MANAGING OUR ENVIRONMENT

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

one plan
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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

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EXECUTIVE SUMMARY

Many rivers in the Manawatu-Wanganui Region are affected by excessive algal growth during summer. This phenomenon is mainly driven by high concentrations of nutrients (nitrogen and phosphorus) in the rivers.

Nutrients in the waterways can come from both point sources (eg. discharges of treated wastewater) and non-point sources (eg. runoff and/or subsurface flow from agricultural land). However, the relative contributions of point sources (PS) and non-point sources (NPS) to the instream nutrients have never been quantified in the Manawatu-Wanganui Region.

The current “One Plan” development creates the opportunity for Horizons Regional Council to develop nutrient management strategies focused on the actual major sources of instream nutrients. In this context, the aim of this work was to quantify the contributions of PS and of NPS to instream nutrients.

A **desktop methodology** (a “screening” model) was developed to provide a **catchment-scale assessment** of the sources of instream nutrient in rivers of the Manawatu-Wanganui Region. This **methodology was then applied to three catchments**, typical of the Region.

For the three study catchments, the model indicates that on an annual basis:

- **Instream nitrogen is mostly from NPS** (95%), while PS contribute to only 5 % of the total,
- **The PS contribution to instream phosphorus is more significant** than for nitrogen: over the three study catchments, an estimated **30 to 55** % of annual instream phosphorus load come from PS, the remainder coming from NPS.
- The three study catchments were selected to be representative of the Region’s land cover, land use and pressures associated with human activity. However, **extrapolating these results to other catchments in the Region, or generalising them to the rest of the Region should not be done without due caution.**

In spite of the limitations outlined above, the results indicate NPS can be major contributor to both instream nitrogen and phosphorus. The direct implication of these findings is that any management regime aiming at controlling or reducing the instream nutrient loads must target both point and non-point sources of pollution.

CONTENTS

Figures

Tables

Maps

Photos

1 Introduction

Horizons Regional Council (Horizons) is currently reviewing its resource management plans and is developing a second generation regional planning document. In doing this, Horizons is combining its Regional Policy statement, Regional Plans and Coastal Plan into a single policy document (the One Plan).

As part of the One Plan, a focus has been placed on four priority environmental issues (the "big four") for the Region:

- Water Quality
- Water Quantity
- Sustainable Land Use
- Biodiversity

Many rivers in the Manawatu-Wanganui Region are affected by excessive algal growth during summer (Horizons Regional Council, 2005a). This phenomenon is mainly driven by high concentrations of nutrients (nitrogen and phosphorus) in the rivers. In order to develop policy to reduce the frequency of these excessive algal growths it is important to understand the source of the high nutrient concentrations.

The current One Plan development creates the opportunity for Horizons to develop nutrient management strategies focused on the major sources of instream nutrients.

Nutrients in the waterways can come from both point sources (eg. discharges of treated wastewater) and non-point sources (eg. runoff and/or subsurface flow from agricultural land). This study seeks to determine the relative contribution of point sources (PS) and non-point sources (NPS) of these nutrients.

This report presents the methods that were developed to estimate nutrient loadings exported from:

1. the nutrient loadings exported from a catchment from non-point sources;
2. the nutrient loadings exported from a catchment from point sources;
3. the total nutrient loadings exported from a catchment using methods 1and2. This is referred to as the screening model throughout the report.
4. the nutrient loadings exported from a catchment using water quality and flow data.

For each study catchment, the results of methods 3 and 4 were compared to cross validate the two methods.

The first part of this report briefly presents the nutrient enrichment issue in the Manawatu-Wanganui Region. In the second part, the methodology developed to estimate instream pollutant loads and point and non-point sources contributions is detailed. The third part presents the results obtained for the three study catchments.

1.1 The instream nutrient issue

The 2005 state of the environment report identified four main water quality issues in the Region (Horizons Regional Council, 2005a).

1. Faecal contamination - compromising the water's recreational quality and affecting its mauri,
2. Sedimentation - High turbidity and deposited sediments, affecting aesthetic and life-supporting capacity values. This is mainly caused by accelerated erosion processes,
3. Life supporting capacity - Modified physico-chemical characteristics of the water and/or presence of toxic substances compromising the life-supporting capacity of the water.
4. Nutrient enrichment - Excessive nutrients can cause excessive plant and algal growth, which in turn has many detrimental effects on river values.

Aquatic plants and algae are a normal and necessary part of aquatic ecosystems, as they form the base of the food web (primary production).

Periphyton is the green or brown "slime" that grows in mats or filaments attached to submerged hard stable surfaces, such as cobbles, rock or dead wood.

Excess nutrients in a waterbody can cause excessive plant and algal growth, which in turn has many detrimental effects on river values, including ecological, recreational, cultural and consumptive use values.

1.2 Monitoring of instream nutrients and periphyton

In the Manawatu-Wanganui Region, both the source of the problem (nutrient concentration) and the problem itself (the quantity of algae growing on the riverbed material or periphyton biomass) are monitored. Each year, horizons' state of environment monitoring program monitors monthly nutrient concentrations[1] at 23 river and stream sites in the Region. A further 28 sites in the Region are monitored once a month for one year out of every 3 years. Periphyton biomass[2] (the amount of algae on the river substrate) is monitored once a year during low flow conditions at 35 sites across the Region.

Periphyton biomass monitoring has shown a number of sites in the Region regularly experience periphyton growth in excess of the guideline levels for the protection of aesthetic and trout fisheries values[3]. With regards to the study catchments, two of them have regular excessive periphyton growth (Manawatu River at Hopelands and Hautapu at Taihape). At the third site (Mangatainkoka River at SH2), periphyton biomass have always been measured within acceptable limits (Death and Death, 2006). However, this does not mean periphyton biomass doesn't breach guideline levels at times, as yearly monitoring is unlikely to capture the maximum periphyton biomass at a site (Dr. Barry Biggs, *pers. comm*.).

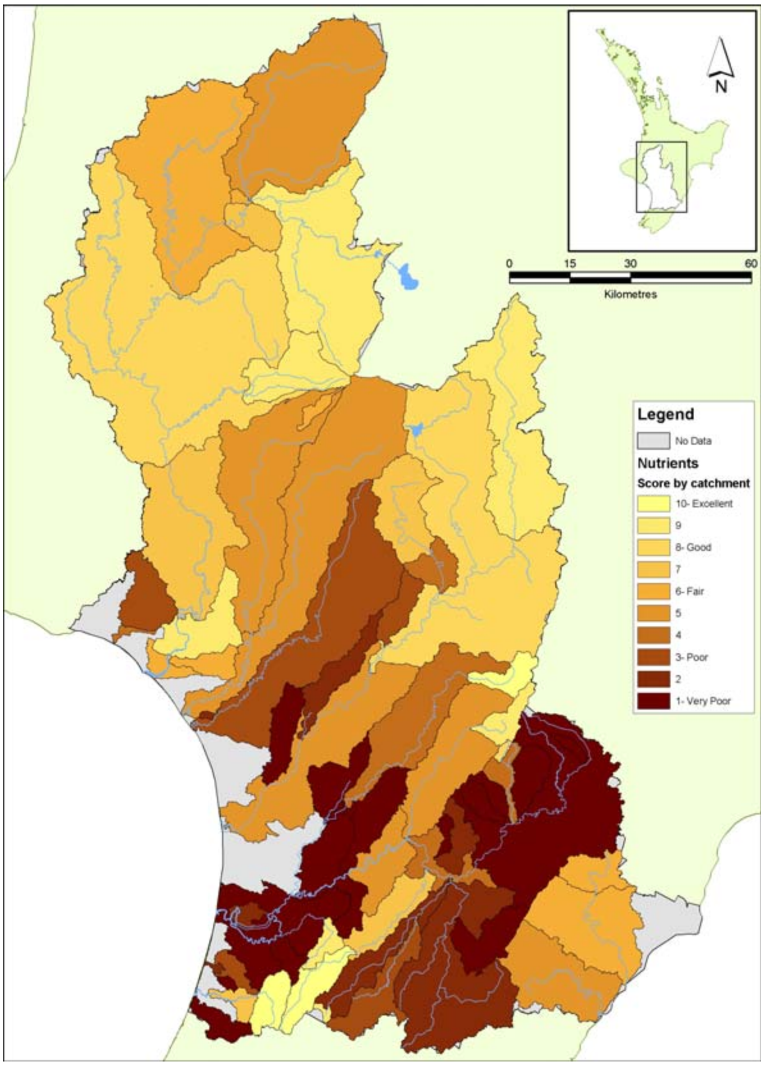
[1] Nitrate, ammonium and dissolved reactive phosphorus are monitored for the moment.

