.20 Point source discharges to land

Relates to key policies in the Proposed One Plan:

- **Policy 6.7: Land use activities affecting surface water quality**
- **Policy 6-9: Point source discharges to land**
- **Policy 6-10: Options for discharges to surface water and land**

6.20.1 Introduction

261. Point source discharges to land are many and varied in the Region. The following sections provide an overview of some technical work in relation to point source discharges to land. The Manawatu Water Quality Catchment Regional Plan (1998) and the Land and Water Regional Plan (2003) each included provisions on the transition from discharges to water to discharges to land. Horizons' SoE Report (Horizons, 2005a) shows that the total number of discharges of livestock operation effluent (including dairy, poultry and piggery effluent) remained fairly steady over the period 1997-2004, at approximately 1,200 consents. The proportion of discharges to water from livestock operations decreased from 35% to 10% over this same period. This section presents information on discharges to land in relation to management of on-site wastewater and farm dairy effluent. Logan Bowler[153] provides evidence in relation to the poultry industry discharges to land.

6.21 On-site wastewater systems

Relates to key policies in the Proposed One Plan:

- **Policy 6-9: Point source discharges to land**
- **Policy 13-3: Management of discharges to domestic wastewater**
- **Rule 13-10: Existing discharges of domestic wastewater**
- **Rule 13-11: New and upgraded discharges of domestic wastewater**
- **Rule 13-12: Discharges of domestic wastewater not complying with Rule 13-10 and Rule 13-11**

6.21.1 Introduction

262. On-site wastewater systems are spread throughout the Region. The numbers of consents for this activity represent the fraction of these systems that have applied for

[153] LINK TO FURTHER EVIDENCE: Logan Bowler provides evidence in relation to the poultry industry discharges to land.

consent. Primarily, consent application will be due to the exceedance of the volume thresholds of current Plans, however, some will be required due to transitional rules.

6.21.2 Technical work in relation to the POP

263. Harold Barnett[154] provides an overview of the on-site wastewater management in the Region and some comment on the proposed National Environmental Standard (NES) for On-Site Wastewater Systems (2008).

264. The primary technical work in relation to on-site wastewater management is the Manual for On-site Wastewater Management[155] (Barnett & Ormiston, 2007). The evidence of Mr Barnett provides detail on the development of the manual prior to notification, and details the further work on the manual since notification of the POP. This work included some review of the document and workshops held with stakeholders. As a result, some amendments to the original manual are recommended, and these recommendations have been incorporated into a new version of the manual (Barnett & Ormiston, 2009[156]). Mr Ormiston[157] provides further evidence in relation to the development of the Manual for On-site Wastewater Management and the technical amendments.

265. A further technical project has been the modelling of the effects on on-site wastewater systems in a subdivision with varying levels of treatment and section sizes (Green, 2008[158]). Dr Clothier[159] provides further information on the modelling by Green (2008)[160] to determine how levels of treatment from on-site wastewater systems and section sizes impacted on nutrient and bacterial losses from a subdivision in the Horowhenua area.

6.22 Farm dairy effluent discharges to land

Relates to key policies in the Proposed One Plan:

- **Policy 6-9: Point source discharges to land**

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[154] LINK TO FURTHER EVIDENCE: Harold Barnett provides evidence in relation on-site wastewater systems, including management of these in the Region, the development of the on-site wastewater system and comments on the proposed National Environmental Standard for wastewater (2008).

[155] REFERENCE TO TECHNICAL REPORT: Barnett & Ormiston (2007). Manual for On-Site Wastewater Systems Design and Management. Technical Report to Support Policy Development. Horizons report 2007/Ext/778

[156] REFERENCE TO TECHNICAL REPORT: Barnett & Ormiston (2009). Manual for On-Site Wastewater Systems Design and Management. Technical Report to Support Policy Development.

[157] LINK TO FURTHER EVIDENCE: Sandy Ormiston provides evidence in relation to the development of the Manual for Management of On-site Wastewater Systems, including management of these in the Region and the development of the on-site wastewater systems.

[158] REFERENCE TO TECHNICAL REPORT: Green (2008). Modelling the fate of nutrient and pathogens from on-site wastewater systems in the Tararua/Gladstone Road area of Horowhenua district using SPASMO. HortResearch client report 25285, prepared for Horizons Regional Council.

[159] LINK TO FURTHER EVIDENCE: Brent Clothier provides evidence in relation to the report of Green (2008).

[160] CLARIFICATION ON MY ROLE: I contracted this project and was involved throughout the project. This project was managed for Horizons by Harold Barnett.

- **Policy 6-7: Land use activities affecting surface water quality**
- **Rule 13-1: Dairy farming , cropping, market gardening and intensive sheep and beef farming and associated activities**
- **Rule 13-6: Farm animal effluent including dairy sheds, poultry farms and existing piggeries**

6.22.1 Concepts and linkages

266. Farm dairy effluent (FDE) is a term that can be used interchangeably with a range of terms, eg. dairy-shed effluent. There has been a significant reduction in the number of FDE discharges to water. The transition from discharge of treated FDE to water, to land application of FDE, has largely been completed within the Region. Numbers from January 2009 show 15 consents for discharges of FDE were to water and 942 were to land. Box 40 (Section 0) shows an estimation of the reduction in the nutrient levels being added to catchment water quality in two catchments, as a result of this transition. For the two sites studied (the upper Manawatu catchment upstream of Hopelands and the Mangatainoka catchment), removal of FDE from the catchments may have removed in the order of 2% of nitrogen from the overall Catchment loadings. Removal of FDE from these waterways was calculated to have a higher impact on overall catchment loadings of DRP with 10% and 25% estimated to be removed from the upper Manawatu and Mangatainoka respectively. This estimation method likely overestimates the reductions in overall loadings as it used the consented maximum daily volume and assumed no attenuation in the stream. The estimates represent contributions at all flows, and it is likely that the percentages of SIN and DRP contributed by FDE as point source discharges to water were significant at low flows in these catchments (see Box 44).

267. Management of FDE is part of the proposed Rule 13-1, in catchments where this applies. Rule 13-1 is further described later in this report in Chapter 7[161]. Outside of these priority catchments, and in the periods leading up to proposed dates for Rule 13-1, discharges of FDE to land are likely to be processed outside of the Rule 13-1 provisions. Map 8 shows the location of the current consents for FDE discharges in relation to the target catchments of the proposed Rule 13-1. Kate McArthur[162] provides evidence on the number of FDE consents to land and water in each of the proposed target catchments of Rule 13-1.

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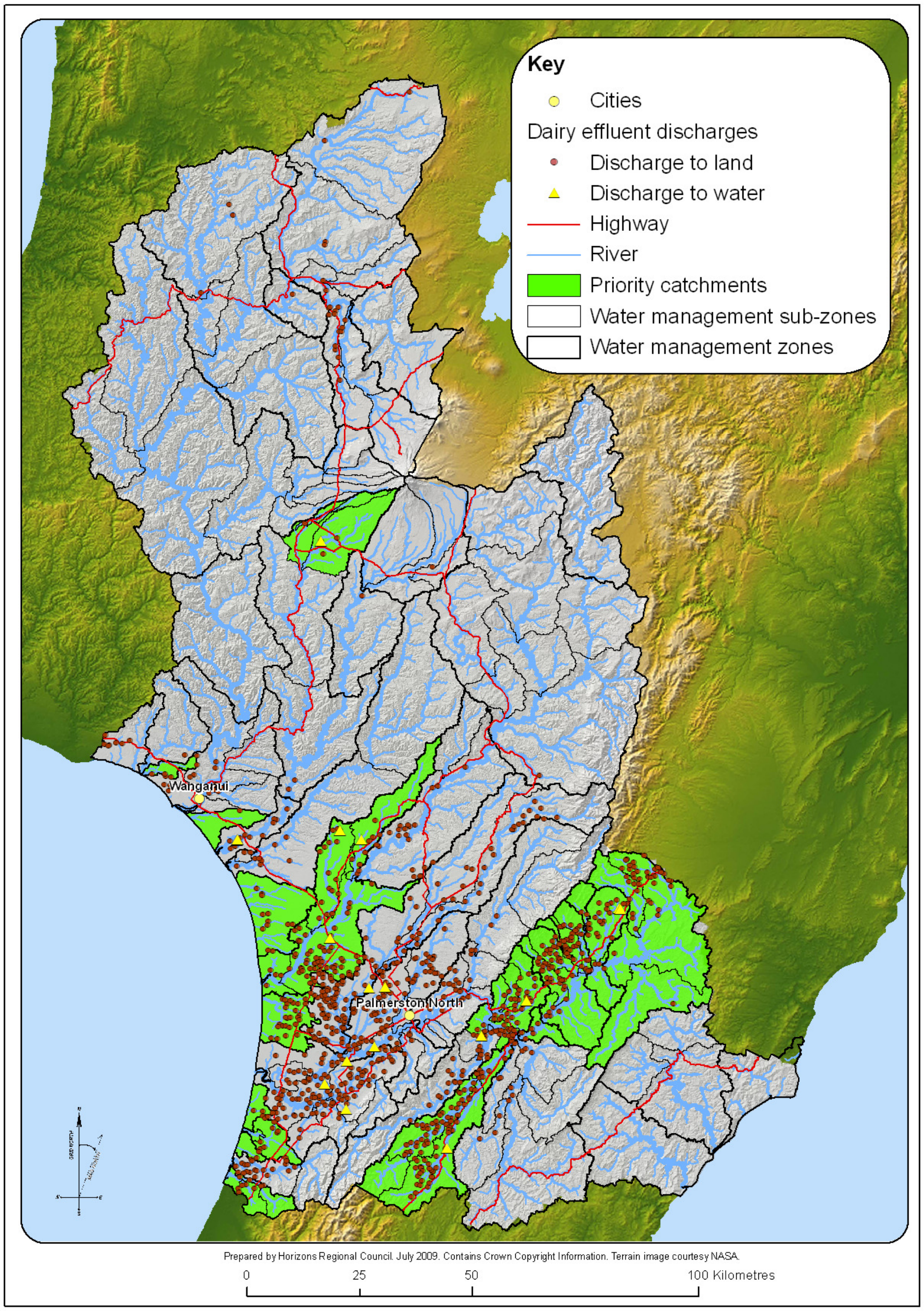
[161] REFER TO: Chapter 7 of this report provides further information on Rule 13-1.
[162] LINK TO FURTHER EVIDENCE: Kate McArthur provides evidence on the number of FDE consents to land and water in each of the proposed target catchments of Rule 13-1.

268. Alison Russell[163] provides evidence in relation the compliance aspects of FDE management.



Map 8. Location of consents for farm dairy effluent discharge to land and water in the Region, in relation to the priority catchments identified in the proposed Rule 13-1.

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[163] LINK TO FURTHER EVIDENCE: Alison Russell provides evidence in relation to compliance with consents for discharge to land for farm dairy effluent.

6.22.2 Technical work in relation to management of farm dairy effluent

269. Technical reports are available that provide information in relation to farm dairy effluent (FDE) management. Horizons sought a single point of reference for this work and initiated an Envirolink project with AgResearch to document best practices for the Region. The report (Houlbrooke, 2008[164]) set out[165] to provide guidance on how best to manage FDE. The aim was to compile the information, or provide quick reference to where information could be found. This report has been used to provide advice to those who have not been meeting consent requirements and to those requesting such advice. Producing this report was a move away from the more traditional approach of Horizons providing the limits to which the systems should be managed, eg. no ponding, but providing little or no advice on how to achieve this. The evidence of Dr David Houlbrooke[166] provides further information about this project and some updates in relation to the recommendations.

6.22.3 Deferred irrigation

270. The primary best management practice recommended by the report is that of deferred irrigation, ie. only applying effluent to land when the soil has capacity to store the added volume of effluent without leaching or run-off occurring. The concept of applying volumes of effluent (hydraulic loadings) that are less than, or equal to, available water storage is a best practice for land treatment of effluents. This concept is based on simple principles of irrigation and is not new to land treatment. For example, this practice was recommended in the National Guidelines (Tomer *et al.*, 2000[167]) for applying sewage effluent to land. The Tomer *et al*. (2000) document also provides a basic software tool[168] for calculating soil moisture deficits and soil water balances within a land treatment system for anywhere in New Zealand.

271. Within a land treatment system, management of the volumes of effluent applied in relation to the soil's ability to store the effluent can significantly reduce the loss of nutrient and bacteria when compared to systems that do not apply such practices. Applying more effluent volume than the ability of the soil to store water at that time can

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[164] REFERENCE TO TECHNICAL REPORT: Houlbrooke, D. (2008). Best Practice Management of Farm Dairy Effluent in the Manawatu Wanganui Region. Prepared for Horizons Regional Council.

[165] CLARIFICATION ON MY ROLE: I initiated, scoped and project-managed this report for Horizons. A small project team from Horizons was involved in the project, including Helen Marr and representatives from the compliance team.

[166] LINK TO FURTHER EVIDENCE: David Houlbrooke provides evidence in relation to best practice for FDE management.

[167] REFERENCE TO TECHNICAL REPORT: Tomer, M., A. Bruere, M. Rosen, J. Roygard, L. Schipper, and B. Clothier(2000). System management and monitoring. Pp 121-150 In: (H. Wang, M. Tomer, and L. Whitehouse, ed.) New Zealand Guidelines for Utilisation of Sewage Effluent on Land. Part 2: Issues for Design and Management. Joint publication of NZ Land Treatment Collective and New Zealand Forest Research Institute, Ltd. Rotorua.

[168] CLARIFICATION ON MY ROLE: Brent Clothier and I developed this tool.

lead to losses of the effluent via run-off and leaching without any further treatment. A further key consideration of any land treatment system is balancing the nutrient inputs to meet the need of the crop without causing excessive leaching or runoff. Managing the nutrient is linked strongly with managing the water balance in these systems.

6.22.4 Recommendations of the Houlbrooke report

272. The report provided, at the request of Horizons staff, decision trees (flow charts) to guide effluent requirements by the Council. The decision tree recommended storage requirements based on soil and land form features, the volume of annual rainfall, and the type of irrigator used to land apply the effluent. The decision support trees are shown in Box 46. The evidence of Dr David Houlbrooke[169] provides further information about this project and some updates in relation to the recommendations.

273. One recommendation of the report was the categorisation of rainfall for farms with sloping land, or land with artificial drainage or restricted (flat land) drainage. The rainfall bands selected were for annual rainfall of less than 1,100 mm, 1,100 mm to 1,500 mm, and greater than 1,500 mm. Horizons have completed an analysis of the dairy farms that fall into these categories using information on land use from Clark & Roygard (2008) [170], and rainfall isohyets information generated by Horizons. The analysis showed that:

i. 64% of dairy farms had annual rainfall of less than 1,100 mm.
ii. 12% had rainfall between 1,100 mm and1,500 mm of rainfall.
iii. 24% had rainfall > 1,500 mm.

274. The areas of higher rainfall will naturally have fewer opportunities to irrigate when soil moisture deficits are available, and therefore are recommended to have greater requirements for storage.

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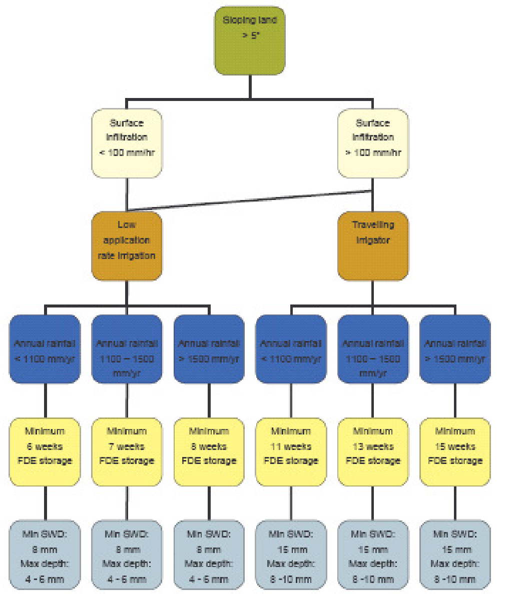
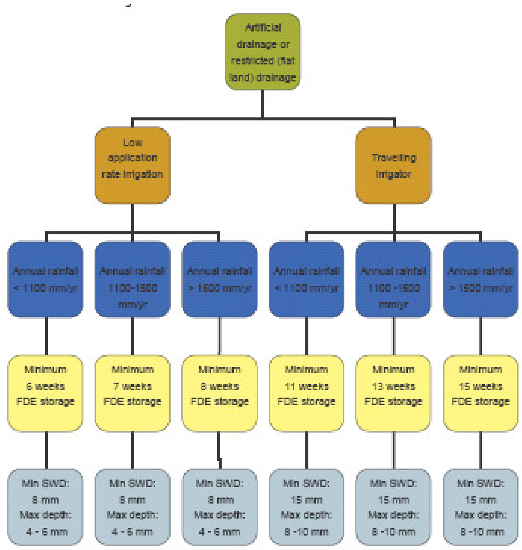
169 LINK TO FURTHER EVIDENCE: David Houlbrooke provides evidence in relation the Houlbrooke (2008) report.
170 REFERENCE TO TECHNICAL REPORT: Clark and Roygard 2008 Land Use and Land Use Capability in the Manawatu-Wanganui Region Internal Technical Report to Support Policy Development. Horizons Report number HRC/INT/616).

Box 46: Technical project summary - Best practice management for farm dairy effluent

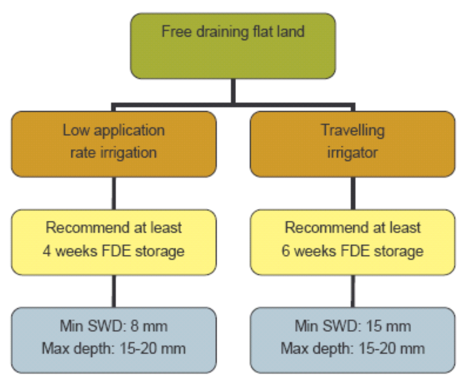


Decision tree B. Sloping land greater than 5°



Decision tree A. Land with artificial drainage or flat land with restricted drainage and/or low infiltration.

- The project recommended three flow charts for Horizons to use in guiding effluent storage requirements, based on soil and land form features and annual rainfall volume.
- The three flow charts were for sloping land (left), land with artificial drainage or restricted (flat land) drainage (below left), or free-draining flat land (below).
- Rainfall (blue boxes) was categorised into three categories <1,100 mm, 1,100-1,500 mm and >1,500 mm.
- For sloping land there was a separation based on surface water infiltration of <100 mm/hr or > 100 mm/hr.
- All three flow charts provided separate recommendations for low application rate and travelling irrigators (high application rate).
- Recommendations varied from four weeks storage on free-draining soil with a low application rate to 15 weeks storage for systems using a travelling irrigator in an area with more than 1,500 mm of rain annually on both artificially drained or restricted (flat land drainage) and sloping land with surface infiltration > 100 mm/hr.



6.22.5 Determining pond size requirements – the pond size calculator

275. The Houlbrooke report on best management practices clearly identified a need for information on pond size requirements. The flow charts recommended storage

requirements in terms of numbers of weeks of storage. To better enable the calculation of storage requirements specific to farms, Horizons staff[171] initiated the production of a pond size calculator based on specific farm variables, climate, and a daily time step model (Box 47). The pond size calculator (Horne *et al*., 2009)[172] enables calculation of specific pond requirements based on long-term daily climate data, physical infrastructure on the farm, and management information. The calculator can be used to see how the current pond size compares to requirements over the long-term data set, and to see how varying management options impact on the size of pond required. The calculator has been used in the Region to provide guidance for new ponds being constructed.

Box 47: Technical project summary - pond size calculator for FDE storage requirements

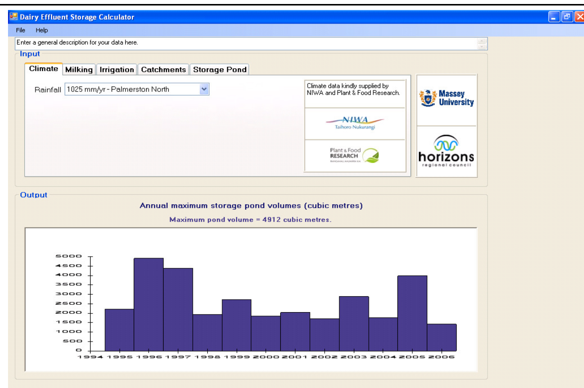


Figure A: example screenshot from the pond size calculator.

The pond size calculator calculates pond size requirements based on:

- Soil available water holding capacity
- Number of cows milked
- Yard area (m^2), shed area (m^2)
- Feed-pad area (m^2), pond area/cow
- Milking hours/day
- Trigger soil moisture deficit before application of FDE can commence
- Irrigation volume applied at trigger deficit,
- Irrigation depth at trigger deficit
- Washdown water/cow/day
- Area irrigated with FDE
- Start milking date, stop milking date
- Rainfall/climate data site
- Irrigation start date

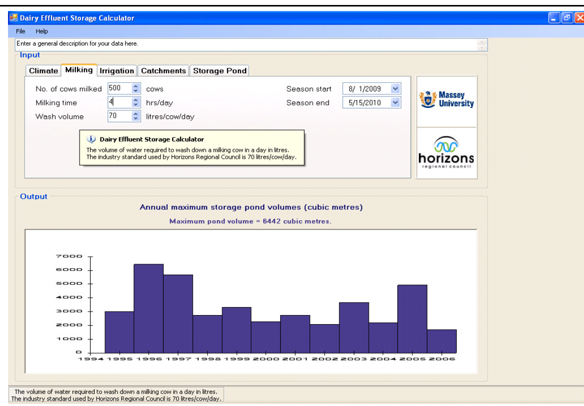


Figure B: Example screenshot from the pond size calculator.

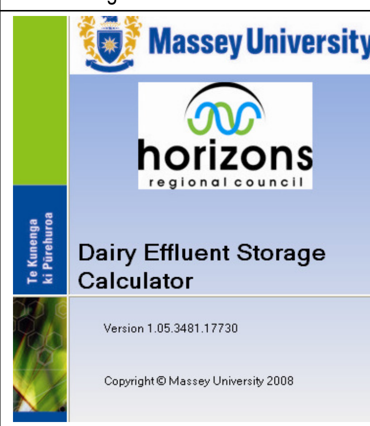


Figure C: Example screenshot from the pond size calculator.

171 CLARIFICATION ON MY ROLE: I conceptualised and initiated this project and project managed it for Horizons.

172 REFERENCE TO TECHNICAL REPORT: Horne, Hanley, Bretherton & Fryett (2009). The FDE Storage Calculator – Identifying the storage volume required to practise deferred irrigation of Farm Dairy Effluent. Massey University Report prepared for Horizons Regional Council.

6.23 Lining of effluent storage ponds

6.23.1 Rule 13-6: Farm animal effluent including dairy sheds, poultry farms and existing piggeries

276. To operate deferred irrigation management of FDE requires storage of the effluent. Historically, the traditional treatment for FDE was the two-pond system with discharge to water. The two ponds comprised the anaerobic pond (primary) pond and the aerobic (secondary) pond. Many of these pond systems (or variations on this theme) continue to be to be in place in the Region, with the land application of effluent occurring from one or more ponds. In some other cases, ponds have been removed and the effluent is applied from some form of sump with minimal storage prior to land application. In some historical cases, ponds have been removed at the request of the Horizons' compliance team because of concerns about losses of effluent through the base of the pond. The remaining ponds are located in a range of soil types, climates and groundwater tables. Sealing methods include artificial lining, clay mixed with concrete, clay lining, and no lining.

277. Proposed Rule 13.6 of the POP as notified included the statement: "*All effluent storage and treatment facilities including sumps and ponds shall be sealed so as to restrict seepage of effluent. The permeability of the sealing layer shall not exceed* $1x10^{-9}$ *m/s*". Dr David Houlbrooke[173] provides evidence in relation to the sealing requirements for FDE. His evidence presents an example farm and how the rate of losses of nitrogen and phosphorus change for the pond on the farm with differing levels of drainage from the base of the pond. A summary of this work is shown in Box 48.

278. The analysis shows that ponds with high drainage losses can have significant losses of nutrient from the base of the pond. For example, the scenario based on leakage rates of $1 x10^{-6}$ could leak as fast as the effluent was produced. Horizons compliance officers have anecdotally reported that some ponds located in areas of gravel have reportedly never required pumping of effluent due to losses from the base of ponds.

173 LINK TO FURTHER EVIDENCE: David Houlbrooke provides evidence in relation to pond sealing requirements.

Box 48: Technical project summary - Pond sealing requirements

Dr David Houlbrooke presents in his evidence a desktop assessment of a farm with a range of different pond leakage rates. The example is summarised below. It assumes:

1. Effluent is only in the pond for the lactation season (ie. 270 days).
2. Concentrations of N & P are 200 mg N/l and 30 mg P /l.
3. The pond area is 1,000 $m^{2.}$
4. The pond receives effluent from 500 cows at 13.5 m^3/cow/year, assuming 50 l/cow/day.
5. The example calculates per year values based on the 270 days the pond is assumed to have effluent. If the pond contained effluent for longer periods these numbers would increase.
6. In summary, the table shows a pond sealed to $1x10^{-9}$ leaches a total of 4.67 kg N/year (the equivalent of 46.7 kg N/ha/y) and 0.7 kg P/year (the equivalent of 7 kg P/ha/y).
7. A pond sealed to $3.8x10^{-8}$ leaches a total of 177.7 kg N/year (the equivalent of 1773 kg N/ha/y) and 26.6 kg P/year (the equivalent of 266 kg P/ha/y),
8. It is noted that $3.8x10^{-8}$ is the leakage rate recommended by Environment Southland as an achievable rate for clay-lined ponds.
9. Table 13.2 of Rule 13.1 of the POP includes N loss limit that range from 2-32 kg/ha/year

Table A. Estimated daily and yearly pond leaching losses of N and P under a range of different pond leakage rates. Conversion from daily losses to yearly losses is based on the pond only containing effluent during the 270-day lactation period.

Drainage rate		Drainage volume	N loss		P Loss	
m/s	mm/day	(L/day)	(kg/day)	(kg/ yr)	(kg/day)	(kg/ yr)
1.00E-09	0.0864	86.4	0.01728	4.67	0.0026	0.7
1.00E-08	0.864	864	0.1728	46.7	0.026	7
3.80E-08	3.28	3283	0.66	177.3	0.1	26.6
1.00E-07	8.64	8640	1.728	467	0.26	70
1.00E-06	86.4	86400	17.28	4666	2.6	700
		m^3/year		kg/ha/year		kg/ha/year
1.00E-09		23.328		46.7		7
1.00E-08		233.28		467		70
3.80E-08		886.41		1773		266
1.00E-07		2332.8		4670		700
1.00E-06		23328		46660		7000

279. Based on this analysis, Dr Houlbrooke concludes: "*Proposed One Plan Rule 13.6 currently states that all FDE ponds must be sealed to a permeability of less than 1x 10^{-9} m/s. Given the assessment above* [in his evidence]*, this relates to a leakage of less than 0.1 mm/day or approximately 23 mm over the duration of the milking season. However, a requirement for a near-zero leakage of FDE through a pond would likely exclude pond construction with a clay base liner and therefore such a limit would not be practically achieved. Environment Southland (2009) have suggested a higher leakage of 3.8 x 10^{-8} m/s in order to more practically allow clay-lined ponds*".

280. Further analysis (Box 49) has been undertaken to compare the loss rates from the two sealing requirement limits, ie. that of 1×10^{-9} in the POP and the 3.8×10^{-8} recommended to allow for clay-lined ponds. Table 12 compares the N & P loss rates from the two scenarios to typical whole farm loss values from Clothier *et al*. (2007). The results show that ponds can be a significant source of N and P loss from farms as shown below:

i. For the clay lining limit of 3×10^{-8} m/s
- Nitrogen losses are 57 times the typical farm loss limits
- Phosphorus losses are 266 times the typical farm loss limits

ii. For the proposed POP limit of 1×10^{-9} m/s
- Nitrogen losses are 1.5 times the typical farm loss limits
- Phosphorus losses are 7 times the typical farm loss limits

.

Table 12. Comparison of two drainage rates from farm dairy effluent ponds comparing loss rates with typical whole farm values.

Drainage rate (m/s)	**Pond losses**		**Typical value**	
	kg/year	**kg/ha/year**	**kg/ha/year**	**Source of typical value**
	___________N losses___________			
1.00E-09	4.67	46.7	31	Whole farm leaching loss for an average dairy farm in the upper Manawatu catchment (Clothier *et al*., 2007; p13)
3.80E-08	177.3	1773	31	
	____________P losses __________			
1.00E-09	0.7	7	0.1 to 1.0	Whole farm leaching loss for an dairy farm (Clothier *et al*., 2007; p6)
3.80E-08	26.6	266	0.1 to 1.0	

281. Further analysis has calculated the losses for these two sealing requirements in terms of the cumulative effect at the catchment level from the two requirements. This analysis relies on a number of assumptions, but provides some broad context to the relationship between sealing of ponds and the catchment outcomes. This broad analysis indicates that:

i. The losses of nitrogen from the base of ponds would unlikely register at the catchment scale if sealing of 1×10^{-9} was standard for all ponds. If the losses were at a rate of $3 \times 10^{-8,}$ they might comprise in the order of 1-2% of the Measured load and 2-4% of the Standard load.

ii. The losses of phosphorus from the base of ponds would unlikely register at the catchment scale if sealing of 1×10^{-9} was standard for all ponds. If the losses were at a rate of $3 \times 10^{-8,}$ they might comprise in the order of 10-12% of the Measured load and 13-25% of the Standard load.

282. The catchment scale analysis indicates that where attenuation in the landscape is not high (eg. in areas close to streams) inputs from the base of ponds with a sealing requirement of $3x10^{-8}$ may have significant inputs of nutrient to water bodies. It is noted that the analysis above has not considered bacterial losses. Based on the analysis above it is likely losses of bacteria to waterways from ponds could also be significant.

6.23.2 Recommendation to the Hearing Panel

283. **I recommend that the Hearing Panel maintain the currently specified sealing limit of $1x10^{-9}$ m in Rule 13.6.**

Box 49: Comparison of pond sealing requirements

The comparison of the pond sealing requirements of $1x10^{-9}$ and $3x10^{-8}$ to water quality outcomes requires a number of assumptions. The analysis presented here is intended to be indicative of the scale of pond losses at the catchment scale, using available information. The example catchments are for the upper Manawatu and Mangatainoka. They present the results of the work by Houlbrooke (Box 48) for a 500-cow herd with the losses calculated for the pond containing effluent for 270 days per year. The average herd size in these catchments is estimated to be closer to 319 for the upper Manawatu (Clothier *et al.*, 2007; appendix 1) and of the same order for the Mangatainoka. An attenuation factor for the liquid (dissolved) nutrient losses below the pond is assumed at 0.5 for both N and P.

This broad analysis indicates that:

1. The losses of nitrogen from the base of ponds would unlikely register at the catchment scale if sealing of $1x10^{-9}$ was standard for all ponds. If the losses were at a rate of $3x10^{-8,}$ they might comprise in the order of 1-2% of the Measured load and 2- 4% of the Standard load
2. The losses of phosphorus from the base of ponds would unlikely register at the catchment scale if sealing of $1x10^{-9}$ was standard for all ponds. If the losses were at a rate of $3x10^{-8,}$ they might comprise in the order of 10-12% of the Measured load and 13-25% of the Standard load.

Table A. Comparison of pond sealing requirements of $1x10^{-9}$ and $3x10^{-8}$ in two catchments.

	Manawatu	**Mangatainoka**	**Manawatu**	**Mangatainoka**
Attenuation	0.5	0.5	0.5	0.5
Number of farms	154	60	154	60
	N t/year	N t/year	P t/year	P t/year
NPS measured load	729	600	16.8	7.83
NPS standard load	358	266	8.1	6
Pond losses	**N loss**	**N loss**	**P loss**	**P loss**
Drainage rate	(kg/yr)	(kg/yr)	(kg/yr)	(kg/yr)
1.00E-09	4.67	4.67	0.7	0.7
1.00E-08	177.3	177.3	26.6	26.6
	______________ loss from base of pond_____________			
	t/year	t/year	t/year	t/year
1.00E-09	0.005	0.005	0.001	0.001
3.80E-08	0.177	0.177	0.027	0.027
	_____________Tonnes/year from all farms_____________			
1.00E-09	0.4	0.1	0.1	0.0
1.00E-08	13.7	5.3	2.0	0.8
	___________Proportion of NPS measured load___________			
1.00E-09	0.0%	0.0%	0.3%	0.3%
3.80E-08	1.9%	0.9%	12.2%	10.2%
	____________Proportion of average standard load ___________			
1.00E-09	0.1%	0.1%	0.7%	0.4%
3.80E-08	3.8%	2.0%	25.3%	13.3%

6.24 Determining the relative contributions of various non-point sources to nitrogen loadings measured in the river

Relates to key provisions in the Proposed One Plan:

- **Policy 6.7: Land-use activities affecting surface water quality**
- **Rule 13-1: Dairy farming , cropping market gardening and intensive sheep and beef farming and associated activities**

Relates to Chairperson's Minute #6:

- **Question 5.1: What data or research shows that intensive farming is the cause of elevated nutrients in the receiving rivers in each of the identified problem catchments?**

6.24.1 Introduction

284. The initial separation of the point sources and non-point sources identified that non-point sources contributed more than 97% of the SIN loading in the two catchments studied (ie. Manawatu upstream of Hopelands and Mangatainoka upstream of SH2). The relative contributions of the various non-point sources to this loading were addressed in the analysis by Clothier *et al*. (2007)[174]. The evidence of Brent Clothier[175] and the report of Clothier *et al*. (2007); pp 9-15[176] provide further detail on this modelling.

6.24.2 Overview of technical work

285. In summary, Clothier *et al*. (2007) used simultaneous equations to calculate the proportion of the nitrogen load measured in the river that was attributable to each individual land use. These equations provided a mechanism to link the nitrogen loads measured in the river for two water quality monitoring sites, with the area of each land use type (eg. dairy, sheep and beef, cropping and forestry) in the catchments upstream of the two monitoring sites. In doing this, the equations accounted for the inputs from background sources (eg. native bush areas) and the point sources (eg. inputs from Dannevirke sewage treatment plant's discharge of treated sewage effluent to the river). These calculations estimated that the average contribution to water quality loadings was 15.4 kg N/ha for dairying and 3.9 kg/ha for sheep/beef farms (Box 50).

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[174] REFERENCE TO TECHNICAL REPORT: Clothier B., Mackay A., Carran A., Gray R, Parfitt R., Francis G., Manning M., Duerer M., and Green S. 2007: Farm strategies for contaminant management. *A report by SLURI (Sustainable Land Use Research Initiative) for Horizons Regional Council.*

[175] LINK TO FURTHER EVIDENCE: Brent Clothier provides further evidence in relation to calculation of relative inputs from various non-point sources to the overall water quality loads measured in the river.

[176] CLARIFICATION ON MY ROLE: Helen Marr and I scoped this project and I project-managed the project for Horizons.

286. The methods applied by Clothier *et al*. (2007) to determine the relative contributions to the river nitrogen loads relate to the amount of nitrogen measured (or sensed) in the river. However, not all nitrogen that is lost from a farm via leaching or run-off necessarily makes it way to the river to be recorded as a part of the loading of nitrogen in the river (termed “river sensed” nitrogen by Clothier *et al*., 2007). Nitrogen can be diverted from being recorded at the river water quality monitoring station as part of its pathway to the river, or once it is in the river. An example of nitrogen being used on its way to the river would be run-off from a farm going onto another farm and soaking into the soils where the nitrogen is subsequently used for pasture growth. An example of nutrient being used in the river is nutrient reaching the river and being used by periphyton for growth. The difference between leaching/run-off values and loads measured in rivers is often referred to as attenuation.

Box 50: Technical project summary – Determining attenuation factors

To determine the link between the river-sensed loads from various land use types and the actual leaching/run-off values from these land use types, Clothier *et al*. (2007) completed another step in their analysis. This step was to calculate OVERSEER nutrient budgets for a typical sheep/beef farm and a typical dairy farm. Agricultural consultants familiar with the upper Manawatu provided information on what a typical farm would be (see Appendix 4 of Clothier *et al*., 2007).

Table A. Comparison of river-sensed losses and OVERSEER-calculated losses for the upper Manawatu Catchment (modified from Clothier *et al*., 2007).

	River-sensed losses	OVERSEER-calculated losses	Attenuation Factor
Dairying	15.4	31 (25-49)	≈ 0.5
Sheep/beef	3.9	7 (6-9)	≈ 0.5

Taking these typical farm losses as calculated by OVERSEER, Clothier *et al*. (2007) were able to estimate the attenuation factor. The attenuation factor that was found was 0.5 (this is a dimensionless parameter, ie. it does not have units). Clothier *et al*. (2007) provide a comparison to another study of catchments in the Waikato that found attenuations of 0.55, 0.56, 0.58 and 0.61 for river catchments and 0.25 for the lower intensity lake catchment of Lake Taupo. Ledien *et al*. (2007) which was largely completed prior to the work of Clothier *et al*. (2007) assumed an attenuation factor of 0.5.

287. Clothier *et al*. (2007) calculated the attenuation factor of 0.5 using the methods described in Box 50. The analysis showed that dairy farms were losing an average of 31 kg N/ha/year and sheep/beef farms were losing an average of 7 kg N/ha/year.

288. An earlier study by Horizons also studied relative contributions from point sources and non-point sources. Ledien *et al*. (2007)[177] used a screening method to estimate relative

[177] REFERENCE TO TECHNICAL REPORT: Ledien, E., Ausseil O. and Roygard J. 2007: Identifying Point Source and Non-Point Source Contributions to Nutrient Loadings in Water Ways in Three Catchments in the Manawatu-Wanganui Region: Technical Report to Support Policy Development. Horizons Regional Council Report 2007/EXT/771, ISBN: 1-877413-65-8.

contributions to water quality losses[178]. This method identified the area of various land uses in particular catchments and used literature values for losses from these farming types. These values were combined with an assumed attenuation factor of 0.5 to calculate inputs from a particular land use type. Ledien *et al.* (2007), then compared these results to what was measured in the river, accounting for point sources. In my view, the approach of Clothier *et al.* (2007) is preferable, as it links directly to the measured river load and uses information from the catchment being studied to estimate leaching losses, as opposed to using national literature values to estimate losses. The results from the two methods show agreement in terms of relative contributions from sheep/beef and dairy in these catchments (as shown in Clothier *et al.*, 2007; p14).