[3] 120 mg/m^2 as defined in Biggs (2000).

The State of Environment report in 2005 identified that the nutrient levels were higher than ANZECC guidelines values for nutrient enrichment in a number of catchments in the Manawatu-Wanganui Region. Map 1 shows the nutrient enrichment index score by catchment in the Manawatu-Wanganui Region. The index summarises nitrate, ammoniacal nitrogen and dissolved reactive phosphorus concentrations. A score of 10 indicates the water quality is less than (ie. better than) the guideline values for 90 to 100 percent of samples collected at that site (details in Horizons, 2005b).

Photo 1: Excessive periphyton growth, Hautapu River 2km downstream of the Taihape sewage treatment plant discharge, February 2005 (Photograph: Malinda Matthewson).

Photo 2 and Photo 3: Excessive periphyton growth, Porewa Stream at Onepuhi Road, February 2005 (Photographs: Olivier Ausseil).



Map 1: Nutrient enrichment index score by catchment in the Manawatu-Wanganui Region (Horizons Regional Council, 2005a, 2005b).

1.3 Major sources of nutrients

A report prepared by Ag Research for Environment Bay of Plenty (Meener *et al*, 2004) identified the following key points in relation to non-point inputs of nutrients to waterways.

The major non-point sources of nitrogen are from agricultural land:

- Nitrogen run-off (surface) is minor relative to leaching losses (subsurface/groundwater) on most soils,
- The majority of nitrate leaching occurs during winter when soil drainage is greatest,
- Some land uses cause more nitrogen leaching than others. The potential for causing nitrate leaching typically follows the increasing order: Forestry < Sheep/Beef/Deer farming < Arable/mixed farming < Dairy farming < Vegetable cropping
- In grazing systems, the main source of leached nitrate is from urine patches: "Direct leaching of fertiliser N has only a marginal effect on nitrate leaching under grazing and only when N applications are excessive

(>400 kg N/ha/year) or untimely (>50 kg N/ha in winter)" In cropping systems, the main sources of leached nitrate are from fertilizer N and crop residues that remain in the soil following harvest.

The major non-point sources of phosphorus are:

- Elevated P-concentration in surface run-off. Subsurface flow contributes to a much lesser degree to the phosphorus loads in rivers
- In general, forestry seems to contribute the least amount of P in the waterways, followed by hill country sheep farming.
- Sheep and beef grazing systems, on hill country farms show considerable losses of phosphorus, mainly in the form of particulate phosphorus linked with sediments.
- Dairy systems have in general a lower contribution to P losses, probably because they are usually developed in lowland landscapes where erosion and runoff is minimal. However, when soil drainage is poor, or in extremely high rainfall areas, P losses can be larger
- P losses from intensive land uses (dairy and cropping systems) are likely to vary dramatically with animal stocking rate, soil type, topography, cultivation, cover crop and P fertilizer management.
- The majority of P (up to 80%) in run-off is particle-bound, while less than 20 % is present as dissolved P.
- Volcanic geology can also be a major diffuse source of phosphorus, and stream draining recent volcanic areas may have naturally high in stream phosphorus concentration (White, 1982). Limestone and Mudstone geologies are also natural sources of phosphorus.

1.4 Goals and scope of this report

To determine ways to maintain periphyton growth under acceptable levels, it is key to determine where the nutrients are sourced from. A first step is to understand the relative contribution of point and non-point source pollution.

This project sets out to test methodologies to increase understanding of the relative contributions of non-point source and point source contributions of nutrients to waterways, as well as methodologies to estimate the nutrient loadings being exported from catchments.

Nutrient export loadings from a catchment can be defined as a rate of export, which can be expressed in a range of units, eg. kg/day or tonnes/ha/year. Based on the time and data available for this desktop study, the approach taken was to calculate the **annual load of nutrients** exiting the study catchment. Some consideration was given to calculation of loads on a shorter period where low flows may occur. The period selected was the eight month period from October to May (section 22.8).

Algal growth rate and peak algal biomass are controlled not only by nutrient concentration in the water but also by climatic (temperature, light) and hydrologic parameters (frequency of floods). Ideally, one should attempt to estimate (in both quantity and origin) the sources of instream nutrients in relation to these controlling parameters. However, there are technical challenges associated with this approach, the main one being a lack of detailed reliable data. Similarly, the scale of the work had to be carefully considered. An ideal situation would be to be able to pinpoint at the farm or paddock scale the sources of instream contaminant. It was recognised such a goal would require a massive data collecting and processing exercise, which didn’t fit with the scope of this work. The approach taken was to use existing data, to provide a catchment-scale estimate of sources of instream nutrient on an annual basis.

In conclusion, this work aimed at developing a **desktop methodology** to provide a **catchment-scale assessment** of the sources of instream nutrients and annual nutrient export loadings in rivers of the Manawatu-Wanganui Region. The approach used existing data, ie. site specific data when available, or regional or national averages/typical loads when site-specific data was insufficient. The **methodology was then to be applied to a limited number (3) of catchments** or sub-catchments.

2 Methodology

2.1 Point – source/non-point source separation

The Ministry of Environment State of the Environment report (1997) identified the major point sources in New Zealand as

- Sewage treatment plants
- Industrial vegetable or meat processing
- Dairy sheds
- Piggeries
- Septic tanks
- Stock stream “crossings”, for example dairy cow crossings on a raceway connecting milking shed and pasture

For the purpose of this report, a narrower definition was adopted. Only the “large” industrial and municipal discharges were considered as point source discharges. The discharges directly linked with farming activities (eg. discharges of dairy shed effluent, dairy herd crossings) were specifically excluded from the definition of point source discharges.

Non-point source pollution is caused by diffuse sources that can cover broad areas. These sources can be either natural (for instance geological erosion, dissolution of nutrient-rich rocks and soils) or linked to human activities (eg. runoff and/or subsurface flow from agricultural, forestry and urban land). For the purposes of this report nutrient inputs from consented land treatment systems such as dairy shed effluent application to land consents, and generally all sources of nutrients from farmed land are considered non-point source.

Similarly direct stock access to water that leads to nutrient to water ways are classed as non-point source inputs by the methods used in the report. Dairy cow crossings of rivers on a raceway connecting milking shed and pasture do not require consent by Horizons and their locations are not known. As the contribution of each stream crossing is not able to be calculated, their general contribution was included in the NPS contribution.

The reasons for these choices were two fold:

- the resource consents allowing “large” industrial or municipal discharges usually have monitoring conditions, ie. data on discharge quality and quantity is usually available, allowing a good characterisation of the nutrient loadings in the discharge,
- it was essential to understand how much nutrient was coming from agricultural land in general. Solutions currently put forward by Horizons to better manage agricultural contribution of contaminants to waterways revolve around the development and implementation of whole farm plans, and agricultural discharges should not be considered separately from the rest of the farming system.

For the purpose of this study, the contribution of septic tanks was also as non-point source pollution. It is noted however the relative contribution is likely to low, given:

- Direct discharges of septic tanks to water is a non complying or prohibited activity under the regional plans,
- Most if not all towns/villages in the study catchments have reticulated connections to a sewage treatment system, the discharge of which will be considered a point source.
- The density of non-reticulated septic tanks is low in the study catchments.

Further the leaching of nutrients from landfills is also not considered in the point source discharge definition of this report due to the technical difficulties in estimating the loading from such sites.

2.2 Principle of load calculations

To calculate the relative contribution of non-point source and point source loadings and annual load of nutrients being exported from the catchment the following steps were identified:

1. Calculate an estimate of non-point source annual nutrient export loading ie. Total load in the river = Load (non-point source 1) + Load (non-point source 2) +…+ Load (non-point source n).

2. Calculate an estimate of the point source annual nutrient export loading ie. Total load in the river = Load (point source 1) + Load (point source 2) +…+ Load (point source n).

3. Calculate a nutrient export from the catchment using the estimates from step one and two, ie. total load in the river = load point source + load non-point source.