289. Consideration should also be given to the knowledge that OVERSEER[179, 180] assumes best practice and therefore the relationship of results produced by the Clothier *et al.* (2007) assumes best practice is already occurring, for example that stock are excluded from water bodies (ie. all water bodies are fenced off and stream crossings are bridged) and farm dairy effluent is being managed to best practice standards. The assumption of best practice on all farms in the upper Manawatu is likely unrealistic, as evidenced by compliance history and the history of discharges to water of farm dairy effluent over the period of water quality record studied. The degree to which this impacts on the attenuation factor is unknown.

6.24.3 Further ongoing technical work in this area

290. Horizons have supported the Institute of Geological and Nuclear Sciences (GNS) to further investigate the attenuation of nitrogen in the upper Manawatu catchment. This project, funded by the Foundation for Research Science and Technology (FRST), project started in July 2009 and will run over three years. Horizons[181] are supporting the project through a range of methods, predominately through sample collection and provision of information. The project is summarised in Box 51. The project (Baisden *et al.*, 2009[182]) proposes indicators that are intended to:

i. Classify the vulnerability of farm units to ongoing losses of N.

ii. Identify the proportion of river nitrate loads from differing farm types.

iii. Quantify the proportion of nitrate lost during transport.

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[178] CLARIFICATION ON MY ROLE: I participated in the project team for this project and am a co-author of the report.

[179] REFER TO: A later section of this report provides a brief overview of OVEERSEER and introduces the further evidence in relation to this model (Section 7.6).

[180] LINK TO FURTHER EVIDENCE: Stewart Ledgard provides evidence in relation to the OVERSEER model and discusses the assumption of best practice by the model.

[181] CLARIFICATION ON MY ROLE: I co-ordinate Horizons' input into this project.

[182] REFERENCE TO TECHNICAL PAPER: Baisden, T., Schipper, G., Stevenson, B., Parfitt, R., Wassenaar, L., Ghani, A. (2009). Theory underpinning the isotopic indicators of land-to-water nitrogen transfers. FRST programme. Massey University Fertiliser and Lime Research Conference proceedings. Massey University.

Box 51: Technical project summary – Isotopic indicators of land-to-water nitrogen (N) transfers programme

To provide some more detail on what the project is about and what it sets out to achieve, the abstract of a paper (Baisden *et al*., 2009) that was presented at the Fertiliser Lime Research Conference is provided below. Further detail of the project is available in Baisden *et al*. (2009).

"Abstract

GNS Science's National Isotope Centre and has obtained FRST funding of $1.05 million over three years to lead the Isotopic Indicators of Land-to-Water Nitrogen (N) Transfers programme, and coordinate a range of collaborations. The programme focuses on developing stable isotope ratios (15N/14N and 18O/16O) as indicators of nitrogen from pastoral agricultural land to surface water. Here, we present the theory underpinning the programme and its application to stable isotopes in New Zealand. The underpinning theory has been developed based on overseas research and limited New Zealand data, and our three-year programme will verify the theoretical basis for the programme, providing the understanding needed to develop robust indicators. The programme centers on the science of developing isotopic indicators, with long-term delivery occurring through large ongoing programmes focused on Feb 2009 Massey Fertiliser and Lime Research Conference Proceedings land use and water quality within AgResearch, Landcare Research and the Sustainable Land Use Research Initiative (SLURI).

Our proposed indicators are intended to:

- *Classify the vulnerability of farm units to ongoing losses of N*
- *Identify the proportion of river nitrate (NO3) loads from differing farm types*
- *Quantify the proportion of NO3 lost during transport*

These indicators recognise that multiple isotopes of N and oxygen (O) exist naturally, and the relative abundance of these isotopes records the sources of N and O, as well as the effects of biochemical processes occurring in soil and water. We believe NZ pastures represent an ideal opportunity to define N and O isotope systematics for agricultural systems in the absence of the pollution that obscures relationships in the Northern Hemisphere. We plan a primary focus on the Upper Manawatu Catchment, to support the development of water quality policies within Horizons Regional Council's One Plan." (*Baisden et al. 2009*)"

6.24.4 Management scenarios for non-point source nitrogen inputs to water bodies

291. The analysis of Clothier *et al.* (2007) described the current state for nitrogen inputs and water quality outcomes. This analysis method enabled scenarios of management of the catchment to be tested to determine the water quality outcomes. Some of the possible

scenarios are presented in the evidence of Brent Clothier[183] and in detail in the report of Clothier *et al.* (2007). These scenarios and results are broadly overviewed below.

292. Scenarios 1 to 4 were completed for the area of the upper Manawatu catchment between the Weber Road monitoring site and the Hopelands monitoring site referred to as "the Hopelands subcatchment" by Clothier *et al.* (2007). The "Hopelands subcatchment" is made up of Water Management Zones (Mana_2, Mana_3, Mana_4 and Mana_5). Clothier *et al*. (2007) identified this area as 27.1% in dairy farming and 61% in sheep/beef.

i. **Scenario 1:** Adopting mitigation practices on dairy farms predicted an 18.3% decrease in the current catchment nitrogen loads.

ii. **Scenario 2:** Intensifying land that is already in dairy farming predicted a 33% increase in the current catchment nitrogen loads.

iii. **Scenario 3:** Adopting mitigation practices on sheep/beef farms predicted a 9.8% decrease of in the current catchment nitrogen loads.

iv. **Scenario 4:** Intensifying land that is already in sheep farming predicted a 8.4% increase in the current catchment nitrogen loads.

293. Scenarios 5, 6 and 7 are based on the entire catchment upstream of the Manawatu at Hopelands monitoring site (ie. Water Management Zones Mana_1, Mana_2, Mana_3, Mana_4 and Mana_5). Clothier *et al*. (2007) identified this area as 16.3% dairy and 77.3% sheep/beef. Scenario 5 models increasing dairy to 25% and decreasing sheep/beef to 68.5%

i. **Scenario 5:** converting the sheep/beef areas to dairying on all lands up to land use capability (LUC)[184, 185] Class III, at current levels of production. This scenario predicted an 17.8% increase in the current catchment nitrogen loads, and that for each hectare of land converted from sheep/beef to dairy, the water quality loading will increase by 11.5 kg N/ha/yr.

ii. **Scenario 6:** Meeting the standard based on a loading equity split. At present, the total loading at Hopelands is split relatively evenly between sheep/beef (51%) and dairy (43%). To meet the standard of 341[186] tonnes N/yr (providing for the attenuation factor) would mean root zone limits for losses of 15.1 kg N/ha/year for dairy and 3.8 kg N/ha/yr for sheep/beef.

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183 LINK TO FURTHER EVIDENCE: Brent Clothier provides further evidence in relation to calculation of relative inputs from various non-point sources to the overall water quality loads measured in the river.

184 REFER TO: A later section of this report provides a brief overview of land use capability and introduces the further evidence in relation to this model (Section 7.5)

185 LINK TO FURTHER EVIDENCE: Grant Douglas provides evidence in relation to land use capability.

186 The standard used by Clothier et al., 2007 was based on calculations from earlier versions of Roygard and McArthur (2008) who report the standard as 358 tonnes SIN/year.

iii. **Scenario 7:** Meeting the standard based on an area equity split. Dairy is calculated to be 16.3% of the area upstream of Hopelands whereas sheep/beef covers 77.3%. To meet the standard of 341 tonnes N/yr (providing for the attenuation factor) would mean root zone limits based on these relative proportions from dairy and sheep/beef of 5.8 kg N/ha/yr. By definition, because the area is equity split, it provides the same limit for every hectare.

294. Overall, the scenarios show the management of dairy farming has a greater impact on catchment outcomes than the management of sheep/beef farming. For the first four scenarios, the results are in a catchment where the area of sheep/beef farming is more than twice that of dairy. For the final scenarios, this increases to approximately 4.75 ha of sheep/beef for each hectare of dairy.

295. The scenarios in relation to dairy do not provide targets that are likely to be achievable in this catchment at current levels of production on the lower LUC class land.

6.25 Determining the relative contributions of various non-point sources of phosphorus to loadings measured in the river

6.25.1 Introduction

296. The initial separation of the point sources and non-point sources identified that non-point source contributions contributed approximately 80-85% of DRP loading in the two catchments studied ie. Manawatu upstream of Hopelands and Mangatainoka upstream of SH2 (Roygard and McArthur, 2008). The relative contributions of the various non-point sources to this loading were addressed in the analysis by Parfitt *et al*. (2007)[187]. The evidence of Roger Parfitt[188] and the report of Parfitt *et al.* (2007)[189] provide further detail on this modelling.

6.25.2 Overview of technical work

297. In summary, Parfitt *et al*. (2007) used simultaneous equations to calculate the loads of P from various non-point and point sources for current management practices, and provides a better understanding of the P sources in the Upper Manawatu Water

187 REFERENCE TO TECHNICAL REPORT: Parfitt R., Dymond J., Ausseil A., Clothier B., Deurer M., Gillingham A., Gray R., Houlbrooke D., Mackay A. & McDowell R. (2007). Best Practice Phosphorus Losses from Agricultural Land. Prepared for Horizons Regional Council. Landcare Research Contract Report No. LC0708/012.

188 LINK TO FURTHER EVIDENCE: Roger Parfitt provides further evidence in relation to calculation of relative inputs from various non-point sources of phosphorus to the overall water quality loads measured in the river.

189 CLARIFICATION ON MY ROLE: I scoped this project and project-managed it for Horizons.

Management Zones (UMWMZ) above Hopelands. This project sets out to quantify the impact of implementing best practice on the water quality of those catchments, and thus better target approaches to P management.

298. The study, which was the first of its kind in New Zealand, concluded there were considerable gains to be made in terms of reducing P in the upper Manawatu River by reducing inputs from erosion (Box 52). The report supported the proposed approaches recommending, "*Based on the findings of this* [study]*, we recommend the two pronged approach offered by SLUI* [Horizons' Sustainable Land Use Initiative] *to reduce total P loadings to the river and FARM strategy to reduce DRP during low flow, to improve the water quality by reducing P contamination in the UMWMZ* [Upper Manawatu Water Management Zones]". It is noted that the area of this study upstream of Hopelands contains five Water Management Zones.

299. In summary, the recommendations of this report were to focus on best management practices to reduce overall total phosphorus loads through erosion control works. For management of dissolved phosphorus the report recommended:

i. Targeted planting of trees in riparian zones;
ii. Reducing point source inputs;
iii. Improving farm dairy effluent management;
iv. Excluding stock from streams; and
v. Limiting soil P fertility to agronomic optimum range.

Box 52: Technical report summary – Best practice phosphorus losses from agricultural land

The following text from the report by Parfitt *et al.* (2007) provides a summary of this project, Best Practice Phosphorus Losses from Agricultural Land, and its main findings.

"*For the first time in New Zealand, SLURI estimated both the total and dissolved phosphorus losses for a large catchment (Upper Manawatu Water Management Zones above Hopelands) by using the Overseer® and NZEEM models together. Using these models for this catchment (126669 ha), that has 77% sheep and beef, 16% dairy and 6% forest, and data for the catchment above Weber Rd, we were able to assess the likely sources of these losses.*

Most phosphorus comes down the rivers in particles of eroded sediment from steeper land during major floods – about 511 tonnes of phosphorus per year goes under the bridge at Hopelands attached to particles of sediment. 90% of the erosion occurs under pastures on steep land and 10% under forest. These phosphorus particle losses could be reduced from 511 to 280 tonnes by targeted planting of trees on Highly Erodible Land (Figure A).

During low flows sediment particles on the bed of the river release about 4 tonnes of dissolved phosphorus per year. This could be halved by reducing erosion.

Dissolved phosphorus causes blooms of periphyton in summer. Most dissolved phosphorus, however, comes from pastures. For sheep and beef farms this could be reduced from 14 tonnes per year down to 10 tonnes per year with targeted planting of trees and riparian zones. For dairy farms it could be reduced from 9 tonnes down to 5 tonnes per year with changes to management of effluent, excluding cows from streams and limiting soil P fertility to the optimum agronomic range (Figure B).

Dissolved phosphorus from point sources at Dannevirke and Oringi could be reduced from 7 down to 2 tonnes per year with changes to management of effluent.

Based on the finding of this, we recommend the two pronged approach offered by SLUI to reduce total P loadings to the river and the FARM strategy to reduce DRP during low flow, to improve the water quality by reducing P contamination in the UMWMZ. Monitoring of phosphorus concentrations in the Manawatu River should be carried out on a regular basis to define a more precise base line, and to monitor improvements to water quality as SLUI and the FARM strategy programmes progress.

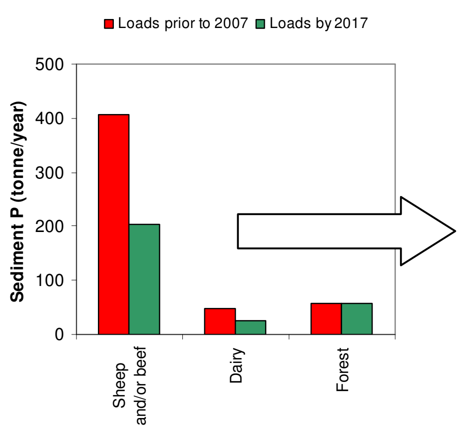

Figure A. Estimates of sources of particulate phosphorus in the Manawatu River at Hopelands in 2007, and loads achievable by 2017 if recommendations are implemented (tonnes P per year).

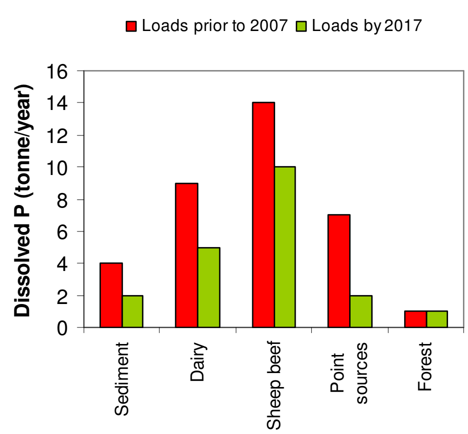

Figure B. Estimates of sources of dissolved phosphorus in the Manawatu River at Hopelands in 2007, and loads achievable by 2017 if recommendations are implemented (tonnes P per year). Note: Some of the 511 tonnes of particulate phosphorus remain on the bed of the river and generate about 4 tonnes of dissolved phosphorus per year"

6.26 Summary of nutrient-related aspects of this chapter

300. This chapter has addressed a number of technical projects in relation to nutrient in water bodies, and linkages with the pressures from point sources and non-point sources. Box 53 provides a summary of this work identifying some of the linkages relating to various aspects of the POP including the Farmer Applied Resource Management strategy approach of the proposes Rule 13-1.

Box 53: Summary of technical work in relation to nutrient with linkages to the POP	
Section /Message	**Linkages**
State of nutrients in water bodies ▪ Nutrients are an issue in some of the Region's water bodies. ▪ Some water bodies have significant nitrogen issues, some phosphorus, and some have both.	The FARM strategy approach has been targeted to catchments where nutrients are an issue.
Trends in water quality for nutrient parameters ▪ Trends vary by catchment and over time-scales. ▪ The shorter-term trends analyses in some catchments show some improvement in trends, although the longer-term trends indicate an overall degrading trend.	Water quality trends were a factor in determining target catchments.
Nutrient limitation of periphyton growth ▪ Catchments can have different limiting nutrients at different sites on the same day. ▪ The limiting nutrient at a site can change.	The FARM strategy approach includes factors to address both N and P losses from farms.
Nutrient standards ▪ Nutrient standards have been recommended for N and P year-round, except at very high flows (ie. above 20^{th} percentile flow). ▪ Standards are different for different water bodies, reflecting the values.	The FARM strategy approach includes factors to address both N and P losses from farms.
Converting nutrient standards to target loads ▪ Converting the concentration-based standards to annual loads or target loads incorporates the inherent variability in flow regimes. ▪ Conversion of standards to loads for one year may calculate loads 50% greater or lower than the long-term average Standard loads.	Setting target loads for the catchment outcome has to take account of the annual variation in flows (and therefore water quality).
Relative inputs from point & non-point sources at all flows ▪ Overall, in the two catchments studied, the non-point source SIN and DRP inputs totalled more than 97% and 80-85% of the total load at the water quality monitoring sites respectively.	The FARM strategy approach has targeted catchments where nutrient is an issue and non-point source contributions are a major source of this nutrient.
Relative inputs from point & non-point sources at various flows ▪ Overall, in the two catchments studied, the point source SIN and DRP inputs totalled more than 3% and 15-20% respectively. ▪ When assessed at low flows in the upper Manawatu, the point sources DRP contribution increased to approximately 66% of the total loading. ▪ Removing this single point source at the lowest flows (that occur less than 20% of the time) would go a long way to both the SIN and DRP standard being met at these flows.	The FARM strategy approach targets overall contributions to nutrient loadings into water bodies, and contributions at low flows. A policy in the POP provides for customising management of discharges to land and water in relation to flows.
Relative NPS contributions of SIN from different farming types ▪ Management of intensive farming provides greater overall impact on water quality in catchments than targeting the less intensive farms that are the predominant land use in the catchment. ▪ If an even per hectare loss limit is used for every hectare in the catchment, meeting the water quality standard for N is likely to be unachievable for dairy farms.	The FARM strategy approach targets intensive farms. Alternatives to targets based on every hectare having the same loss standard have been used.
Relative NPS contributions of DRP from different farming types ▪ Significant gains can be made from implementing best practice to reduce phosphorus losses from farming systems. ▪ To reduce total P loads, a focus on hill country erosion management is recommended. ▪ To reduce DRP loads, improving dairy farm effluent management, reducing stock access to water bodies, and limiting P soil fertility to agronomic optimum are recommended.	The FARM strategy approach targets overall contributions to nutrient loading of P into water bodies at low flows. Horizons Sustainable Land Use Initiative (SLUI) targets managing hill country erosion.

7. FARM STRATEGIES FOR CONTAMINANT MANAGEMENT

Relates to key provisions in the Proposed One Plan:

- **Policy 6-7: Land use activities affecting surface water quality**
- **Rule 13-1: Dairy farming, cropping market gardening, intensive sheep and beef farming, and associated activities**

7.1 Chapter Theme Summary

301. **The proposed framework for management of non-point sources of nutrient, faecal contamination and sediment has been informed and tested by a range of technical projects. The proposed approach that intensive farms in targeted catchments be required to complete a Farmer Applied Resource Management (FARM) strategy. The selection of target catchment areas relates to Water Management Sub-zones and has been informed by the state, trends and the relative contributions of non-point sources to water quality. Within these zones, the approach focuses on intensive farms, as management of these has been identified to have the greatest impact on overall water quality. The FARM strategy document includes requirements in relation to nutrient, faecal and sediment management. These requirements include N loss limits for intensive farming systems that have been linked to water quality outcomes. This chapter provides an overview of the technical work in relation to the development of the policy and the subsequent testing of the proposed policy. Some technical projects in relation to this work are documented in the previous chapter because of the inherent link this approach has with water quality. New work completed since notification of the POP has provided further information in relation to this approach and this work is also overviewed in this chapter. The chapter also provides some feedback in relation to the Chairperson's Minute #6.**

7.2 Introduction

7.2.1 Overview

302. The proposed framework for management of non-point source inputs has been informed by a range of technical work. This chapter provides an overview of this work and the technical work that has subsequently tested the proposed approach. The chapter provides feedback in relation to the Chairperson's Minute #6. The questions from the minute are addressed in this report from a technical perspective; therefore some of the

questions have not been addressed in this specific report but are addressed by the planning reports.

303. In summary, the technical work for the non-point source management of nutrients has drawn on a range of technical projects. Some of the key reports include the FARM Strategies for Contaminant Management report (Clothier *et al*., 2007[190]) (see Box 54) and the Implementation of FARM Strategies for Contaminant Management (Mackay *et al*., 2008[191]) (see Box 55). The results and conclusions from these projects are discussed in the context of the FARM strategies approach in subsequent sections of this report and in the evidence of Brent Clothier[192] and Alec Mackay[193]. The technical work has also tested the proposed policy and the associated FARM strategy workbook. As a result of the further work, some amendments to the workbook are recommended. The technical testing of the policy proposal has included work at the broader level, such as catchment level modelling of outcomes through to very detailed on-farm assessments and applications of the methodologies.

7.2.2 Chapter contents

304. The following sections provide an overview of technical work in relation to:

i. The targeted farming types (Section 7.3)
ii. The target Water Management Zones in Table 13.1 (Section 7.4)
iii. The Land Use Capability nitrogen leaching/run-off values (Section 7.5)
iv. The use of OVERSEER as part of the approach (Section 7.6)
v. Testing the FARM strategy approach on-farms (Section 7.7)
vi. Summary of FARM strategy approach (Section 7.8).

[190] REFERENCE TO TECHNICAL REPORT: Clothier B., Mackay A., Carran A., Gray R, Parfitt R., Francis G., Manning M., Duerer M., and Green S. (2007). FARM Strategies For Contaminant Management. A report by SLURI (Sustainable Land Use Research Initiative) for Horizons Regional Council. Horizons report 2007/Ext/787

[191] REFERENCE TO TECHNICAL REPORT: Mackay A., Clothier, B. Gray R and Green S. (2008). Implementation of FARM Strategies for Contaminant Management – Further questions. A report by SLURI (Sustainable Land Use Research Initiative) for Horizons Regional Council. Horizons report 2007/Ext/870

[192] LINK TO FURTHER EVIDENCE: Brent Clothier provides evidence in relation to the Clothier *et al.* (2007) report.

[193] LINK TO FURTHER EVIDENCE: Alec Mackay provides evidence in relation to the Mackay *et al.* (2008) report.

Box 54: Technical Project Overview – FARM strategies for contaminant management

Farm Strategies for Contaminant Management (Clothier *et al*., 2007) addressed the following 15 questions:

1. What types of farming have the highest potential effect on water quality?
2. What is the best practice acceptable nutrient loss from a farm that Horizons should endorse?
3. What are the key/critical hotspots of nutrients input into waterways? How should these be managed to reduce their impact on contamination of waterways?
4. Application of effluent to land is currently an activity that requires resource consent. If Horizons were to make it a permitted activity subject to compliance with best management practice, which best management practices are recommended?
5. What improvements and mitigation measures are likely to be included in OVERSEER®
6. What progress has been made in integrating NPlas and Overseer®? Could it be applied to the Manawatu-Wanganui region?
7. What are the Best Management Practices Horizons should be endorsing to minimise faecal runoff from farms?
8. If Horizons is to include requirements to fence waterways to achieve reductions in nutrient and faecal loss, what definition of a waterway should be used? One similar to the Fonterra clean streams accord definition, or some other definition?
9. What are the appropriate upper limits for Table 16-1 in the "One Plan" for N and P? [it is noted that table 16-1 of draft 4 of the one plan was based on input limits for various types of production system]
10. Are the current conditions on Rules 16-2 to 16-7 [Biosolids, Offal Holes & Farm Dumps] appropriate to achieve best practice?
11. What significant research work is occurring that could benefit on-farm resource management methods?
12. Are there any trends within the farming community that may influence the format of individual farm resource management plans/strategies (ie. computer literacy, environmental awareness, market accountability, etc)?
13. What would be the most effective way of measuring the actual nitrogen and phosphorus loss from farms?
14. Why does Overseer not consider soil-test results to account for the existing N content of soil?
15. The Waikato Farm Environment Award Trust has produced a guide to preparing a nutrient budget. How useful is this simplified tool?

Box 55: Technical project Overview - Implementation of FARM Strategies

The implementation of Farm Strategies report (Mackay *et al*., 2008) addressed the following seven key questions:

1. Determine ability to incorporate into the rule more detailed information in the extended legend (eg. soil type, drainage class, rainfall, distance from water courses, etc).
   - How do the detailed sub class approach versus the broader scale LUC class approach compare for water quality outcome.
   - The same numbers across the region are used for LUC class output is it necessary to tailor this on a catchment by catchment basis in terms of water quality outcome and farming systems parameters in that catchment (rainfall soils etc). Compare for the Mangatainoka the water quality outcome and the upper Manawatu.
   - Impact of the LUC handbook update
2. Explore the efficiency of resource use by soil within each LUC class eg. Product/ unit N lost.
   - Should the loss limit be weighed equally across all soil units to the same degree?
   - List the mitigation options (types and cost benefits and dollars) available by soil within each LUC class.
   - Land owners on soils in class I have more mitigation options than those of land classes with limitations to use, should weighting of the loss limits reflect the greater flexibility that affords land owners on that land class.
   - What are the implications of having weighted nutrient loss limits for example on hill country farms?
3. What impact does cropping have at a catchment level? Document the current level of knowledge around this type of activity including
   - Where does cropping take place?
   - What is the contribution to water quality from cropping?
   - What is best practice for cropping in terms of contaminant management?
   - What needs to be done to advance this approach in relation to cropping?
   - What is the recommended approach to nutrient management plans for cropping?
4. How do the calculations for upper Manawatu in terms of river sensed and OVERSEER® output compare for the Mangatainoka?
5. What information is required to roll out this approach? For example [catchments with] commercial vegetable [production], lake catchments, water quality information, land use information, flow data etc. Consider all catchments where the Rule will apply.
6. How will the FARM strategy approach be linked into the farm practice?
   - Please outline an approach as to how this could be rolled out.
   - To what extent do you see need for expertise around fertiliser, farm management, financial management to be involved?
   - Consult with industry representatives in answering this question.
7. Overseer, the FARM strategy and the water quality outcomes work on long-term averages.
   - How will the farm strategy work with farm management changes in response to weather eg. using N to fill a gap in the feed budget.
   - Examine the impact of extreme events (flooding, drought, etc).

7.3 The targeted farming types

Relates to Chairperson's Minute #6

- **Question 5.1: What data or research shows that intensive farming is the cause of elevated nutrients in the receiving rivers in each of the identified problem catchments?**
- **Question 5.11: Why are the land uses specified in Rule 13-1 targeted and not other land uses?**

7.3.1 Introduction

305. Many studies have investigated the relative losses of nutrients, bacteria or sediment from farming systems. Horizons asked SLURI (the Sustainable Land Use Research Initiative) to identify what types of farming have the highest potential effect on water quality. The results from their literature review are shown in Box 56, ranked from highest to lowest (ie. market gardening, cropping, dairying, and sheep/beef).

Box 56: Technical project summary - Types of farming and potential effects on water quality

The question as to what types of farming have highest potential effect on water quality was addressed by Clothier *et al*. (2007) via a review of the literature. The review was limited to market gardening, cropping, dairying, and sheep/beef. Clothier *et al*. (2007) did not assess intensive beef operations as the descriptors of this land use type were difficult to identify in terms of any particular database that was available to Horizons (ie. Horizons policy staff stated that if Horizons were to set a policy targeting this land use type it would be difficult to identify what farms fit the criteria). It is noted that land uses such as piggeries and poultry farms were not included in this literature search. These were likely considered to have come under other parts of the POP via land treatment rules.

Table A below from Clothier *et al*. (2007) shows the relative rankings of the four land use types included in the literature review. The rankings were the same for both nitrogen and phosphorus with the order, from highest losses to lowest, being: market gardening, cropping, dairying, and sheep/ beef. The report did not identify losses from market gardening or cropping for phosphorus, but did note: *"Published results from throughout New Zealand show, in general, that the risk for winter nitrate leaching is greater from market gardening than from arable cropping (Di and Cameron, 2002). This is because vegetable crops are inefficient in their uptake of N and high fertiliser rates are often applied when these crops are grown over the winter. Generally, the P losses from these two land uses are likely to be associated with sediment moving in overland flow when land is cultivated or left fallow over winter before crops are sown.*"

Table A. Intensive forms of farming and their likely losses of nitrogen and phosphorus

Ranked Nitrogen Loss	**Ranked Phosphorus Loss**
Market Gardening (100-300 kg-N ha^{-1} yr^{-1})	Market Gardening
Cropping (10-140 kg-N ha^{-1} yr^{-1})	Cropping
Dairying (15-115 kg-N ha^{-1} yr^{-1})	Dairying (0.2- 1.0 kg-P ha^{-1} yr^{-1})
Sheep/beef (6-60 kg-N ha^{-1} yr^{-1})	Sheep/beef (0.1-1.6 kg-P ha^{-1} yr^{-1})

306. The results from the literature review included studies outside Horizons' Region. There are many studies available within the Region that have investigated losses from farming systems. Brent Clothier[194] provides evidence on the literature review of Clothier *et al.* (2007) and other nutrient loss studies, and provides other examples of farming system losses from within the Region. These include:

i. An intensive commercial vegetable growing operation in the Horowhenua District that was estimated to be leaching 215.5 kg N/ha/yr over a two-year period.

ii. Potato production in the Opiki area (lower Manawatu) with three levels of irrigation on five different soil types, with N leaching predicted to average 33-90 kg N/ha/yr, depending on soil type and irrigation management.

iii. A typical dairy farm in the upper Manawatu that leaches an average of 31 kg N/ha/yr with a range of 31-49 kg N/ha/yr, depending on management and situational variables such as climate, soil, etc.

iv. A typical sheep/beef farm in the upper Manawatu that leaches an average of 7 kg N/ha/yr with a range of 6-9 kg N/ha/yr, depending on management and situational variables such as climate, soil, etc.

307. Further studies will be presented as part of the POP evidence where more than 20 detailed assessments of farms in the Region have been completed to test the FARM strategy approach. The details of these farms and their nitrogen losses are provided in the evidence of Andrew Manderson[195] and Peter Taylor[196].

308. The POP Rule 13-1 targets intensive farms including market gardening, cropping, dairying and intensive sheep and beef farms (defined as irrigated sheep and beef farms). The selection of irrigated sheep and beef farms was a pragmatic methodology to identify some of the intensive sheep and beef operations in the Region. Irrigation has the potential to increase the losses of nutrients from farms, particularly where best practice is not adopted. Other mechanisms for defining intensive sheep/beef operations, such as stocking rate, were not considered practical due to the technical difficulty in establishing an accurate measure of these with currently available data.

309. At regional level, the land uses identified as intensive would likely total less than 10% of the overall land area in the Region (Table A, Box 26, Section 6.5.1). It is difficult to accurately characterise the extent of the area in market gardening due to the nature of

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194 LINK TO FURTHER EVIDENCE: Brent Clothier provides evidence in relation to the Clothier *et al.* (2007) report and nutrient losses from various production systems.

195 LINK TO FURTHER EVIDENCE: Andrew Manderson provides evidence in relation to the nutrient losses calculated from the testing of the FARM strategy approach.

196 LINK TO FURTHER EVIDENCE: Peter Taylor provides evidence in relation to the nutrient losses calculated from the testing of the FARM strategy approach.

these farming systems which means locations of the actual cropping changes vary considerably from year to year. The POP approach does not apply to all land in these land uses in the Region, rather it is targeted to specific Water Management Sub-zones, as outlined in the section below.

7.4 The target Water Management Zones

Relates to Chairperson's Minute #6

- **Question 5.4: Why is Rule 13-1 proposed to become operative in different catchments in different years?**
- **Question 5.1: What data or research shows that intensive farming is the cause of elevated nutrients in the receiving rivers in each of the identified problem catchments?**
- **Question 5.2: Has that situation changed since the POP was notified?**

7.4.1 Concepts and linkages

310. The selection of the target (priority) Water Management Zones was based on a range of factors[197]. One selection criteria was to select catchments that had water quality issues with non-point source as a major contributor. The catchments that were selected are shown in Map 9 with the dates when Rule 13-1 is proposed to apply to them. Priority zones are shown in relation to the nitrate, dissolved phosphorus and turbidity indicator maps in Map 10. In terms of identifying where the water quality issues were, sources of information included:

   i. SoE monitoring information.
   ii. Water resource assessments.
   iii. Water quality trends.
   iv. Swimming spots monitoring information.
   v. Reports in relation to point sources (eg. McArthur & Clark, 2007[198]).

311. Some sites with similar water quality were not selected because point source discharges were known to be major contributors to the water quality in the catchment. Examples of this include:

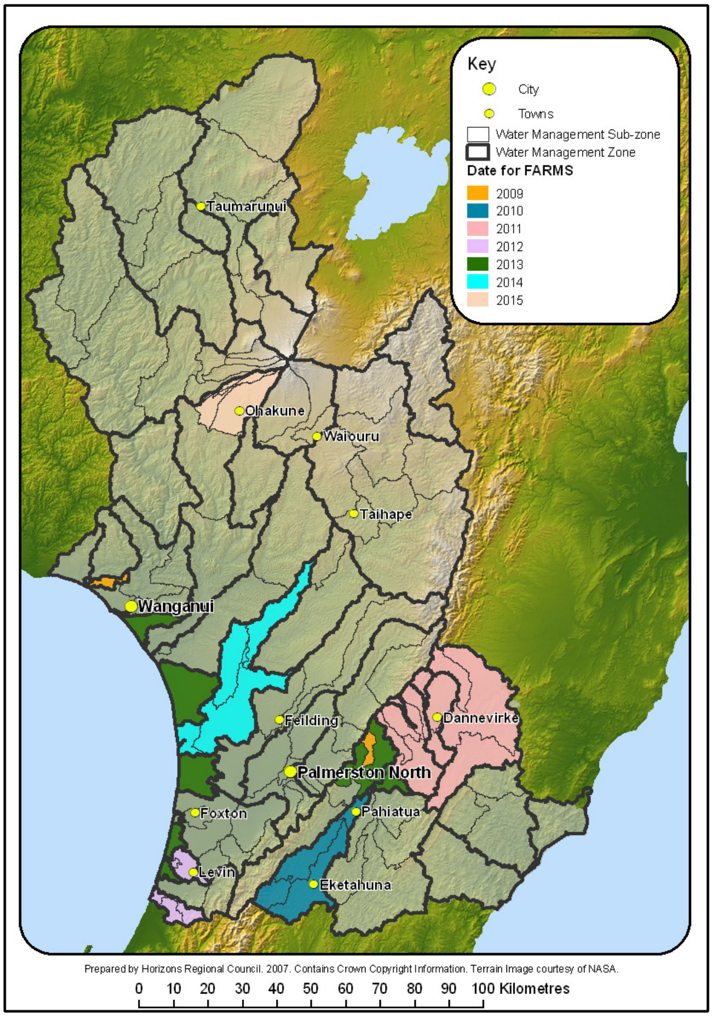
   i. The lower Oroua River, which is strongly influenced by the discharge of treated sewage from Feilding; and

[197] CLARIFICATION ON MY ROLE: I was a member of the team that selected the priority catchments for Rule 13-1.
[198] REFERENCE TO TECHNICAL REPORT McArthur, K.J. and Clark, M. (2007). Nitrogen and Phosphorus Loads to Rivers in the Manawatu-Wanganui Region: a regional analysis of low flow state. Horizons Regional Council Report 2007/EXT/793.

ii. The lower Manawatu River, which is strongly influenced by the discharge of treated sewage from Palmerston North.

312. Other zones with primarily turbidity, sediment and phosphorus issues were not selected as priority catchments for the FARMs approach. The primary issue in these catchments is related to hill country erosion. These zones have been selected for prioritisation for Horizons' Sustainable Land Use Initiative (SLUI, Map 11).

313. The SLUI catchment work is targeted for a range of outcomes, and in relation to the POP Water chapter this work will provide benefits in terms of water clarity improvement, and turbidity, sediment and phosphorus reduction. This programme is not discussed in detail in this evidence as it has been discussed previously in the POP hearings in relation to the land chapter.



Map 9. Locations of the proposed target catchments and the proposed timing for Rule 13-1 to apply in these catchments.

7.4.2 Technical Amendments

314. Further, more specific, information on the water quality in each of the priority catchments is presented in the evidence of Ms McArthur[199]. Further monitoring work has been undertaken in some of the priority catchments to better understand the water quality in these areas. The Mangapapa, Mangatainoka, upper Manawatu, Mowhanau and Lake Horowhenua areas have all had some form of specific water quality investigation outside of the regular and upgraded monitoring programmes. As part of upgrading the SoE and discharge monitoring programmes, these zones have been given a high priority and monitoring in most of the zones has increased. There are clearly some zones with considerably more monitoring information than others. In particular, there is little available monitoring information for the coastal lake catchments.

7.4.3 Recommendation

315. As a result of the further monitoring in the Mowhanau catchment, near Wanganui, it is now recommended that this catchment be removed from the table of target catchments (Table 13.1) as the water quality issue has been somewhat narrowed. A key component of the initial selection of this zone was the swimming spot monitoring information for the stream near the sea. This catchment contains two dairy farms and is predominately sheep/beef farms. An alternate approach to addressing the water quality issues in this catchment is required to reduce faecal contamination in this catchment.