4. Calculate an estimate of the nutrient export loading observed in the river, using water quality data and river flow data. This provides an estimate of nutrient export loadings by an independent method which can be used to cross validate the results of the first method (steps 1, 2 and 3 above).

5. Compare and cross-validate the results of methods 3 and 4 above ie. check how well the estimates of what's coming from the land compare to what's being observed in the river.

2.3 Calculating the non-point source loading

Urban run-off was considered to be a small contributor to non-point source inputs as the study catchments are mostly rural. No attempt was made to quantify the inputs from urban runoff.

Natural NPS was also not characterized by this study. Recent volcanic geology is likely to be a significant natural source of phosphorus (White, 1982). Limestone and mudstone geology are also potential sources of phosphorus. In some catchments of the Region, reference water quality sites provide some information on background inputs from natural sources eg. forested headwaters. Reference sites are the sites in the water quality network that have little or no land used for agricultural production in their upstream catchments. Whilst inputs can be estimated from reference sites, springs, geology etc will further contribute downstream of these sites which are predominately in the headwaters.

Inputs from septic tanks, direct stock access to water ways and leachate from landfills are also considered non-point source by this report. The relative contribution of these can not be estimated due to lack of available information.

As this study does not estimate nutrient inputs from natural sources, urban runoff, septic tanks direct stock access to water ways and landfills, it is likely that the loading estimates will be slightly underestimated.

To assess NPS contribution to the instream nutrient loads, an **export coefficient** method was used. This is a simple approach based on the land use and export coefficient (or specific yield) for each land use.

A nutrient export coefficient is the mass of that nutrient leaving the catchment, per unit area of catchment, and per unit of time (typically in kg/ha/year). Export coefficients take into account the attenuation within the catchment (landscape and aquatic transport). They are measured at the outlet of a catchment, when this is totally covered by a specific land use. Export coefficients, based on national averages, are available for the dominant land uses.

An obvious drawback of using an export coefficient method is that it does not take into account the physical characteristics of catchments, which determine pollution attenuation. However, they enable a first approximation of non-point source contribution to river loads.

Export coefficients have been estimated for most of New Zealand's land uses. When unavailable, typical nutrient loss figures were used (which do not take into account the attenuation within the catchment, as they measure nutrient losses at the outlet of a paddock). The attenuation during landscape and aquatic transport were estimated at 50% of the load.

Export coefficients for dairy farming include the land application of the dairy shed effluent to land.

The export coefficients used in this study are summarized in Table 1. The source references for this data are given in Appendix 2. Land use in the study catchment was assessed using both the Agribase Database and the land cover database (LCDB2).

Table 1: Nitrate and DRP export coefficients used in this study (see Appendix 2 for the sources). Note these export coefficients are rates after attenuation (50% of the load from the land use) see text for details.

Land use	Nitrate export coefficient/ specific yield (kg/ha/y)	DRP export coefficient, (kg/ha/y)
Dairy pasture	20.0	0.3
Sheep and beef or sheep on Hill pasture	7.2	0.20
Low intensity pasture	4.2	0.05
Cattle grazing	20.0	0.3
Arable farming	15-30	0.25
Vegetable cropping	88.5	0.25
Forestry	1.5	0.005

2.4 Point sources of nutrients

Point source discharges comprise of consented activities for discharges to water (sewage treatment plants, effluent form vegetable or meat processing plants, dairy sheds, piggeries). Note for this report the, the dairy shed discharges to water or land are considered as non-point source. The only discharge to land that was considered as a point source in this report was Richmond Oringi meat works (see section 3.1.3 for details).

The nature and location of each consented activity is known, and consent conditions usually require that water quality parameters are monitored in either or both the discharge and the receiving environment. For these activities it is possible to either calculate or estimate their individual contributions to the total contaminant load.

To assess the contribution of consented activities to nutrient loads in surface water, the three following methods were used in decreasing priority order:

- Method 1: when discharge volumes and nutrient concentration in the discharge were available, this data was used to calculated monthly and annual loads. In this case the annual load is the product of the volume by the concentration added up over the year.

- Method 2: when the available data was insufficient to use method 1, upstream (u/s) and downstream (d/s) instream nutrient concentrations and river flow data were used to calculate the nutrient load, or
  Discharged load = $\int$ (Conc. d/s - conc. u/s) * River flow
  Which is estimated using the formula:
  Annual discharged load (tonnes/year) = $\sum_{Months}$ (conc. d/s – conc. u/s) (January, February, …) (in g/m3) * Average flow (January, February, …) (in m^3/s) 3600*24 * 365/(12 * 1,000,000)

  River flow data at or near the discharge site is necessary to use this method.

- Method 3: In all other cases, typical nitrogen and phosphorus loading ranges corresponding to the discharge type (Table 2), and information supplied with the resource consent application (eg. population size for sewage treatment plants and herd size for a dairy shed discharges) were used to estimate an annual load figure.

The typical loads provided in Table 2 correspond to total nitrogen and total phosphorus. To get the soluble inorganic nitrogen and the dissolved reactive phosphorus loads, it was assumed that, on average:

- Nitrogen losses from these point sources are in the form of soluble inorganic nitrogen
- The ratio DRP/TP are:
  - 85% for effluents of sewage treatment plants (typical ratio used by the environmental agency of England and Wales)
  - 30% for dairy shed effluent spread onto land (same as the ratio used for the export coefficient of DRP from dairy farming land, see appendix).

It is noted that all resource consents granted since 2004 for municipal or industrial treated wastewater discharges to water require monitoring of the discharge volume and quality. This practice is likely to continue in the future, which should make future calculations of instream contaminant loads more accurate.

Table 2: Typical nutrient loads for some point sources, adapted from (Ministry for the Environment, 2002).

Point source type	Degree of treatment	Total N load	Total P load
Dairy shed effluent	Untreated	5.4 kg/cow/year	0.66 kg/cow/year
	Treated (dual pond)	75 % removed	60 % removed
Domestic sewage	Untreated sewage and septic tank effluent	4.2 kg/p/year	1.5 kg/p/year
	Conventional secondary treatment	5-40 % removed	5-40 % removed
	Enhanced nutrient removal		
		50-95 % removed	70-85 % removed
Piggeries	Untreated	8 kg/pig/year	2.7 kg/pig/year
	Treated (anaerobic lagoon)	60 % removed	40 % removed

2.5 Estimating nutrient export loads observed in the river

A key step of this work consists of estimating the total rate of nutrient load (SIN and DRP) running through the outlet of the study catchments, in units of tonnes/year for example. The study catchments were selected based on the availability of water quality and flow data at the outlet of the catchment. Water quality is typically measured once a month. River flow is typically measured once every 15 minutes at the monitoring stations. It is noted that flows can vary considerably over a day.

The instantaneous contaminant load in a river can be estimated by multiplying the contaminant concentration in the water by the river flow. The basic assumption of this calculation method is that the contaminant is evenly distributed over a cross-section of the river. If continuous measurements of both flow and pollutant concentrations were available, the load calculation would be simple:

$$Load(year_i) = \int_{01/01/year_i}^{31/12/year_i} [Pollut](t) \cdot Flow(t) \cdot dt$$

As nutrient concentrations are usually measured only once a month the integral formula above has to be approximated.

The literature review as a part of this study found three main approaches to estimate the loads (Richards, 1998; Ferguson, 1985). All three are trialled in this study.

1. An *averaging approach* when pollutant concentration and flow are independent variables
2. A *regression approach* if pollutant concentration and flow are well correlated, and
3. A *ratio approach* if there is a positive linear relationship between pollutant flux (g/s) and flow, which passes through the origin.

The choice of the appropriate approach depends on the correlation between concentration and flow data. A description of each of these methods is provided in Appendix 1.

2.6 Study catchments

As explained above, the timeframe and resource for this study did not allow to assess all the nutrient pressures on all the rivers of the Region. It was chosen to study three catchments. The selection criteria were:

- the range of landuse and discharges to the river were representative of the Region,
- water quality and flow data were available at the downstream end of the study catchment (necessary for annual load calculations).