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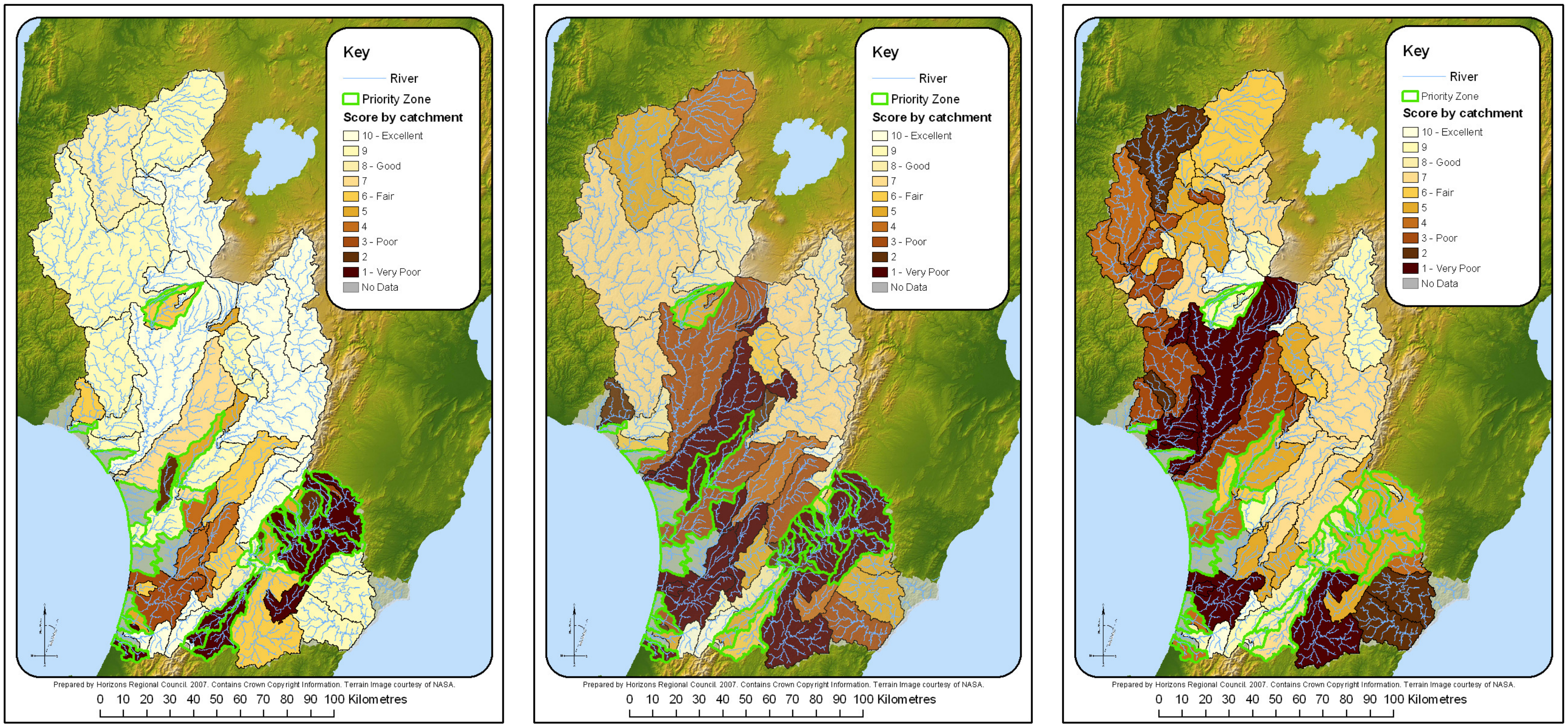
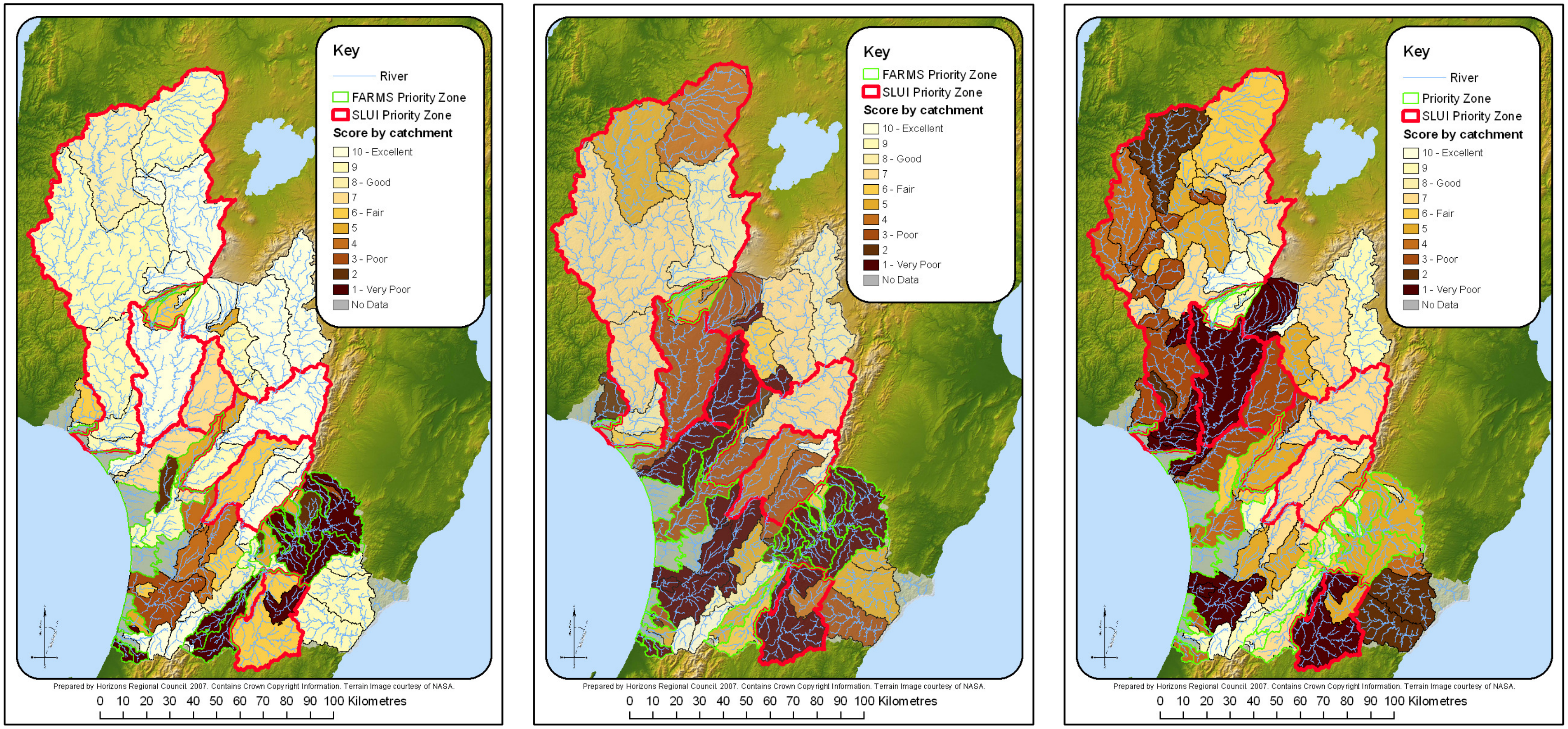
[199] LINK TO FURTHER EVIDENCE: Kate McArthur provides further information on the water quality in each of the selected priority Water Management Zones.



Map 10. State of the Environment (SoE) maps showing the location of the priority zones for Rule 13-1 Left: SoE map for nitrate. Middle: SoE map for dissolved reactive phosphorus. Right: SoE map for turbidity.



Map 11. State of Environment (SoE) maps showing the location of the priority zones for the FARM strategy (Rule 13-1) and the Sustainable Land Use Initiative SLUI. Left: SoE map for nitrate. Middle: SoE map for dissolved reactive phosphorus. Right: SoE map for turbidity.

7.5 The Land Use Capability Nitrogen Leaching Run-Off Values (Table 13.2)

Relates to key provision in the Proposed One Plan:

- **Table 13.2**

Relates to Chairperson's Minute #6

- **Question 5.5: Are the Nitrogen Leaching/Run-off Values in Table 13.2 measured as root zone leaching or nitrogen reaching in the river after attenuation?**
- **Question 5.8: How were the Year 1 Nitrogen Leaching/Run-off Values in Table 13.2 selected?**
- **Question 5.9: How were the Nitrogen Leaching/Run-off Values for years 5 and beyond in Table 13.2 selected?**

7.5.1 Introduction

316. The nitrogen leaching/run-off values are N loss limits from the farm boundary/root zone (ie. before attenuation). This section of the report provides an overview of the Land Use Capability (LUC) system that underpins the values in Table 13.2, and the technical work in relation to the methodology for the allocation of N loss limits based on LUC.

7.5.2 The Land Use Capability system

317. The Land Use Capability (LUC) classification system is defined as: "a *systematic arrangement of different kinds of land according to those properties that determine its capacity for long-term sustained production. Capability is used in the sense of suitability for productive use or uses after taking into account the physical limitations of the land.*" (Lynn *et al*., 2009[200], the updated Land Use Capability Survey Handbook). The evidence of Grant Douglas[201] provides an overview of the LUC system, the underlying principles, where it is currently being applied and recent projects in relation to LUC. An overview of the system is provided from this evidence in Box 57. A map of the land use classes of region is shown in Map 5, Section 6.5.2 and current land use in relation to the classes of land use capability is shown in Table 8 (Section 6.5.2).

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[200] REFERENCE TO TECHNICAL REPORT. Lynn, I. Manderson, M, Page, M, Harmsworth, G., Eyles, G., Douglas, G., MacKay, A. and Newsome, P. (2009). Land Use Capability Survey Handbook - A New Zealand handbook for the classification of land 3rd ed. Hamilton, AgResearch; Lincoln, Landcare Research; Lower Hutt; GNS science. 163p.

[201] LINK TO FURTHER EVIDENCE: Grant Douglas provides evidence in relation to Land Use Capability, its development and use and recent projects in relation to the Land Use Capability classification system.

Box 57 – Technical Concept Summary - Description of the LUC classification system

The following excerpt from the evidence of Grant Douglas provides an introduction to the Land Use Capability (LUC) classification system:

"*The LUC classification comprises three hierarchical levels – LUC class, LUC subclass, and LUC unit – which collectively describe the land's overall capability for use. It notes the main physical limitation or hazard to sustained productive use, and groups areas of land that require similar management and conservation treatment, and which are suitable for the same kind of crops, pasture or forestry species. The relationship between the three components is shown in Figure A (Lynn et al., 2009).*

The LUC class is the broadest grouping in the classification and indicates general capability for sustained production, after considering the land's physical limitations and versatility of use. There are eight classes (Figure B; Lynn et al., 2009), with LUC Class 1 being the most versatile multiple-use land with negligible physical limitations to arable use. LUC Class number increases with increasing limitations to use, and decreasing versatility of use. LUC Classes 1-4 are suitable for multiple uses whereas LUC Classes 5-7 are suitable for pastoralism or forestry. Class 8 is unsuitable for sustainable productive use, and is referred to as conservation land, retirement land or protection land."

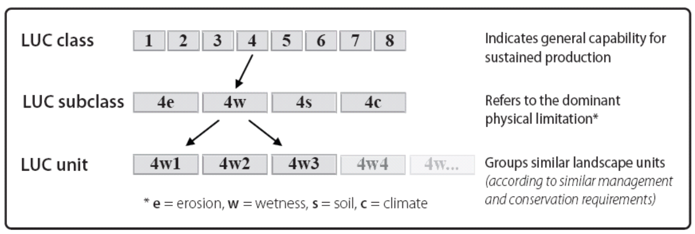

Figure A. Components of the Land Use Capability Classification (Lynn *et al*., 2009)

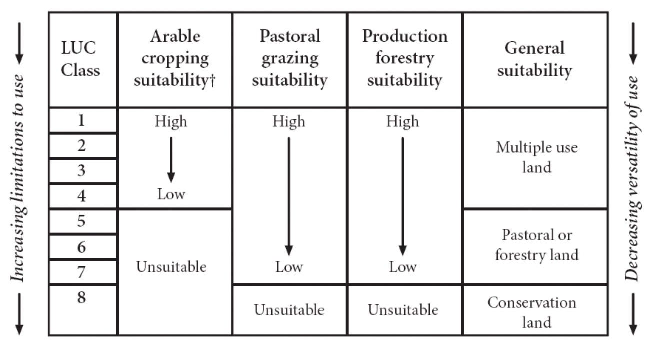

Figure B. Increasing limitations to use and decreasing versatility of use from LUC Class 1 to LUC Class 8 (Lynn *et al*., 2009)

318. The updated handbook further states "*Assessment of land for long-term sustained production is based on an interpretation of the physical information in a Land Resource Inventory (LRI) which is compiled from a field assessment of rock types, soils, landform and slopes, erosion types and severities, and vegetation cover. Land Resource Inventory is supplemented with information on climate, flood risk, erosion history and the effects of past practices.*" Lynn *et al*., 2009.

319. The LUC classification system is being used around New Zealand by a range of agencies and applications of the system include Horizons' Sustainable Land Use Initiative (SLUI), soil conservation plans of Taranaki Regional Council, Environment Bay of Plenty and Greater Wellington Regional Council, and the East Coast Forestry project. A LUC-based map layer has been used in a Gisborne District Council (a unitary authority) Plan.

320. Horizons has been involved in a number of projects in relation to LUC over the past few years, including:

i. The LUC upgrade scoping report (Douglas *et al*., 2006[202]),

ii. The LUC Handbook upgrade (Lynn *et al*., 2009),

iii. The LUC correlations project (Box 58, Harmsworth & Page, 2009[203, 204]).

Box 58: Technical project summary – Land use capability correlations project

The Correlation of Land Use Capability (LUC) Units into a Single LUC Classification for the Horizons Regional Council Area was a separate project to the LUC Handbook upgrade. New Zealand has 12 Land Resource Inventory (LRI) regional survey regions (Figure A) each has an individual regional legend. This project set out to correlate the six LUC regional legends that occur in the Horizons Region (Figure B) into a single regional legend. The new single regional correlation provides a single map for regional-scale assessments. This provides a single legend for those who complete mapping in the Region and provides a single legend for regional-scale analysis of Land Use Capability information.

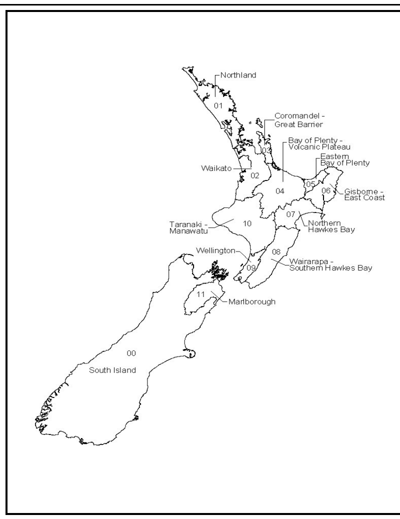

Figure A. New Zealand Land Resource Inventory (LRI) survey regions.

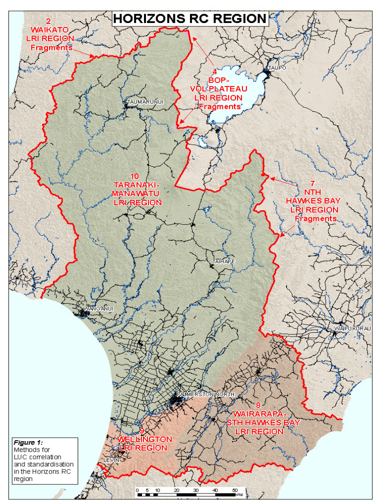

Figure B. The regional extent and existing NZLRI map region names.

[202] REFERENCE TO TECHNICAL REPORT: Douglas, G., Harmsworth, G., and McIvor, I. (2006). Updating the Land Use Capability Handbook – A Scoping Report. Horizons Regional Council. AgResearch Client report prepared for Horizons Regional Council.

[203] REFERENCE TO TECHNICAL REPORT: Harmsworth G. & Page M. (2009). Correlation of Land Use Capability (LUC) Units into a Single LUC Classification for the Horizons Regional Council Area. Landcare Research report prepared for Horizons Regional Council, LC0809/082.

[204] CLARIFICATION ON MY ROLE: I initiated this project and project-managed it on behalf of Horizons.

7.5.3 Using the Land Use Capability system in allocating nitrogen loss limits

321. The proposed policy framework in the POP aims to manage outputs or losses of nitrogen. From a technical perspective, this provides more flexibility than input based controls. Focusing on losses provides more flexibility for farm management as there are a range of land uses, and management options, that can be considered and customised to achieve loss limits on a given farm. This recognises that each farm is unique. One of the questions for Horizons policy team was at what level these limits should be set.

322. The analysis of Roygard and McArthur (2008) identified the methodology for determining the standards load limits from the concentration standards. Clothier *et al.* (2007) modelled the loss limits that would be required to achieve the standard load limits based on models of loading equity split and every hectare being allocated the same loss limit.

i. The loading equity split method calculated the current proportion of loading from sheep/beef and dairy to the Measured load in the river. This available allocation from Standard load was then split on this proportional basis.
ii. The per hectare method simply gave each hectare an equal split of the available loading at the Standard.

The allocations determined from these two methods did not seem feasible targets for dairy farming to meet.

323. Building on this analysis, the work of Clothier *et al*. (2007); Appendix 6 of that report, put forward a concept of allocation that reflected that some areas of land in the catchment had higher natural capital than others and that the loss limits attributed to land should reflect the capability of the land. Alec Mackay[205] and Helen Marr[206] present further information on this methodology and how it compares to other methods of allocation.

324. The method put forward by Clothier *et al.* (2007) used LUC as a proxy for the natural capital of the land. The LUC index assesses aspects of rock types, soils, landform and slopes, erosion types and severities, and vegetation cover. The LUC assessment is supplemented with information on climate, flood risk, erosion history, and the effects of past practices. LUC has a hierarchy of detail ranging from broadest level of eight LUC classes through to the sub classes (four for each of the classes) and units. LUC classes were used by the method in Clothier *et al.* (2007). These range from Class I, with no limitations, through to class VIII, which has many limitations to production.

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205 LINK TO FURTHER EVIDENCE: Alec Mackay provides evidence in relation to nitrogen allocation methods.
206 LINK TO FURTHER EVIDENCE: Helen Marr provides evidence in relation to nitrogen allocation methods.

325. The LUC index also includes a measure of productive potential. Appendix 6 of Clothier *et al.* (2007) used LUC information on potential production from a well-managed legume-based system without any improvement (ie. no fertilisers, irrigation etc) as a measure of the underlying capacity of the soil to produce and cope. Case studies for the upper Manawatu and Mangatainoka were completed by running OVERSEER for these production systems for each LUC class, to calculate N loss limits under pastoral use. The outputs from the OVERSEER runs were combined with the area of each LUC class and the attenuation factor to calculate catchment water quality outcomes (target non point source loadings for nitrogen). For more detail in relation to this work, refer to Clothier *et al*. (2007); Appendix 6, and/or the evidence of Dr Mackay[207] .

326. In Appendix 6, Clothier *et al*. (2007) provided two tables for each of the study catchments (upper Manawatu and Mangatainoka). These tables were used to inform the development of the table recommended by Policy 13.2. Ms Marr[208] presents further information on the derivation of Table 13.2.

7.5.4 Catchment outcomes from Table 13.2 in relation to catchment nitrogen loading

327. The catchment outcomes in terms of nitrogen loadings in river provide a measure of the anticipated environmental result. A further measure is the outcome in terms of effects on periphyton growth, which is discussed in Section 7.5.5 of this report.

328. Predicting nitrogen loading outcomes using the output loss limits from Table 13.2 is a simple process using the identified area of LUC classes in the study catchment and an attenuation factor. In a similar manner to water allocation and the core allocation limits, minimum flows, and surety of supply, the catchment outcomes make some assumptions in terms of every hectare of each LUC class of the catchment losing the full amount specified in Table 13.2. This assumption is unlikely to be being met in any of the catchments at present, but to show the potential policy outcome, this scenario is one that needs to be presented. Like surety-of-supply calculations for water allocation, these scenarios of catchment nitrogen loading present a “worse case scenario” under the proposed policy. The predicted outcome, once the approach is implemented, is likely to produce loadings that are different to these because:

i. Within the catchment, some areas will not be intensified to the level where the leaching losses specified in Table 13.2 will be occurring (ie. some areas will be

207 LINK TO FURTHER EVIDENCE: Alec Mackay provides evidence in relation to nitrogen allocation methods
208 LINK TO FURTHER EVIDENCE: Helen Marr provides evidence in relation to nitrogen allocation methods

losing less than the specified limits). This is likely to lower the predicted catchment loading outcome.

ii. Those areas that are losing more than the limits in Table 13.2 are likely to be required to reduce outputs to meet these limits The reductions from these areas will likely lower the loading in comparison to the current Measured load in the river.

iii. With the approach targeting intensive farming, some farms not included in the plan definition may lose more than the limits specified. This would increase the predicted leaching loss limit.

iv. The policy provides the choice of N loss limits from the regional-scale LUC mapping or from farm-scale mapping. The ability to chose between maps is likely to increase N loss limits for the farm and therefore the theoretical catchment outcomes would increase above those calculated by the regional-scale mapping.

v. Point source inputs are likely to increase the loading limits above those predicted based on Table 13.2

329. Roygard and McArthur (2008) documented the predicted catchment outcomes of Table 13.2 in the two study catchments (ie. upper Manawatu and the Mangatainoka). The Measured loads and the Standard loads are also compared for these study catchments. Box 59 outlines this work. In summary, the catchment outcomes of the table differ in relation to current Measured load and the Standard load limit. This is due to differences in the area of the various land use classes within each of the study catchments, and the differing hydrology in each of the catchments:

i. **For the Manawatu at Hopelands example**

   a. The Year 1 non point source load target of 859 t/year is higher than the current Measured load of 745 t/y.

   b. The Year 20 non point source load target of 751 t/y is higher than the current Measured load of 745 t/y, and the average Standard load limit of 358 t/y.

ii. **For the Mangatainoka catchment**

   a. The Year 1 non point source load target of 360 t /year is lower than the current Measured load of 603 t/y.

   b. The Year 20 non point source load target of 301 t/y is lower than the current Measured load of 603 t/y, and higher than the average Standard load limit of 266 t/y.