The following catchments were selected:

- The **Upper Manawatu catchment** upstream of the Hopelands monitoring site (1260 km^2). The Manawatu River at Hopelands has high concentrations of both nitrogen and phosphorus. The land is mainly used for sheep and beef farming (56%) and for dairy farming (17%). A number of towns and industries discharge treated wastewater into the catchment above Hopelands: Dannevirke, Ormondville and Norsewood sewage treatment plants (STPs), Dannevirke and Ormondville landfills, and PPCS Richmond Oringi abattoir.
- The **Mangatainoka catchment** (421 km^2). The lower Mangatainoka River has very high concentrations of nitrogen and medium concentrations of phosphorus. The land is mainly used for dairy farming (32%) and for sheep and beef farming (23%). Point source discharge include: DB Breweries, Fonterra Kiwi Mangamutu, and Pahiatua and Eketahuna STPs and landfills.

- The **Upper Hautapu catchment**, upstream of the Hautapu at Taihape monitoring site (290 km^2). This catchment has high concentrations of phosphorus but not of nitrogen. The land is mainly used for sheep and beef farming (46%). A large part of it is covered with low production grassland or tussock or native forest. There are no known point sources in this part of the catchment contributing to nutrient loads.

2.7 Water quality indicators of river nutrient status

Nitrogen and phosphorus occur in different chemical forms in natural freshwater river environments. A number of water quality indicators, corresponding in turn to different laboratory analysis techniques, can be used. Two main options are available to measure the nutrient status in relation to algal growth in freshwater river environments.

Total Nitrogen and Total Phosphorus (TP and TN) represent the total concentration of each nutrient, including organic (part of living or dead organisms) and inorganic forms. Some forms are directly available to plant growth, while others are not. In a lake system, there can be significant recycling of nutrients. For this reason, the total stock of nutrients is the most relevant indicator of algal growth, and TN and TP are the usual indicators of choice in New Zealand Lakes in relation to algal bloom issues (Burns and Bryers 1999). In relatively fast-flowing river systems however, only the fraction of nutrients directly bioavailable can be used by periphyton growth. For this reason, and in spite of a reasonable amount of scientific debate, TP and TN are not the preferred indicators of nutrient enrichment in river systems.

Soluble inorganic nitrogen (SIN) and dissolved reactive phosphorus (DRP) represent the nutrient fraction directly available to plant growth. The New Zealand Periphyton Guidelines use a model that define SIN, DRP and flood frequency as the main variables for predicting peak periphyton biomass (Biggs, 2000). Accordingly, and like many other Regional Councils, Horizons' policy[4] and monitoring[5] use DRP and SIN as measures of nutrient in waterways.

Consequently, the nutrient indicators used in this study are:
- Soluble inorganic nitrogen (nitrate + nitrite + ammonia)
- and soluble (or dissolved) reactive phosphorus (DRP)

Horizons has also developed a set of water quality indicators to summarise the state of water quality in relation to each major water quality issue (Horizons 2005b). The indicators summarise the proportion of samples in each of five categories (excellent, good, fair, poor and very poor) or two categories (Satisfactory/unsatisfactory[6]). In this report water quality for the study catchments is presented using the five category summary. For Nitrates (mg/m^3): Excellent< 75; Good 75 to 167 ; Fair: 167 to 444 ; Poor : 444 to 667 ; Very Poor >667. For DRP (mg/m^3) the categories were defined as Excellent<

[4] Manawatu Catchment Water Quality Regional Plan Rule 2.4.g sets a numerical standard (15 mg/m3) in water classified for Contact Recreation.

[5] Horizon's State of the Environment monitoring programme measures DRP, Nitrate-Nitrogen and Ammonia-Nitrogen (which in turn are the principal components of SIN in the Region's natural waterways.

[6] This is done by adding the scores in the excellent, good and fair categories to calculate the number of samples in the satisfactory and adding the number of samples in the poor and very poor categories to calculate the number of samples in the unsatisfactory categories

3; Good 3 to 6; Fair: 6 to 10; Poor: 10 to 26; Very Poor >26. It is noted that the DRP water quality standard 15 mg/m^3 for the Manawatu Catchment Water Quality Plan was not used as a part of the indicator.

2.8 Summer loads

In the Manawatu-Wanganui Region excessive periphyton growths are more typically observed in summer than winter. Predominately wet conditions in winter provide less favorable growth conditions (lower temperatures, lower sunlight) and higher frequency of floods, and subsequently the peak periphyton biomasses reached in winter usually remain within acceptable limits. Based on a high level of local experience, the period of the year when low river flow conditions may occur was estimated to be from October to May.

To reflect this, nutrient loads and their relative non-point and point source contributions were calculated for that period in the Manawatu above Hopelands study catchment (referred to in this report as being the "summer" or "low flow" loads).

The nutrient export loads observed in the river was calculated using data collected during these months.

The point source contribution was approximated as being proportional to the annual load for the 8 "summer" months. The export coefficient used to estimate annual NPS loadings are based on annual cycles. One would expect significant differences in the nutrient load exported at different times of the year, as, for example, nitrate leaching is known to be higher during wet winter months when soils are at field capacity. For this reason, annual export coefficients should not be used to derive monthly export loads. The non-point sources contribution was estimated as the difference between the total load and the point source load.

3 Results: Nutrient loads and sources in the study catchments

This chapter presents the nutrient loads and nutrient sources as assessed in three study catchments. For each study catchment the following sections are presented:

1. A brief outline of the catchment (location, land use, nutrient related consents).

2. A quick assessment of the state of water quality in the study catchment.

3. An estimation of the non-point source export loading in the catchment.

4. An estimation of the point source export loading in the catchment.

5. An estimation of the total nutrient export loading using non-point source and point source estimations from 3 and 4 above.

6. An estimation of total nutrient export loading using river flow and water quality data.

7. A comparison of the total export loadings from 5 and 6 above.

8. A summary of findings.

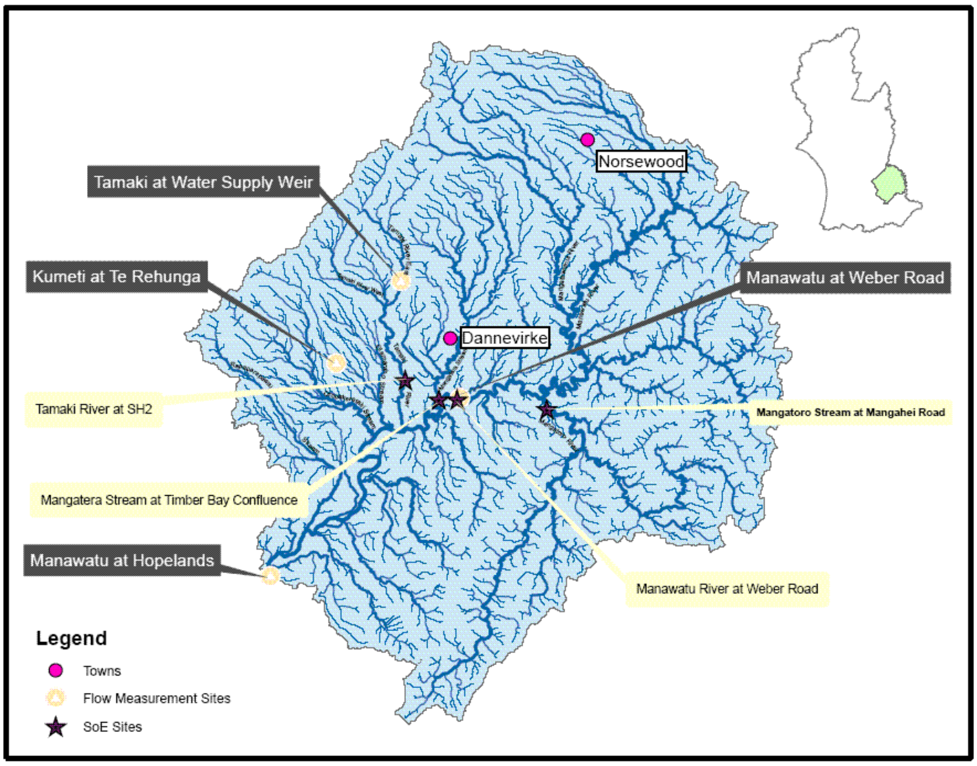
3.1 The Upper Manawatu catchment above Hopelands

3.1.1 The study catchment

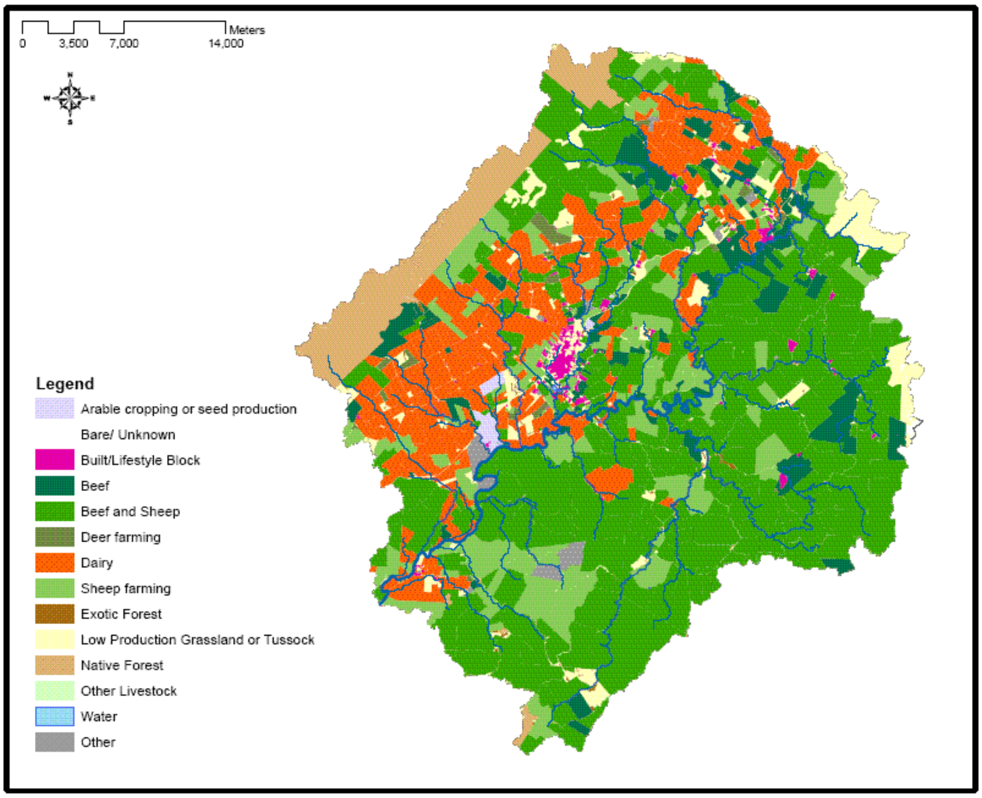
The Upper Manawatu above Hopelands catchment (Map 2) is 1260km^2 and forms the Upper section of the Manawatu River catchment. Land is mainly used for sheep and beef farming (56%) and for dairy farming (17%) (Map 3). The main town centres are Dannevirke and Norsewood.

The point source discharges of nutrients in this study catchment (Map 4) are the Dannevirke, Ormondville and Norsewood oxidation pond, and Richmond abattoir. The Dannevirke and Ormondville landfills are shown on the map however these are considered non-point source by this study.

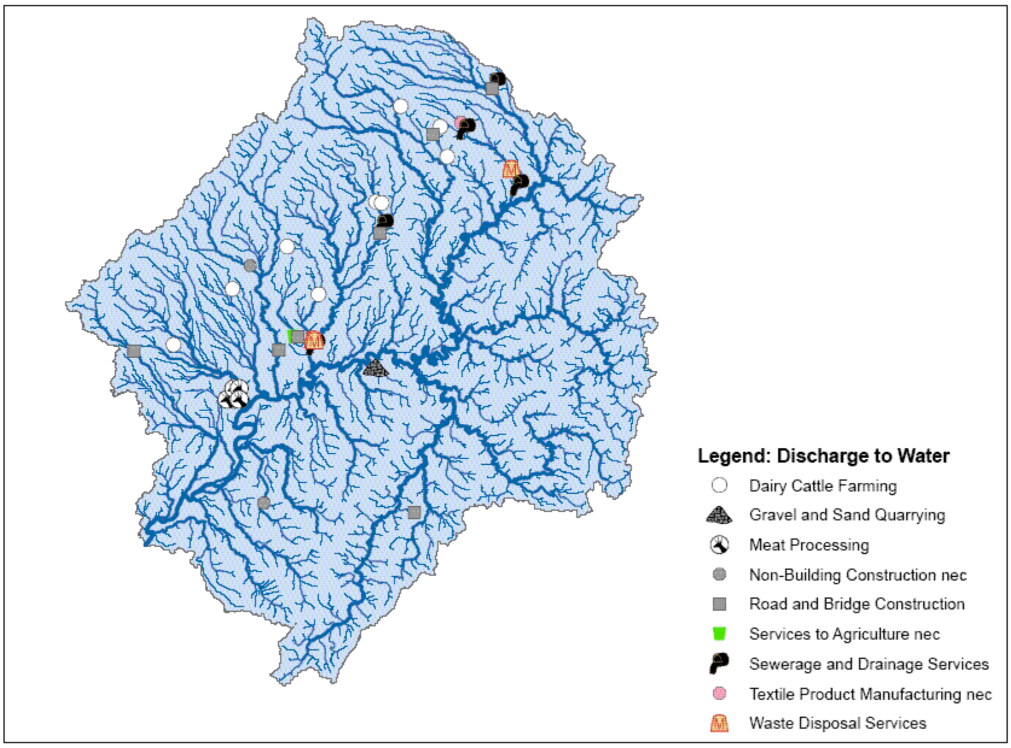
Map 5 shows the discharges to land that have been consented in this management zone. These are considered as non-point source contributors by this study. Most of the dairy sheds have got an oxidation pond, the effluent of which is usually spread onto pasture land. The meat processing discharges to land for Richmond Oringi are included as point source as an estimation of the loading from this land treatment system was able to be calculated.



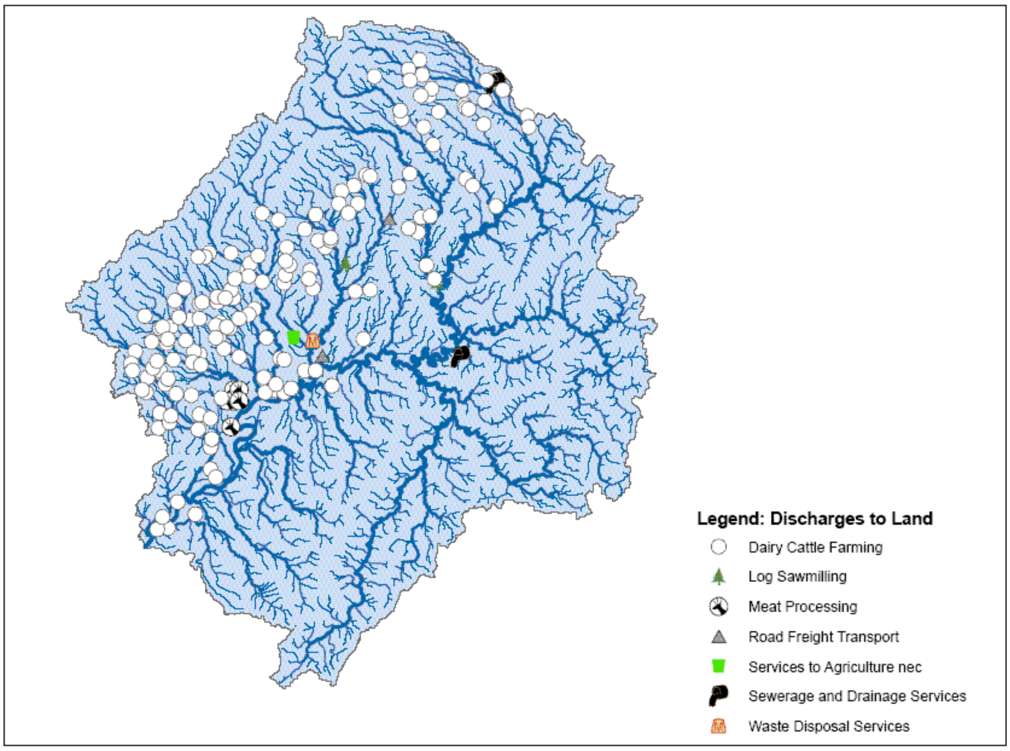
Map 2: Location in the Manawatu above Hopelands study catchment of towns, state of environment water quality monitoring sites (SOE sites) and flow measurement sites.