Box 59: Determining catchment outcomes from Table 13.2

The catchment outcomes from the N loss limits specified in Table 13.1 are calculated using the N loss limits (assuming these to be the actual loss) and the area of each LUC class in the catchment, and the attenuation factor. For the examples below[209], an attenuation factor 0.5 has been used.

Example 1: Manawatu at Hopelands

- The Year 1 target of 859 t /year is higher than the current Measured load 745 t/y. The Year 20 target of 751 t/y is higher than the current Measured load and the average Standard load of 358 t/y

Upper Manawatu		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 Manawatu (ha)		0	12,424	20,257	11,508	907	57,254	22,108	5,180	129,638
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

Example 2: The Mangatainoka catchment

- The year one target of 360 t /year is lower than the current measured load 603 t/y. The year 20 target of 301 t/y is higher than the average standard load of 266 t/y.

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	10,394	6074	1498	409	18,110	8,057	3,874	48,965
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	12.0	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
Standard load limit (Tonnes/year)										266
Measured load (Tonnes/year)										603
NPS load (Tonnes/year)										599.6

[209] Some of the numbers for Measured load and non-point source load differ from those of Mackay *et al.* (2008) and are the numbers from the later analysis by Roygard and McArthur (2008).

330. Potential catchment outcomes for other priority catchments in relation to Table 13.2 are documented in the evidence of Ms McArthur[210]. Roygard and McArthur (2008) also documented a range of catchment outcomes for these two catchments using the recommendations of Clothier *et al.* (2007) for implementation of best management practices and mitigation options could reduce nitrogen loss from the root zone by up to one third. Roygard and McArthur (2008) further incorporated into the non-point source scenarios, management for point source discharges for both nitrogen and phosphorus.

7.5.5 Catchment outcomes from Table 13.2 in relation to periphyton biomass

331. A key part of the approach of Table 13.2 is to reduce the impact of periphyton on values for Life Supporting Capacity, Aesthetics, Contact Recreation, and Trout Fisheries. This impact from the nutrient loading needs to be considered in the areas of the catchment where the approach is being applied, and downstream parts of the river systems, and other downstream receiving environments (lakes, estuaries and coastal waters).

332. Dr Barry Biggs has modelled the maximum monthly periphyton biomass under several nutrient loading scenarios (including the Standard load limit and Table 13.2 related loads) for the two study catchments. The model predictions indicate that a shift in soluble inorganic nitrogen (SIN) and dissolved reactive phosphorus (DRP) from current state to the Standard load limits would be accompanied by 30 to 75% reductions in maximum monthly periphyton biomass. Dr Biggs presents further detail on this analysis in his evidence, and an overview of the work is presented in Box 60. A key assumption of this modelling is the use of average number of days between flushing flow events or mean days of accrual (MDA). In-river there is a high level of variation around the average number of days between events. For example, during extended dry periods, the days of accrual can be considerably higher than the average number of days of accrual. When this occurs, periphyton biomass has longer to grow and to accrue to a level where it impacts on the values of a water body.

333. The modelling scenarios predict for the current state that, compared to the proposed standard of 120 mg/m^3, the average accrual of periphyton between flushing flow events is 205 mg/m^3 in the upper Manawatu and 75 mg/m^3 in the Mangatainoka. This is consistent with Horizons' annual monitoring of periphyton data, which shows that the Manawatu River at Hopelands exceeded the proposed Standard value 56% of the time it has been sampled (Death 2009). For the very limited data set for the Mangatainoka

[210] LINK TO FURTHER EVIDENCE: Kate McArthur provides evidence in relation to the potential catchment outcomes from Table 13.2 in target catchments

River, only one exceedance has been recorded. The historic monitoring data collected annually by Horizons does not necessarily reflect the monthly maximum conditions, as the timing of sampling in relation to accrual periods differed considerably. Further, historic sampling was done using an acetone-based method, whereas the correct standard method uses hot ethanol. There is a question as to whether the acetone method measures all chlorophyll *a*. For more detail in relation to this refer to the report of Kilroy *et al.* (2007)[211] or the evidence of Ms McArthur[212].

334. The periphyton modelling results reflect the N loadings results in the two study catchments. In the upper Manawatu River, the periphyton outcomes are predicted to increase from the current state of 205 mg/m^3 to 224 mg/m^3 in Year 1, then decrease to 209 mg/m^3 in Year 20. In the Mangatainoka River, the periphyton outcomes are predicted to decrease from the current state of 75 mg/m^3 to 60 mg/m^3 in Year 1 then decrease to 54 mg/m^3 in Year 20.

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211 REFERENCE TO TECHNICAL REPORT: Kilroy C., Biggs B. and Death R.G. (2008). A periphyton monitoring plan for the Manawatu-Wanganui region. Prepared for Horizons Regional Council. NIWA Client Report CHC2008-03.

212 LINK TO FURTHER EVIDENCE: Kate McArthur provides further evidence in relation to periphyton monitoring programme (historic and current) and some of the monitoring results from these.

Box 60: Technical project summary – Periphyton response to changes in nutrient loading

Dr Barry Biggs modelled the periphyton response to various nutrient loading scenarios for the upper Manawatu River and Mangatainoka River. The results of the modelling reflect the predicted maximum monthly periphyton biomass under nitrogen limited conditions. The standards for periphyton biomass in both of the study catchments at the monitoring sites at Hopelands and SH2 are 120 milligrams chlorophyll *a*/m². The modelled results are for an average mean days of accrual of 36 days. This reflects 36 days between flushing events. The timing between flushing events can be more or less than this, and the periphyton biomass would likely be lower (better) when flushing events are closer together and greater (worse) when the accrual periods are longer, eg. during a dry year with few high flow events.

The modelled scenarios included the nutrient loadings calculated by Roygard and McArthur 2008 for:

- Current (Measured) load.
- Standard load (based on the standard of 0.444 g SIN/m³).
- Ideal load as calculated using the more stringent nitrogen standard for Hopelands and the Mangatainoka (0.110 g SIN/m³).
- Year 1, Year 5, Year 10 and Year 20 outcomes from Table 13.2 of the POP.

Further scenarios were based on the modelling of Clothier *et al.* (2007):

- Including the one third reduction in non-point source inputs via implementation of mitigation practices.
- Intensification scenario for sheep/beef.
- Intensification scenario for dairy to higher production (1,200 kg/MS/ha).
- Intensification scenario for dairy expansion to all LUC class I to III.

Table A: Predicted instantaneous SIN and DRP concentrations, and periphyton biomass for the Manawatu River at Hopelands and the Mangatainoka River at SH2, under different nutrient loading scenarios. MDA: mean days of accrual. Nutrient concentrations are mg m^{-3}. Chlorophyll *a* biomass is in mg chlorophyll *a* m^{-2}. Chl(N): predicted maximum periphyton biomass under nitrogen-limited conditions. Chl (P): predicted maximum periphyton biomass under phosphorus-limited conditions. SIN concentrations rounded to 10 mg m^{-3}, DRP concentrations rounded to 1 mg m^{-3}. Sourced from Dr Barry Biggs' S42A report)

	River							
	Manawatu River at Hopelands (MDA: 36 d)				Mangatainoka River at SH2 (MDA: 22 d)			
Scenario	**SIN**	**DRP**	**Chl (N)**	**Chl (P)**	**SIN**	**DRP**	**Chl (N)**	**Chl (P)**
Current state	870	23	205	89	1,210	12	73	18
1/3 reduction	580	13	167	25	910	9	64	6
Standard load limit	430	9	144	21	600	9	52	6
Ideal load	110		72		150		26	
Rule 13-1 Year 1 load	1,030		224		820		60	
Rule 13-1 Year 5 load	980		218		760		58	
Rule 13-1 Year 10 load	920		211		710		56	
Rule 13-1 Year 20 load	900		209		690		54	
1200 kg MS/ha load	1,180		240					
Sheep & beef intensification	960		216					
LUC dairy expansion	1,040		225					

7.5.6 Catchment outcomes from Table 13.2 when using more detailed rainfall and LUC information

335. The Implementation of FARM strategies for Contaminant Management Report (Mackay *et al.* 2008[213]; Appendices 2 and 3) tested the use of more detailed information in relation to rainfall and LUC, to see how this changed the calculated water quality outcome. Dr Mackay[214] provides evidence in relation to this work. In summary, the approach calculated the different catchment outcomes using more detailed LUC information (eg. at the class, sub class and unit level) and also tested the use of more detailed rainfall information, in 200 mm bands, combined with the more detailed LUC unit information. The rainfall in 200 mm bands was determined by isohyets used by Horizons prior to the availability of the Tait and Sturman (2008) report. This work confirmed that the more detailed LUC information, combined with average rainfall, provides the same catchment outcomes (Table 13). Combining the most detailed LUC unit information with the 200 mm bands of rainfall produces a similar (lower) catchment nitrogen loading outcome.

Table 13. Nitrogen loading in two study catchments summed for the N losses calculated in OVERSEER using 75% of the average weighted (by area) "Attainable potential livestock carrying capacity" for the soils (a) in each LUC class and average rainfall; (b), LUC sub class and average rainfall; (c) LUC unit and average rainfall; and (d) LUC unit and rainfall in 200 mm bands.

		Catchment	
		Upper Manawatu	**Mangatainoka**
Level of LUC detail	**Rainfall[a]**	**N loading in river (tonnes/year)**	
(a) Class	Average	1,254.843	554.679
(b) Sub class	Average	1,254.843	554.679
(c) Unit	Average	1,255.464	554.679
(d) Unit	200 mm bands	1,220.358	494.147

[a] Average rainfall in the upper Manawatu is 1,357 mm, average rainfall in the Mangatainoka is 1,789 mm

336. At the overall level for catchment outcomes, the use of more detail makes little difference. However, if the more detailed tables (similar to those of Appendix 1 to 4 of Mackay *et al*., 2008) were used, individual N loss limits for specific farms would likely change with the inclusion of further detail. As a general rule, it was determined that:

i. The N loss limits on farms with flat to rolling landscapes, which also include hill land and steep land, would reduce due to:

[213] REFERENCE TO TECHNICAL REPORT: Mackay A., Clothier, B. Gray R and Green S. (2008). Implementation of FARM Strategies For Contaminant Management – Further questions. A report by SLURI (Sustainable Land Use Research Initiative) for Horizons Regional Council. Horizons report 2007/Ext/870.

[214] LINK TO FURTHER EVIDENCE: Alec Mackay provides evidence in relation to the Mackay *et al*. (2008) report.

a. The inclusion of less versatile soils by more detailed mapping.

b. Use of actual rainfall, which is often lower than the catchment average.

c. Low slope classes.

ii. The N loss limits on farms with hill land and steep land, which also include flat to rolling landscapes, would increase due to:

a. The inclusion of more versatile soils identified by more detailed mapping.

b. Use of actual rainfall, which is often higher than the catchment average.

c. Higher slope classes.

7.5.7 Mitigation options in relation to LUC class

337. Mackay *et al*. (2008) considered mitigation options for N leaching losses in relation to the soils of each LUC class (Figure 2). This work is further presented by Dr Mackay. The conclusion of the work was that: "*As a general rule mitigation options decrease as the producer moves from elite and versatile soils (LUC classes I and II) to those with limitations to use (Classes III and greater). The absolute cost of mitigation (eg. application costs) and/or the cost of mitigation as a function of production or income from land increases, as the limitations to use increase*" (Mackay *et al*., 2008).

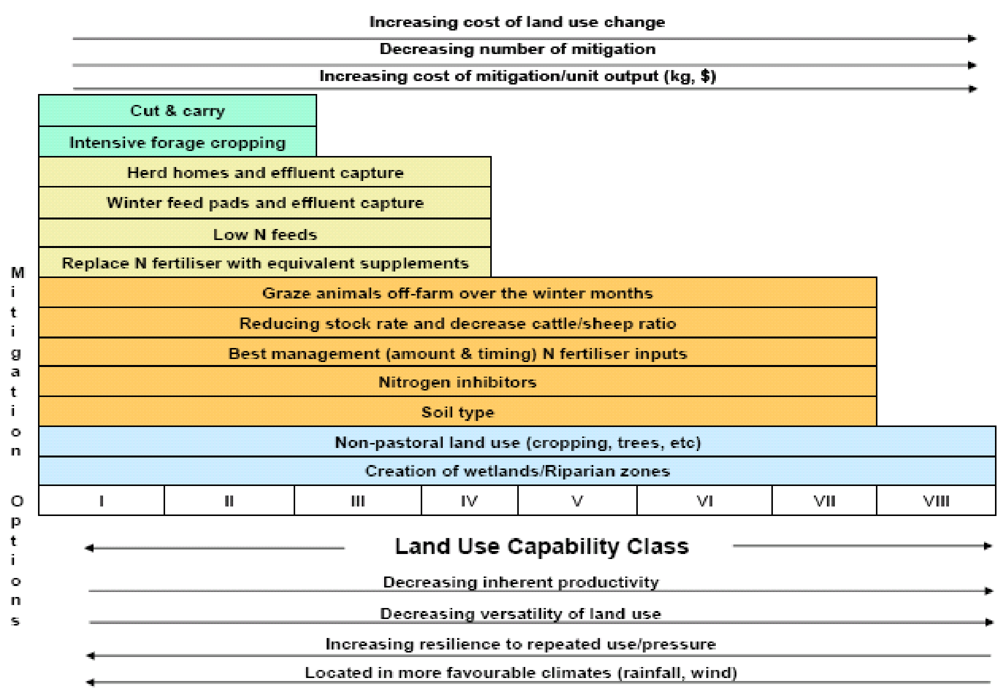

Figure 2. Number and alignment of the mitigation options with the soils in each LUC class.

7.5.8 Weighting of nitrogen leaching losses in relation to LUC class

338. Mackay *et al.* (2008) addressed a range of questions in relation to the weighting of nitrogen leaching losses in relation to LUC classes. This work concluded that: "*If the goal of policy is to encourage efficient land resource use with the least environmental impact, the N leaching loss limit should be weighted towards those soils with the greatest natural capital. If an imperative of policy is to retain land use options on soils with little natural capital, the weighting of the N leaching loss limit would need to be increased on these soils. These options could be explored in further analysis.*" (Mackay *et al.*, 2008). Some further testing of leaching losses in relation to LUC class has been completed during testing of the approach on farms in the Region, as outlined in (Section 7.7).

7.6 Use of OVERSEER

7.6.1 Introduction

339. The nitrogen loss limits specified in Table 13.2 are to be calculated using the OVERSEER nutrient budget model, which has been selected as the tool for calculating losses from farms. Possible alternatives to the use of this model are outlined in the evidence of Brent Clothier[215]. Alternatives to using a model to calculate the leaching losses are discussed in the report of Clothier *et al.* (2007); p47 and Appendix 3. Because of the variation in losses across farms, and at differing times on farm, it can be difficult to accurately measure the total losses from a farm on an annual basis, and this is currently not considered economically feasible for the purpose of nutrient management, given the level of monitoring required. Research projects have measured farm losses and have informed the development of the OVERSEER model. The evidence of Dr Ledgard shows that the model shows close agreement with field measurements of losses of nitrogen.

340. The OVERSEER model has been used widely in the technical work carried out in relation to the POP approach to nutrient management. The model is also used by the fertiliser industry and Fonterra for nutrient budgets in relation to the Clean Streams Accord, and is used by Environment Waikato in relation to its approach to nutrient management around Lake Taupo. The evidence of Dr Ledgard[216] includes an overview of how the model works and how it can be applied in nutrient management in agricultural

[215] LINK TO FURTHER EVIDENCE: Brent Clothier provides evidence in relation to OVERSEER and how it compares to other models that are available.

[216] LINK TO FURTHER EVIDENCE: Stewart Ledgard provides evidence in relation to OVERSEER.

systems. In relation to its suitability for use, the model has sound scientific underpinning, is well understood, has an ownership structure that is committed to continuous improvement, is freely available for use, and has a mechanism for training through courses at Massey University.

341. Reliable input information is needed to ensure accurate outputs from the OVERSEER model, and Dr Ledgard states that uncertainty associated with this can be in the order of ±20%. This shows the importance of an operator who has a good understanding of how the model works (ie. preferably someone who has been trained in the model's use through the training courses available at Massey University).

342. OVERSEER has been developed based on research information using good practices for various inputs. Therefore, the processes within OVERSEER assume these practices are being managed similarly for the farm for which it is making predictions. Where these good practice assumptions are not being met for that farm, the outputs predicted by OVERSEER may not be accurate and may require some level of adjustment to accurately relate to the outcome for that farm. The good practice assumptions, which are discussed in the evidence of Dr Ledgard, relate to fertiliser application, farm dairy effluent management, and no direct excreta connectivity to water bodies such as via direct stock access to water bodies or via stock crossings, etc.

7.6.2 Recommendation

343. The information requirements for inputs to the model and best practice assumptions can influence the accuracy of OVERSEER predictions. It is recommended that, as part of the application of OVERSEER, the source of input information and any assumptions in relation to it are documented.

344. Further, it is recommended that the best practice assumptions be checked for the farm and checked as part of running the OVERSEER model. Where these assumptions are not being met, the influence of these best practice assumptions on the overall result should be determined and documented.

7.6.3 To what inputs to the model are the OVERSEER N leaching results most sensitive?

345. Based on a sensitivity analysis of the model for Environment Waikato, Dr Ledgard reports: "*The high impact user-derived variables were: 1) annual rainfall; 2) pasture*

development status; and 3) clover content. For each of these variables, it is important that the user takes a consistent approach, such as a using an annual average rainfall map based on long-term monitoring sites. OVERSEER has been well validated with pasture development status in the "developed" mode and therefore it is appropriate to use this as a default input. Similarly, for clover status it is recommended that the default Medium level is used in almost all cases, since all research used in model development refers to this category. As noted on the model, this Medium status accounts for variation over time and with inputs such as N fertiliser, and it should only be changed in extreme situations, such as where clover root weevil has markedly reduced clover content in the long-term."

346. A map of rainfall information to use for input data for OVERSEER model runs has been produced for Horizons' Region. The information is a high-resolution map of long-term average annual rainfall produced from the available long-term rainfall stations operated by Horizons and NIWA. The project, and the maps produced, are documented in the report Annual rainfall maps for the Horizons-Manawatu Region" (Tait and Sturman, 2008[217, 218]). The period of rainfall record selected for this project was 1971-2001, which was selected because it was the latest climate "normal" period (Tait and Sturman, 2007). The period 1978-2007 is also mapped in the report to represent the most recent 30-year period. There are some minor differences between the maps.