Map 3: Land cover and land use in the Manawatu above Hopelands management zone. (AgribaseTM data is a product of Agriquality).



Map 4: Consented discharges to water in the Upper Manawatu above Hopelands study catchment.



Map 5: Consented discharges to land in the Upper Manawatu above Hopelands study catchment.

Water quality in the study catchment

The Manawatu at Hopelands water quality monitoring site is located at the most downstream point of the study catchment. Results show frequent breaches of both nitrogen and phosphorus ANZECC (2000) guideline levels. (Figure 1).

Figure 2 presents the median monthly nitrate and DRP concentrations, showing:

- A clear seasonal trend in nitrate monthly median concentrations, with a significant increase during the winter, wettest months. This pattern could indicate a predominance of non-point sources regarding instream nitrate, as the concentration variation follows rainfall variations.
- No clear seasonal trend regarding DRP monthly median concentrations.

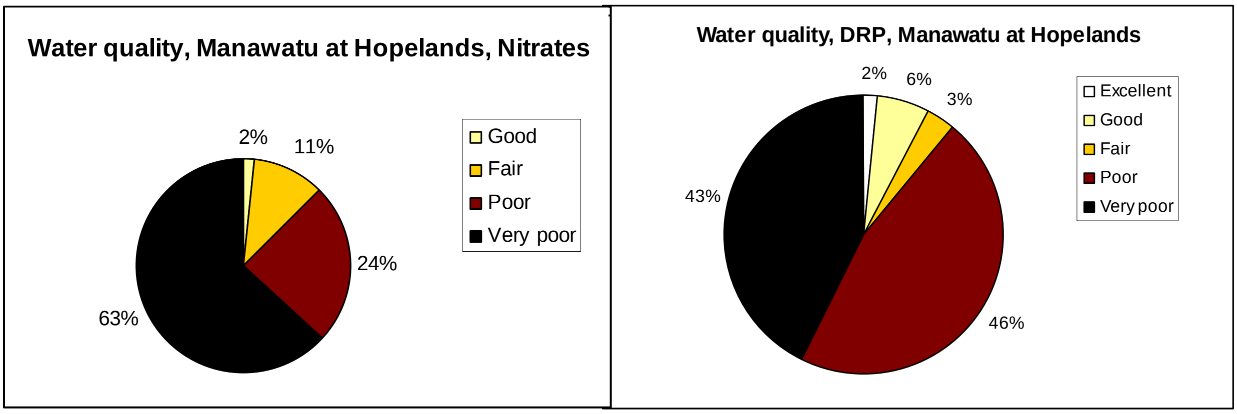


Figure 1: Water quality indicators at Manawatu at Hopelands showing the percentage of samples that are rated in five categories ranging from excellent to very poor [7].

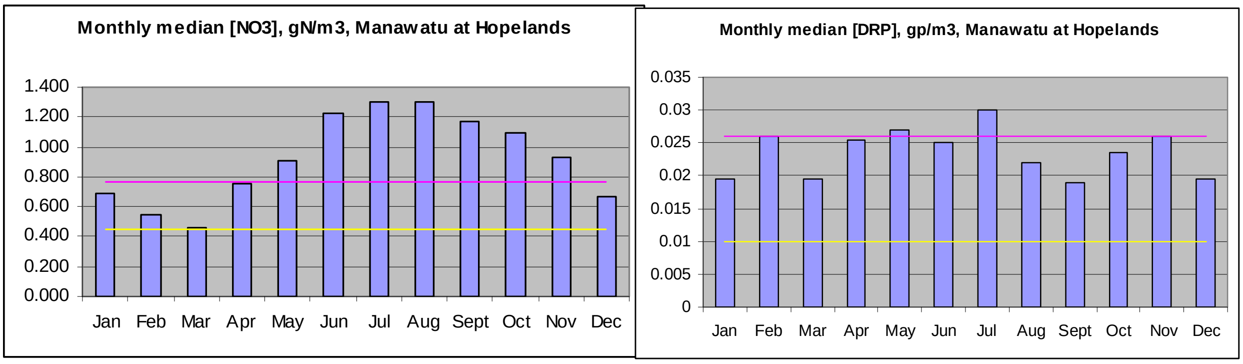


Figure 2: Monthly median concentrations of nitrate and DRP, at Manawatu at Hopelands[8].

[7] Water quality samples were classified in 5 categories. For DRP (mg/m^3): Excellent< 3; Good 3 to 6; Fair: 6 to 10; Poor: 10 to 26; Very Poor >26. For Nitrates (mg/m^3): Excellent< 75; Good 75 to 167; Fair: 167 to 444; Poor: 444 to 667; Very Poor >667.

[8] The yellow and purple lines are the thresholds for poor and very poor states respectively.

3.1.2 Estimation of non-point sources export loading

The calculation results are presented in Table 3. The total non-point source loading estimated to be exported from the Upper Manawatu above Hopelands study catchment is 1000 tonnes/year for SIN and 21 tonnes for DRP. This equates to 2740 kg/day for SIN and 58 kg/day for DRP.

This study shows that in the Upper Manawatu study catchment sheep, beef and deer farming which comprise 56% of the catchment contribute approximately 51% of the non-point SIN load and 61 % of the phosphorous load. By comparison dairy farming which comprises 17% of the catchment contributes approximately 41% of the non-point SIN load and 30 % of the phosphorous reflecting the higher export coefficients for dairying.

The estimated NPS export rates from the "farmed" part of the catchment were 9.1 kg SIN/ha/yr and 0.19 kg DRP/ha/yr.

Table 3: Non-point source load estimation for the Upper Manawatu study catchment

	Area (ha)	% of the catchment area	SIN load (T/year)	% of SIN NPS load	DRP load (T/year)	% of the DRP NPS load
Sheep and beef farming or deer farming	70,499	56 %	508	51 %	14	67 %
Dairy Farming	20,724	16 %	414	41%	6.2	30 %
including Dairy shed effluents[9]			(90)	(9 %)	(4.8)	(23 %)
Sheep farming	14,891	12 %	62.5	6 %	0.7	3 %
Forestry	3,404	2.7 %	5	0.5 %	0.02	0.1%
Vegetable Cropping/Market gardening	57	0.05%	5	0.5 %	0.01	0.05 %
(fruit, nuts, potatoes, vegetables)						
Barley, Wheat, Maize and Cropping	263	0.2 %	6	0.6 %	0.06	0.3 %
Total of NPS contributions			1000.5	100%	20.99	100%
Other	16,162					
Total farmed area (hectares)	109,838	87				
Total loading from farmed area (kg/ha/year)			9.11		0.19	

3.1.3 Estimation of point sources export loading

3.1.3.1 Point sources of SIN

The monitoring of the point sources (nitrogen concentration measurements downstream and upstream) indicates that:

- **Norsewood oxidation pond** has no impact on nitrate concentration in the Mangarangiora stream (nitrate concentrations are similar between the upstream and downstream sample sites)
- **Ormondville oxidation pond** has no impact on nitrate concentrations in the Mangarangiora stream (there was no discharge during most of 2003, according to Horizons environmental compliance officer Mark Hamer). It is

[9] The dairy farm export coefficients take into account the different types of nitrate loss related to dairy farms: nitrate leaching and runoff from pasture, dairy shed effluents, etc. An estimate of the dairy shed effluent contribution to the total load is given here, using the regional council consents database (number of cows per dairy shed and treatment of the effluent).

unknown as to how frequently this discharge actually reaches flowing water.

- **Dannevirke sewage treatment plant** has an impact on nitrate concentrations in the Mangatera stream (nitrate concentration increases of 25% on average). The annual soluble inorganic nitrogen load is estimated at 21 tonnes NO_3-N/year using typical ratio for sewage treatment plants - 5500 people, 4.2 kg N/pers./year, This report assumes 10% of nitrate is eliminated by the treatment. It is noted that this consent has recently been renewed and recent upgrades to the plant to enable compliance with new consent conditions will likely alter the environmental impact of this discharge.
- **PPCS Richmond Oringi Ltd** point source discharges have a minor impact on nitrate concentration in the Manawatu river and in the Oruakeretaki Stream (nitrate concentrations are similar upstream and downstream of the discharge)
- **Dannevirke landfill** has little impact on nitrate concentration in the Mangatera stream (average nitrate concentrations are lower downstream than upstream of the landfill).
- **Ormondville landfill** has no measurable impact on SIN concentrations of the Mangarangiora stream

Summary:
The total point source loading of SIN that is estimated to be exported from the Upper Manawatu above Hopelands study catchment is 21 tonnes/year. This equates to 58 kg/day. This is entirely sourced from the Dannevirke sewage treatment plant discharge which was the only discharge noted to impact on the SIN loadings in the river.