7.6.4 Recommendation

347. The report of Tait and Sturman (2008) maps both median annual rainfall and mean annual rainfall for these two time periods. I recommend that the map of mean annual rainfall for 1971-2001 (as presented in Map 12) is used to define rainfall inputs into the FARM strategy approach of the POP. NIWA recommend this period as a climate "normal" period. The mean annual rainfall map is recommended because OVERSEER operates on a long-term annual-average basis.

348. The recommendation for use in the FARM strategy approach is that the information from this spatial data set will provide the average rainfall for the area within the farm boundaries. The spatial resolution of the data is 500 m^2. The methods used to produce these grids from the available information are described in the report of Tait and

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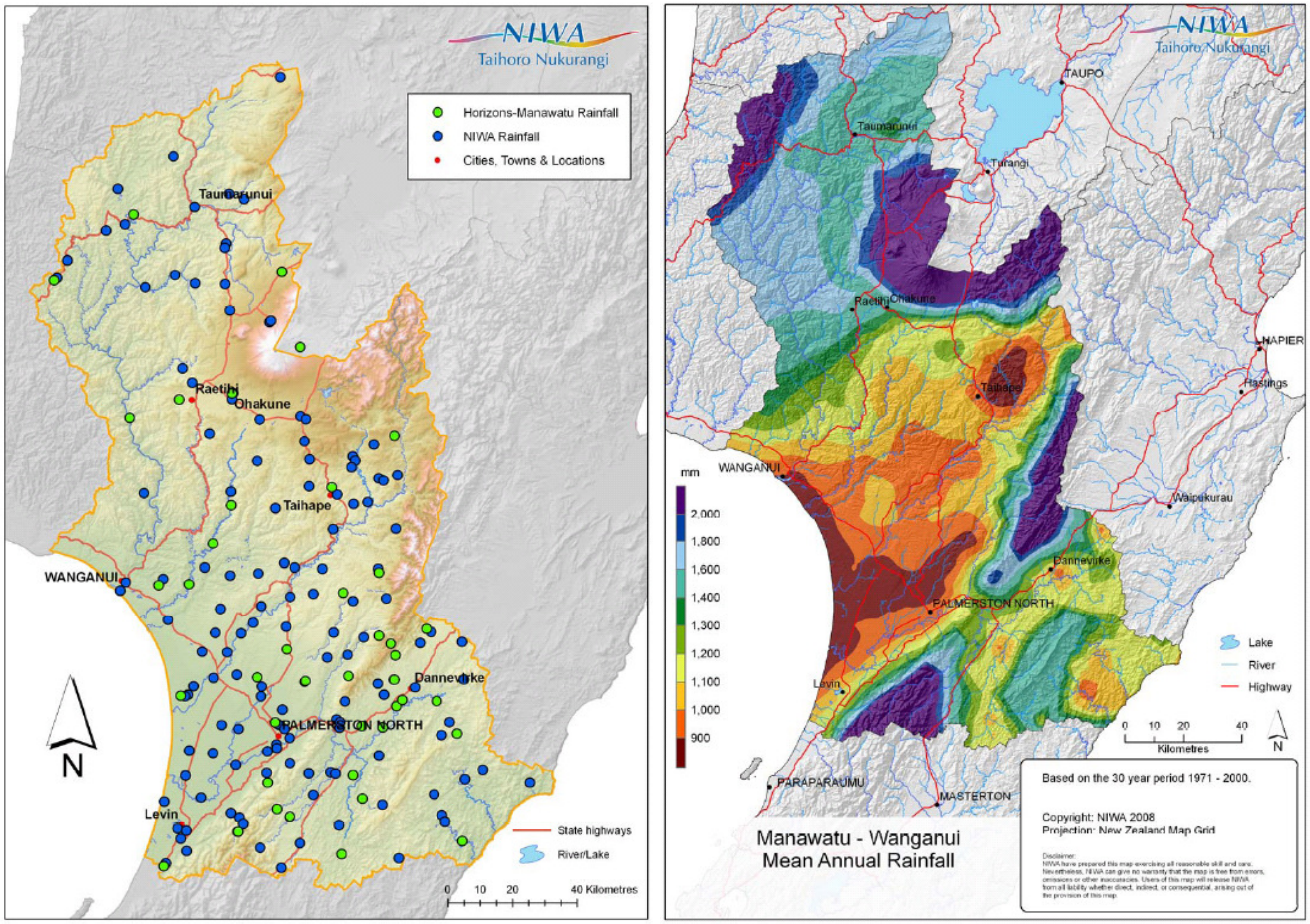
[217] REFERENCE TO TECHNICAL REPORT: Tait, A., and Sturman J., (2008). Annual rainfall maps for the Horizons-Manawatu Region. Prepared for Horizons Regional Council. NIWA Client report WLG2008/69. Envirolink project HZLC60.

[218] CLARIFICATION ON MY ROLE: I initiated this project and sought funding for it via Envirolink. Raelene Hurndell project managed the project for Horizons.

Sturman (2008). To my knowledge, this is the most accurate estimation of annual rainfall information available for the Region.



Map 12. Rainfall information from Tait and Sturman (2008). Left: Location of the rainfall sites used in the analysis. Right: Mean annual rainfall data for the period 1971-2000.

7.7 Testing the FARM strategy approach on-farm

7.7.1 Introduction

349. The proposed Farmer Applied Resource Management (FARM) strategy document is a reporting tool to complete farm-specific assessments of factors that may contribute to non-point source contamination of water bodies. The strategy covers a range of factors in relation to non-point source contamination, eg. stock access to water bodies, management of effluent (for farms where this applies), and nutrient losses from the farm. Many aspects of the FARM strategy can be considered best practice, and align with current requirements either from Horizons or as part of industry initiatives. The major new component is the assessment of nitrogen loss from the total farm area, and assessing that in relation to the N loss limits specified in Table 13.2 of the POP.

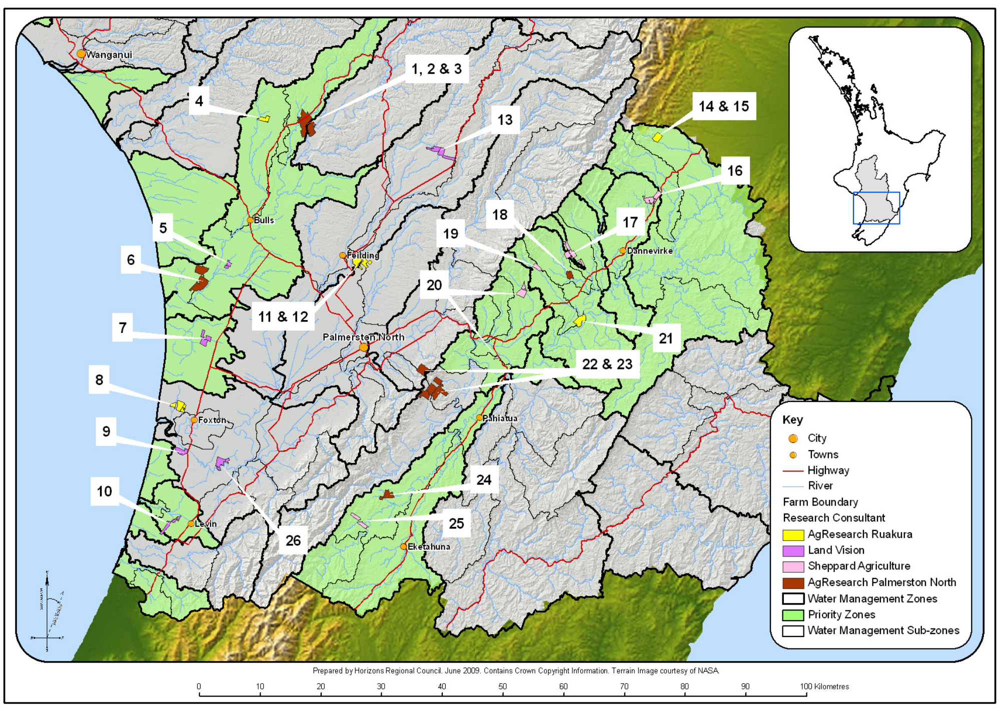
350. The originally proposed FARM strategy document was largely completed as a policy project. The technical work tested the requirements within the document and the document itself, to identify improvements to the overall approach and the FARM strategy document. This testing included assessment of the costs of preparing and implementing the strategies. A further component of this work was to separate the costs of existing requirements eg. to be compliant with existing consents or to be compliant with industry initiatives such as the Clean Streams Accord.

351. The test FARM strategy projects also involved testing the outcomes of some of the proposed policies in relation to options related to use of Land Use Capability (LUC) mapping. These included testing the choice to use the regional-scale LUC mapping or to complete more detailed farm mapping, and how this choice related to specific farm results and overall catchment outcomes. A further LUC-based question was how the use of adjustments of LUC class, where limitations in relation to water availability had been overcome by irrigation, would impact on the overall catchment outcomes. This adjustment of LUC where irrigation is in place is a recommended practice in the updated Land Use Capability Handbook (Lynn *et al*., 2009)[219] and is discussed further in the evidence of Peter Taylor.

[219] REFERENCE TO TECHNICAL REPORT. Lynn, I. Manderson, M, Page, M, Harmsworth, G., Eyles, G., Douglas, G., MacKay, A. and Newsome, P. (2009). Land Use Capability Survey Handbook - A New Zealand handbook for the classification of land; 3rd ed. Hamilton, AgResearch; Lincoln, Landcare Research; GNS Science.

7.7.2 Overview of technical work

352. The project work for testing the FARM strategy approach has been completed in two phases. The first phase included completion of six comprehensive FARM strategies, as documented in Manderson and Mackay (2007)[220]. The second phase of FARM strategy work involved using three different providers. Two of these were agricultural consultants (LandVision and Sheppard Agriculture). The third provider was the Emissions Unit of AgResearch, which complete the majority of the benchmarking for Environment Waikato in relation to the nutrient management approach around Lake Taupo. Each of these providers completed five FARM strategies and provided both the individual reports and an overview of the results from these, including recommendations on ways to improve the approach. The locations of the test FARM strategy projects in relation to the priority catchments are shown in Map 13. The test FARM strategies do not include any market gardening/commercial vegetable growing operations as multiple offers to do such studies were not taken up by the growers or Horticulture New Zealand.



Map 13. Locations of the Horizons' test FARM strategies in relation to the priority catchments. Some locations are numbered more than once to indicate scenarios tested, eg. including or excluding a support block; or sheep/beef and potential conversion to dairy.

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220 REFERENCE TO TECHNICAL REPORT. Manderson A. and Mackay A. (2008). FARM test farms project: Testing the One Plan approach to contaminant management and linking the FARM strategy to the SLUI Whole Farm Plan Design. A report by SLURI (Sustainable Land Use Research Initiative) for Horizons Regional Council.

7.7.3 The first test farms project

353. The first test FARMs project[221] was completed for Horizons by AgResearch. This project involved very specific comprehensive analyses that were well beyond the minimum requirements for a standard FARM strategy. The project placed considerable emphasis on testing and refining the approach. The study farms were selected to provide a geographic spread of above-average production farms, with a range of rainfalls, with a mix of enterprises that had willing farm owners, who were farming leaders. Not all of the originally selected farms had strategies completed. Two farm owners withdrew, one before work had started and one when the work was close to completion (this work remains unavailable to Horizons). The FARM strategy on a third farm, Waitatapia in the coastal Rangitikei, was not undertaken due the scale of the work required to complete the strategy on this large, technically advanced mixed enterprise that includes forestry, mixed cropping, vegetable production, large-scale irrigation, and many precision agriculture practices. To limit the scope and timeframes of the test farms study, it was decided to select an alternative farm to study.

354. The results, findings and recommendations of the first test farms project are documented in detail in the report of Manderson and Mackay (2008). The report includes each of the FARM strategies that were produced and a summary of the combined results for these. The report also has sections on:

    i. FARM strategy reporting formats and preparation guidelines.
    ii. Comparison of N loss limits from various mapping scales.
    iii. Recommendations for FARM strategy development.
    iv. Adjusting LUC class information in relation to irrigation.

    Andrew Manderson[222] provides evidence in relation to this project and the report, and further information in relation to his work following this report to improve the FARM strategy document. A summary of some of the findings is presented in Box 61.

7.7.4 Dissemination of results

355. Following completion of the work of Manderson and Mackay (2008), Horizons held a workshop with stakeholders to disseminate and discuss the findings. Findings from further work by the dairy industry were also discussed; however these reports were not disclosed to Horizons at that time. Horizons offered to work with any provider to

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[221] CLARIFICATION ON MY ROLE: I was a part of the project team that scoped this project and I project-managed it on behalf of Horizons.

[222] LINK TO FURTHER EVIDENCE: Andrew Manderson provides evidence in relation to the first test farms project and subsequent project work in relation to the improving the FARM strategy document.

complete FARM strategies in order to refine the FARM strategy approach. The FARM strategy reports have been in the public domain for a considerable time and Horizons has sought feedback on these.

Box 61: Technical project summary -Test FARMs project 1- Manderson & Mackay (2008)

The findings and recommendations of Manderson and Mackay (2008) in relation to the N loss limits included:

1. Recommending the use of total farm area as opposed to the effective area of the farm. The use of whole farm area is built into the catchment outcomes that include every hectare of the catchment.
2. Land use intensity on the farms was not uniform, and less intensive areas could be used to balance more intensive areas. The overall result at the farm level is what is assessed.
3. Several case studies had mitigation practices in place and, in the main, the case study farmers were managing their N inputs efficiently.
4. Year 1 N loss targets were identified as being achievable for all case studies, without any major changes to their farming systems.
5. Extrapolating these results, similar results were expected for the rest of the Region.
6. Exceptions to this were identified as including: ultra-intensive operations in traditionally marginal landscapes, and farms with particular land use environment combinations such as high rainfall, coarse shallow soils (eg. sands), low capability land, few trees or non-farmed areas, and high stocking rates.
7. Common recommendations to enable achieving the N loss limits on-farm included requirements such as fulfilling existing current consent requirements (particularly farm dairy effluent management), completing Clean Stream Accord requirements (particularly stream fencing) and in some cases supplementary practices (eg. use of N inhibitors).
8. All four dairy farms had recommendations for improving farm dairy effluent management and common themes for this were larger ponds and bigger effluent application areas. All four dairy farms required further stream fencing.
9. Recommended protocols for preparing FARM strategies could be dove-tailed with similar farm planning documents for the Sustainable Land Use Initiative (SLUI)
10. Three levels of reporting where identified: 1) a minimum level to meet the requirements of the rule; 2) a medium level that included further detail (eg. on-farm mapping); and 3) a comprehensive level, which would prepare very detailed assessments of options.

7.7.5 Further test farms

356. The further test FARMs projects[223] sought to test the FARM strategy in situations where meeting the N loss limits would be difficult, as identified by Manderson and Mackay (2008). Further farms were also selected to get a better geographic spread. This was completed in relation to the proposed Rule 13-1 applying to conversions outside of the priority catchments. The evidence of Mr Taylor[224] summarises these further test FARMs projects and reports on further work to improve the FARM strategy document. Each of the three providers has completed an overview report to summarise the work completed on the five test farms that they each completed. These reports are: AgResearch (2009)[225]; Sheppard Agriculture (2009a)[226]; and LandVision (2009)[227]. A full reference

[223] CLARIFICATION ON MY ROLE: I was a part of the project team that scoped and contracted this further project work. Peter Taylor managed these projects.

[224] LINK TO FURTHER EVIDENCE: Peter Taylor provides evidence in relation to the further test farms project and provides a summary of the combined results from all of the test FARMs projects.

[225] REFERENCE TO TECHNICAL REPORT: AgResearch (2009a). FARM Strategy – Overview Report. Report prepared for Horizons Regional Council by Bob Longhurst.

list for each of the FARM strategy reports is provided in the evidence of Mr Taylor. The Emissions Unit of AgResearch and LandVision were requested to complete medium-level FARM strategies, including farm-scale mapping. All farm mapping was completed by LandVision. Sheppard Agriculture was requested to complete minimum-level assessments and subsequent to these initial assessments, further work on two farms was requested, which is reported in Sheppard Agriculture, 2009b[228]). The evidence of Mr Taylor provides an overview of this work, Rachel Rogers[229] of Sheppard Agriculture, Mark Sheppard[230] of AgResearch and Lachie Grant[231] of LandVision each present a summary of the FARM strategy work they have completed.

357. The second phase of test FARM strategy work set out to identify where the N loss limits would be difficult to meet. A broad summary of this is outlined in Box 62. In very broad terms it may be difficult to meet the proposed N loss limits, with current technologies, where two or more of the following variables coincide:

i. high rainfall;
ii. high stocking rate; and
iii. high proportions of the farm in LUC Class 4 and above.

Some farms in these situations have been able to meet the proposed loss limits through:

iv. Changes to some farm practices;
v. incorporation of associated support blocks to the farm;
vi. improved information in relation to on-farm LUC mapping; and
vii. the adjustment of LUC class in relation to overcoming the limitation of water through irrigation.

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226 REFERENCE TO TECHNICAL REPORT: Sheppard Agriculture (2009a). Reporting the effect and implications the One Plan and FARM Strategy has on individual dairy farm properties in the Tararua District. A case study approach. Prepared by Rachel Rogers.

227 REFERENCE TO TECHNICAL REPORT: LandVision (2009a). FARM Strategy Summary Report. Prepared for Horizons Regional Council by LandVision Ltd., Wanganui.

228 REFERENCE TO TECHNICAL REPORT: Sheppard Agriculture (2009b). Reporting the effect and implications the One Plan and FARM Strategy has on individual dairy farm properties in the Tararua District. A case study approach – Further Analysis. Prepared by Rachel Rogers.

229 LINK TO FURTHER EVIDENCE: Rachel Rogers provides evidence in relation to the FARM strategies completed by Sheppard Agriculture.

230 LINK TO FURTHER EVIDENCE: Mark Sheppard provides evidence in relation to the FARM strategies completed by AgReseach's Emissions Unit

231 LINK TO FURTHER EVIDENCE: Lachie Grant provides evidence in relation to the FARM strategies completed by LandVision.

Box 62. Technical Project Summary – Further test FARM strategies to identify areas where the N loss limits are difficult to achieve

The second phase of test FARM work set out to identify where the N loss limits would be difficult to meet. As the project specifically targeted the areas where it was expected to be difficult to meet the limits, extrapolation to regional averages by pooling all of the information is not recommended for some purposes. However, using groups of the farm results, where they are representative of a situation that occurs in the Region, can enable extrapolation to similar situations in the Region.

A range of farms was identified as requiring reductions to meet the N loss limits of Table 13.2. For most of these farms, these reductions were achievable through: 1) changes in some practices; 2) improved farm mapping changing the required N loss limit; and 3) through inclusion of support blocks that were not identified during the initial analyses and 4) the adjustment of LUC class in relation to overcoming the limitation of water through irrigation

Of the farms that showed difficulty in meeting the standard, four in particular were identified as having difficulty meeting the loss limits without major changes to the farming system. These are outlined in the table below. These farms each have high proportion of LUC land Class 4 and above. Other factors that combine with this are high rainfall and high stocking rates and/or production.