3.1.3.2 Point sources of DRP

The monitoring of the point sources (DRP concentration measurements downstream and upstream) enables the following statements:

- **Norsewood oxidation pond** has an impact on DRP concentrations in the Mangarangiora stream: [DRP] increase of 127% on average between the downstream and the upstream point.
  - The annual DRP load is estimated at 0.25 tonnes DRP-P/year (using typical ratios for a 220 people sewage treatment plant,)
- **Ormondville oxidation pond** has no impact on DRP concentrations in the Mangarangiora stream (there was no discharge during most of 2003, according to Horizons environmental compliance officer Mark Hamer).
- **Dannevirke sewage treatment plant** has an impact on DRP concentrations in the Mangatera stream (concentration increases of 256 % on average).
  - The annual DRP load is estimated at 1.6 tonnes DRP-P/year for the year 2003 (using the average DRP concentration in the discharge and a ratio of 200 l/person/day, for 5,500 people connected to the sewage treatment plant).
- **PPCS Richmond Oringi Ltd,** that holds several discharge permits, has an impact on DRP concentrations in the Manawatu river ([DRP] mean and median increase of 33 % between monitoring sites upstream of the land treatment site (M DS0, 65 m downstream of the Oruakeretaki confluence with the Manawatu River) and immediately downstream of the land treatment site (M DS1). The impact on the Oruakeretaki Stream is less certain ([DRP] mean increase of 15% in average but of 0% considering the median annual concentrations).

- o The annual load is estimated to be between 2.0 and 4.9 tonnes DRP/year, using an averaging approach on a bi-monthly basis, with the upstream and downstream concentration data, and the flow of the Manawatu River at Weber Road and at Hopelands. Using the Weber Road river flow data to calculate the loading gives and estimate of 2.0 tonnes DRP/year but is likely to underestimate the loading as Weber road is considerable upstream of Oringi. Using flow data from the Hopelands site probably over estimates the loading as other tributaries join the Manawatu River between the PPCS Oringi site and Hopelands. For the purpose of this report an average of the two is used 3.5 tonnes DRP per year, but it is noted that the Hopelands data is likely to provide the closer estimate of flow at the monitoring site.

- **Dannevirke landfill has an impact** on the DRP concentrations in the Mangatera stream with an average increase of 55% between the points upstream and downstream of the landfill. This load is not been included in the estimates of loadings for point source contributions. However the results of this impact will be a part of the water quality measures in the downstream monitoring at Hopelands.
- **Ormondville landfill** has no measurable impact on DRP concentrations of the Mangarangiora stream.

Summary
The total point source loading of DRP that is estimated to be exported from the Upper Manawatu above Hopelands study catchment is 5.3 tonnes/year. This equates to 14.5 kg/day. This is predominately sourced from PPCS Richmond Oringi 3.5 tonnes/year and from the Dannevirke sewage treatment plant discharge 1.6 tonnes/year.

3.1.4 Estimation of the total nutrient export loading using non-point and point source estimations

The annual loadings for SIN in the Upper Manawatu study catchment estimate a **total SIN loading of 1021 tonnes/year**. **This is predominately (98%) from non-point sources** with sheep, beef and deer farming contributing 50% of the NPS load from 56% of the catchment. By contrast **dairy farming contributed 41% of the NPS load from 16% of the catchment** (Figure 5). Point source inputs of SIN totalled 2% and were sourced from Dannevirke sewage (Figure 3).

The relative contributions of NPS and PS inputs of SIN changed by a few percent when the period October to May was considered as a “summer” period. In this time it was estimated the point source inputs were approximately 5% of the annual loading compared to 2% for the year round analysis (Figure 4).

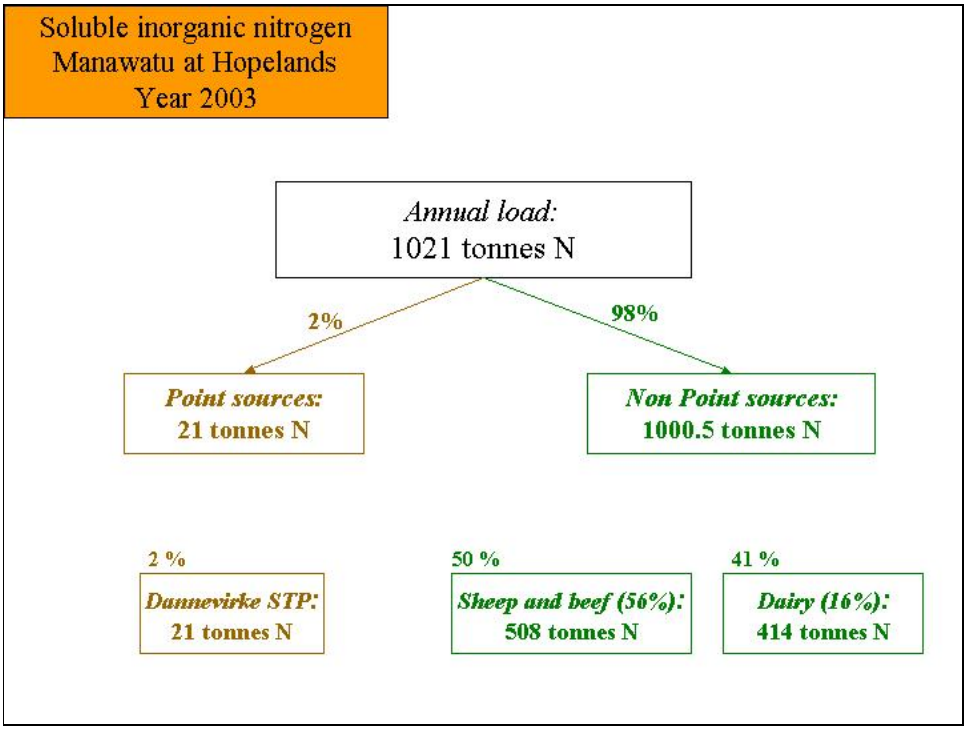


Figure 3: Annual soluble inorganic nitrogen load at Manawatu at Hopelands, and major sources for the year 2003.

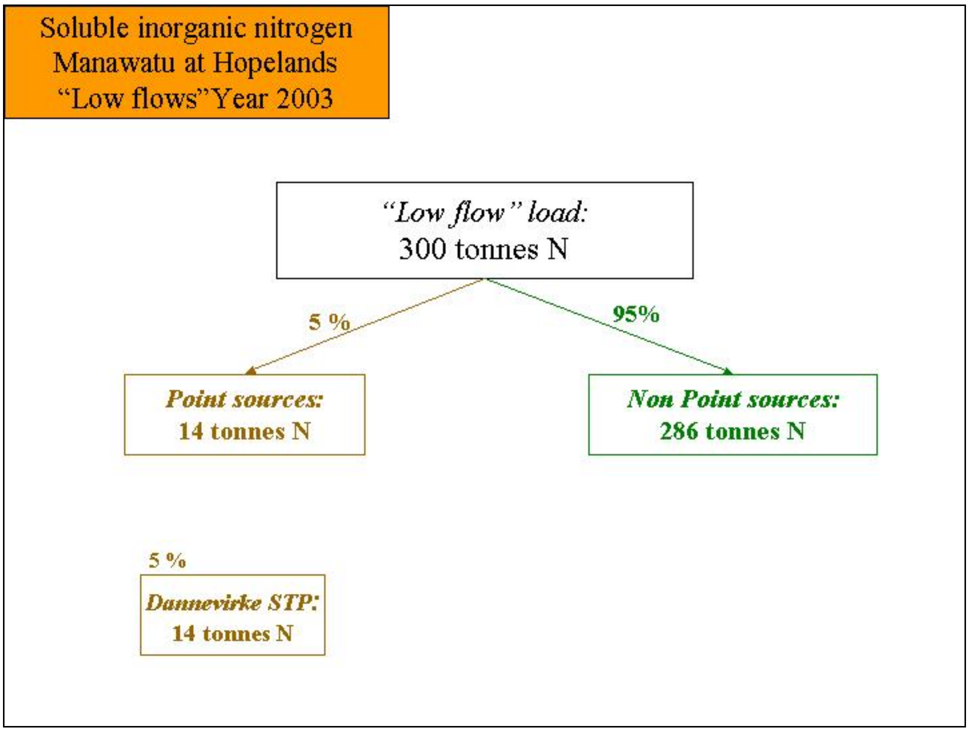


Figure 4: Summer ("low flow") soluble inorganic nitrogen load at Manawatu at Hopelands, and major sources for the year 2003.