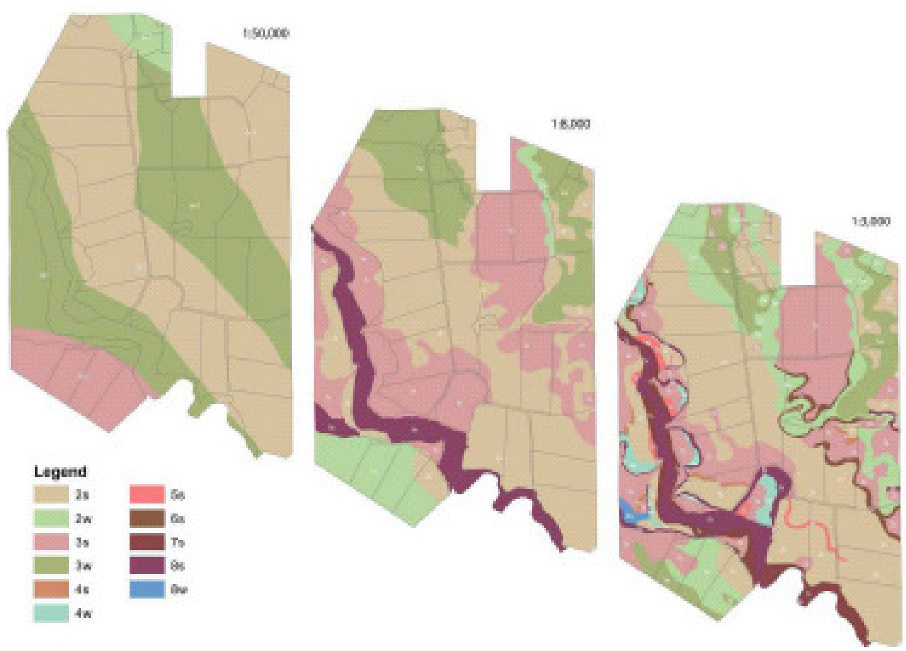
Farm Name	Stoney Creek Partnership (Boyden)	Muskit Enterprises (Kelly)	Jala Enterprises (Galloway)	Janssen
Farm type	Dairy	Dairy	Dairy	Dairy
Location	Woodville	Matamau, Dannevirke	Nireaha, Eketahuna	Norsewood
Total Farm Area inclusive of support block (ha)	231	275	170	156
Effective Farm Area Dairy Unit(ha)	187	229	78	148
Irrigated	No	No	No	No
Cows milked	417	690	194	380
Stocking rate (Total Farm Area)	1.8	2.5	1.1	2.44
Stocking rate Effective Farm Area	2.2	3.0	2.5	2.57
MS/ha/yr (effective dairy unit)	754	1,270	897	1284
Rainfall (mm)	1,300	1,300	2,300	1718
%age of land in LUC IV or above	55	91	81	65
Current N loss	34	34	31	28
Reduction to achieve Year 1 target	13	-18	-11	-9
Further reduction to meet Year 5	1	-1	-2	2
Further reduction to meet Year 10	2	-1	-2	-1
Further reduction to meet Year 20	2	0	0	-1

7.7.6 Mapping at different scales of LUC

358. The proposed FARM strategy approach in the POP provides the farm owner with the choice between loss limits calculated from the regionally available 1:50,000 scale mapping or more specific mapping on farm. It is noted that the water quality targets for the various catchments have been calculated using catchment-scale analysis of the regional-scale NZLRI data at 1:50,000 scale. The implication is that if farmers choose the option with the greatest N-loss limit for their farm, then the water quality outcome (ie. nitrogen loading) predicted by the model may be higher than it was originally calculated

to be. However, allowing the farm owner to have the farm mapped provides an opportunity to ensure the data for the farm is accurate. There are likely to be cases where the broad-scale mapping is not indicative of what is found on farms. Map 14 provides an example of how the regional-scale mapping and farm-scale mapping can differ. The example is for the Barrow Farm (case study 1) from Manderson and Mackay (2008).

359. As part of the test farms projects, a total of 13 assessments of N loss limits from farm-scale mapping and regional-scale mapping have been made (Table 15). Overall, the calculated N loss limits from the farm-scale mapping would provide a greater N loss limit in four of the 13 cases and for one of these, the difference is quite significant. Overall, it can be concluded that this provision will have some impact on predicted water quality outcomes; although based on this small number of indicative figures, this impact is likely to be small and not a major factor in adjusting catchment outcomes in relation to Table 13.2.



Map 14. Land Use Capability (LUC) information for case study farm 1 at three different scales. From Manderson and Mackay (2008).

Table 9. Comparison of permissible N-loss between regional-scale and farm-scale LUC (modified from the evidence of Peter Taylor)

Farm Name	Farm Type	Permissible N-loss at year 1 (kg N/ha/yr)		
		LUC Regional scale	LUC Farm scale	Difference*
Byreburn	Dairy	29	25	-4
Glenbrook	Dairy	23	20	-3
Barrow	Dairy	26	24	-2
Flockhouse	Dairy/ Drystock	25	24	-1
Janssen (380 cows)	Dairy	19	18	-1
Tutu Totara	Whole farm	25	25	0
Stoney Creek Partnership	Dairy	18	18	0
Johnston	Dairy	16	16	0
Pencoed Farm	Crop	31	31	0
Day	Whole farm	10	11	1
Day	Dairy conversion	12	13	1
Oringi Farm	Beef	25	26	1
Windwood	Dairy	14	21	7

* A positive (+) difference shows where it is advantageous to the farmer to use farm-scale mapping and a negative (-) difference shows where regional-scale mapping would be better.

7.8 Summary of the FARM strategy approach

360. The FARM strategy approach provides a mechanism to deliver catchment water quality outcomes through customised farm-level assessments and management. The approach is being applied in a targeted way in catchments where there are water quality issues and where non-point source contributions to water quality outcomes are a major contributor to water quality. The approach is being further targeted to intensive farms. Management of losses from these intensive farms has been shown to be a major contributor to water quality outcomes.

361. The FARM strategy approach is proposed to apply to existing intensive farming in the targeted catchments and to conversions to intensive farming within these target catchments and throughout the Region. There is considerable potential for expansion of intensive farming in Horizons Region. An estimate for dairy farming suggests dairying could possibly more than double in the Region. The FARM strategy approach provides a mechanism to design any future development within a framework that has considered water quality outcomes.

362. The customised FARM strategy assessments incorporate a range of practices that are currently considered best practice, including some that are required already by existing

consenting or policy requirements and some others that are required as part of industry initiatives such as the Clean Streams Accord. The approach tackles many types of potential non-point source contributions of contaminants to water bodies, including nitrogen, phosphorus and sediments. Gains in relation to multiple water quality outcomes can be achieved from some mitigation options, eg. deferred irrigation of effluent may reduce losses of N, P and faecal material to water bodies. Likewise, stock exclusion from water bodies are likely to reduce losses of nitrogen, phosphorus, sediment ,and faecal material to water bodies.

363. The major new item for management on farm is the overall management of whole farm nitrogen losses. Previously, the management of nitrogen has primarily been delivered only through policy around effluent management. However, effluent management only addresses a small component of the overall nitrogen losses from farms, and only some types of farms produce effluent. The proposed approach in the POP targets non-point source nitrogen loss limits from the whole farm that relate through to catchment water quality outcomes. This allows for innovation and flexibility in management to achieve the loss limits at the whole farm level.

364. The FARM strategy approach has been tested in a number of ways, on more than 20 farms, including modelling of catchment outcomes for nitrogen loadings and periphyton levels. The first six of these were studied very comprehensively and it was determined that for the study farms, each of which were above average production, the targets could easily be met without major changes to the FARM system. The extrapolation of these results predicted similar outcomes for most farms in the Region, with the exception of ultra-intensive farms in traditionally marginal landscapes and in areas where particular land use/environment combinations occur, such as high rainfall, coarse shallow soils (eg. sands) low capability land, few trees or non-farmed areas, and high stocking rates. The further test FARM strategies completed by Horizons intentionally sought to find farms in such situations. In very broad terms, it may be difficult to meet the proposed N loss limits, with current technologies, where high rainfall, high proportions of the farm in LUC class 4 and above, and high stocking rate coincide. This may also be the case where only two of the variables coincide. Some farms in these situations have been able to meet the proposed loss limits through incorporation of associated support blocks to the farm, adjustment of LUC class in relation to overcoming the limitation of water through irrigation, and though improved information in relation to on-farm LUC mapping. Overall however, the test FARM strategies projects have shown that the N loss limits are achievable for a range of farming situations, with current technologies and without major requirements for changes in farm management.

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APPENDIX 1: FLOW DISTRIBUTIONS AND EXCEEDANCE PERCENTILES.

The two boxes below provide an overview of flow distributions and exceedance percentiles.

Flow Distribution and Exceedance 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.

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 exceedance percentiles.

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

~~~ Hilltop Hydro ~~~ Version 5.40
~~~ PDist Version 3.1 ~~~
Source is N:\water\Loadings\hopelands.hts
Flow (m³/s) at Manawatu at Hopelands_no1992
From 6-Jul-1989 16:00:00 to 1-Jul-2005 00:00:00

Exceedance 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 m³/s

Note: the flow percentiles shown in this report differ from those of Roygard et al. (2006) and Henderson & 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 River at Hopelands site are plotted over the long-term flow record in the figures below.

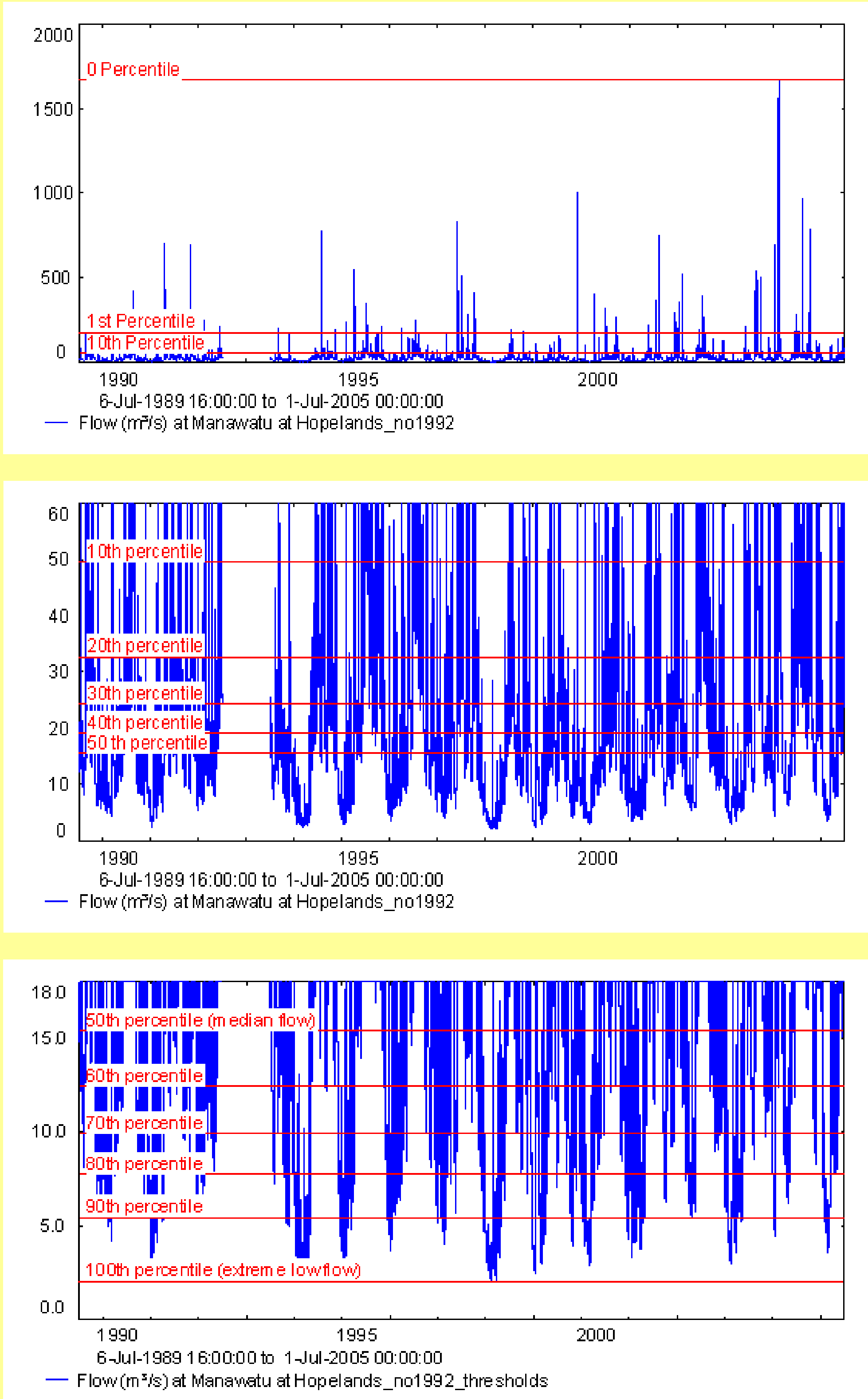

Figure A. Flow record for the Manawatu River at Hopelands showing instantaneous data in relation to flow percentiles.

APPENDIX 2: COMPARISON OF METHODOLOGIES FOR CALCULATING LOADINGS

As a part of calculating nutrient loadings for waterways, Horizons sought a methodology to separate point sources and non-point sources of nutrient that could calculate the changes in relative contributions at different flows. To do this, the report of Roygard and McArthur (2008) addressed the calculation of average annual Standard load limits and Measured loads in water bodies via a flow-stratified approach. The flow-stratified approach using flow decile bins to calculate loads was derived from first principles and I am not aware of others using this methodology in New Zealand. An alternative method used in the literature from New Zealand studies is the averaging approach, which has been used in publications by Dr Bob Wilcock and Dr Ross Monaghan (Wilcock *et al.*, 2007b), and Monaghan *et al.* (2006).

The main difference between the two methods (flow-stratified and averaging approach) can be described using an example of each of these methods being applied to SoE water quality data collected once a month (ie. the typical data set available).

The flow-stratified method of Roygard and McArthur (2008) separates the flows in the river into 10 categories based on the frequency of occurrence of flows in the river. Each of the bins (deciles) represents a range of flows that occur 10% of the time. The method uses the flow at the time of sampling and concentration of the water quality sample to characterise the load (flow * concentration). This load is then used as a representative sample for a flow bin that the flow at the time of sampling falls within. These representative samples are then used to calculate the mean for the flow bin. These means are multiplied by the frequency of occurrence of the flows within that bin and summed to calculate a long-term loading estimate over a time period. Further detail is provided in Roygard and McArthur (2008).

By contrast, the averaging approach uses the concentration from the single monthly sample multiplied by the average flow for the month. This provides an indication of the total loading for that month. These monthly loadings are added up to give an annual loading. An adjustment is then made based on the mean flow for the entire period of record to correct for the use of average monthly flows ie. the summation of the mean monthly flows divided by the length of period these represent does not equal the actual mean flow and a correction is required for this.

In my view, each of these methods has advantages. For the averaging method, a result can be calculated at the end of each month and annual Measured loads can also be calculated. The disadvantage of this, in my view, is that it may not necessarily reflect the true loads in the water body during the month or the year as accurately. The method is likely to work well in conditions where changes in flows and changes in relative sources of nutrient are not frequent. An example to consider in terms of accuracy of this method is the sample collected at low flows before a large rainfall event occurring in the same month. In this case, large volumes of water may be calculated for the month but the concentration by which they are multiplied maybe more representative of low flows. A further disadvantage of the averaging approach is the inability to separate relative inputs from non-point and point sources at various flows.

The advantage of the flow-stratified method, in my view, is that the variations in nutrient transport mechanisms with flow are accounted for. The samples that occur at similar flows (ie. either rising or falling flow) are grouped together, and through averaging the results for these “samples at similar flows”, the frequency of such events in the flow record can be accounted for. Disadvantages of the flow-stratified method include not being able to calculate the monthly or annual loads to that level of resolution. The method is better placed to have a large number of samples over a number of years, to get accurate estimations for each flow decile bin. Targeted sampling at particular flow ranges may be necessary to achieve this. Horizons’ water quality monitoring programme is now actively trying to target particular flow ranges (ie. very high and very low flows). Scheduled monthly sampling runs may have difficulty populating some flow ranges without this type of targeted sample collection. Horizons is planning further use of auto-samplers to better enable calculation of daily/monthly loadings.

Comparisons between methods were included in the report of Roygard and McArthur (2008, Appendix 6). In summary, for the Manawatu at Hopelands site, the flow-stratified method provides the lowest estimates of load for the site. The agreement between the discharge-weighted mean (964 tonnes/year) and the averaging methods (963 tonnes/year) from the Roygard and McArthur (2008) report is expected, given the similarity of the calculation methods and the use of the same set of data. The averaging method of Ledein *et al*. (2007) gives a slightly higher result than these methods (at 991 tonnes N/year) and likely reflects the different length of data used (ie. a much shorter data set used by Ledein *et al.* 2007). The screening method of Ledein *et al*. (2007), which estimates 1,021 tonnes N/year, is likely to be an overestimate. This is because the methodology used typical values of losses for farming systems nationally as being representative of the losses from farming systems in the upper Manawatu. Manderson and Mackay (2008) and Clothier *et al*. (2007) both provide some context on the relationship between national averages for nitrogen losses typically being higher than those observed in this Region.

Table 14. Comparison of nutrient load estimates for the upper Manawatu River above Hopelands using several methods. Sourced from Roygard and McArthur (2008).

Method	SIN load (tonnes/year)	DRP load (tonnes/year)
Flow-stratified, Roygard and McArthur (2008)	745	21
Averaging, Roygard and McArthur (2008)	963	26.8
Discharge-weighted mean, Roygard and McArthur (2008)	964	26.8
Averaging, Ledein *et al.* (2007)	991	20.6
Screening, Ledein *et al.* (2007)	1,021	26.3

Some further sensitivity analysis checks of the flow-stratification method were completed in the report of Roygard and McArthur (2008).

One of the primary tests of this method was the influence of the length of water quality record available on the calculated Measured loads. Applying the method to the upper Manawatu data for the period July 1989 to July 2005, calculated an average N load of 745 tonnes/year. This increased to 782 tonnes/year when only the data from 1997-2005 were used (Table 15). This indicates that the addition of the extra eight years of data (nearly doubling the amount from 1997 to 2005) resulted in a lower calculation of the 'Measured load' by about 5%. The change for the DRP loads in Table 15 was a 14% increase in average load for the shorter, more recent period of data. A number of factors could contribute to this. One of these might be that the increased number of samples in each flow decile bin provided a more accurate estimate for each bin, and therefore more accurate results. Other factors that may have contributed include a significantly increasing trend in both nitrates and phosphorus in the catchment, as identified by Gibbard *et al.* (2006).

Table 15. Comparison of measured nutrient load for the Manawatu River at Hopelands site for two different time periods. Sourced from Appendix 7, Roygard and McArthur (2008).

Period of record	Measured SIN load (tonnes/year)		Measured DRP load (tonnes/year)	
	All flows	< 10th %ile flows	All flows	< 10th %ile flows
July 1997-September 2005	782	513	24	14
July 1989-July 2005	745	478	21	13

The sensitivity analysis checks also included assessing the influence of the 1992 partial year on the average Standard load calculations. For nitrogen, including what was available of the flow data for 1992 increased the Standard loading from 358 kg N/ha/year to 361 kg N/ha/year. This is considered a very minor change in the estimated average standard given the variation in annual standard load limits for each year (Appendix 4 of Roygard and McArthur (2008) contains further information on this).

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