The annual loadings for DRP in the Upper Manawatu study catchment estimate a **total DRP loading of 26.3 tonnes/year**. **This is predominately (80%) from non-point sources** with sheep, beef and deer farming contributing 53% of the NPS load from 56% of the catchment. By contrast dairy farming contributed 24% of the NPS load from 16% of the catchment (Figure 5). Point source inputs of DRP totalled 20% of the annual loading exported from the catchment 5.3 tonnes DRP/year. PPCS Richmond Oringi 3.5 tonnes/year and Dannevirke sewage treatment plant (1.6 tonnes/year) were the major contributors of this load (Figure 5).

The relative contributions of NPS and PS inputs of SIN changed considerably when the period October to May was considered as a "low flows" period. In this time it was estimated the **point source inputs were approximately 44% of the summer loading** compared to 20% for the year round analysis (Figure 6).

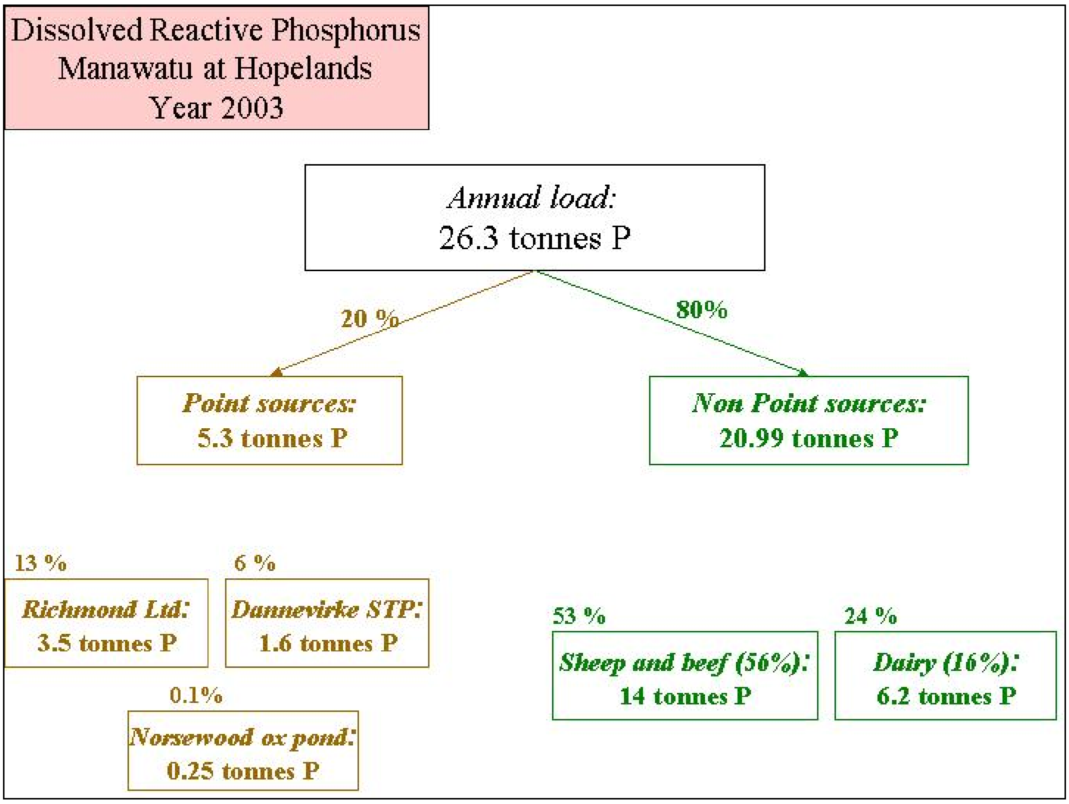


Figure 5: Annual dissolved reactive phosphorus load at Manawatu at Hopelands, and major sources, for the year 2003.

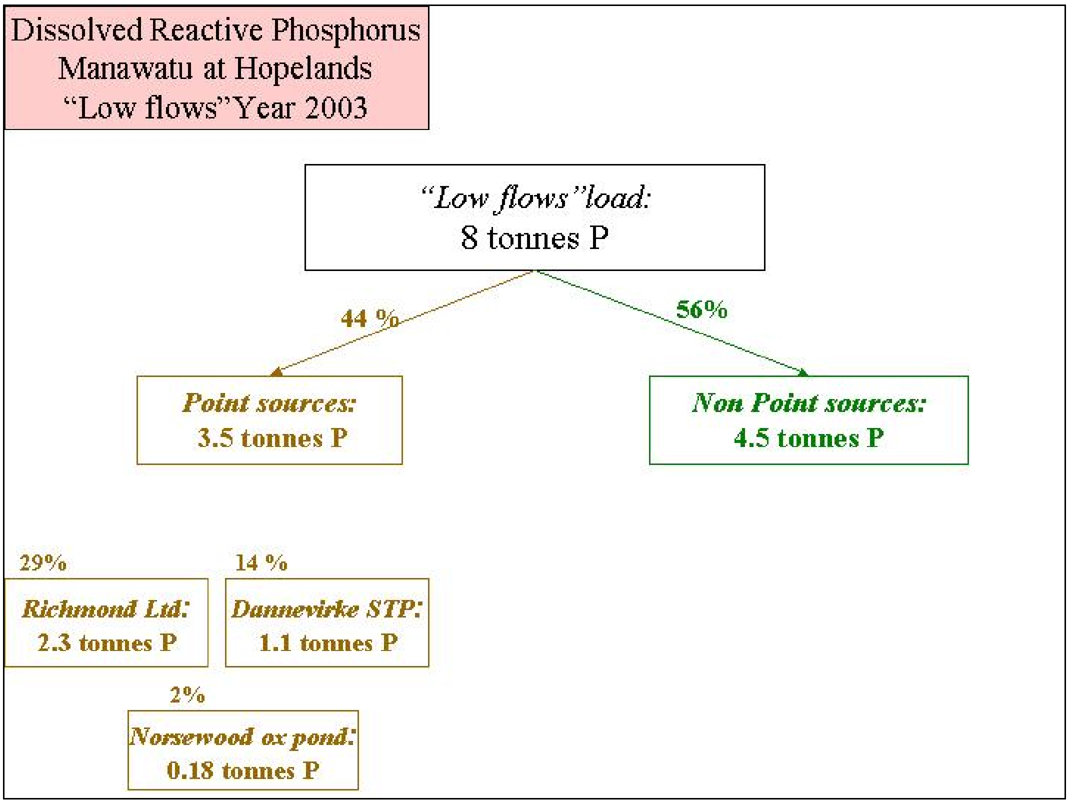


Figure 6: Summer ("low flow") dissolved reactive phosphorus load at Manawatu at Hopelands, and major sources, for the year 2003.

3.1.5 Estimation of nutrient loads calculations using flow and water quality data

In the case of the Upper Manawatu above Hopelands study catchment, nitrate, ammonia, and DRP concentrations have low correlation coefficients with flow (ie. the correlation coefficients were between 0.5 and -0.5). The averaging approach and the Beale ratio estimator were therefore the most appropriate approaches, as explained in Appendix 1.

On an annual basis, the total loading that is estimated to be exported from the Upper Manawatu above Hopelands study catchment using the river flow and water quality data range from 991 to 1099 tonnes/year for SIN (Table 4) and from 20.6 to 23.0 tonnes for DRP (Table 5).

For the October to May "low flow" period, the total loading that is estimated to be exported from the Upper Manawatu above Hopelands study catchment using the river flow and water quality data range from 282 to 345 tonnes/year for SIN and from 6.4 to 8.8 tonnes for DRP. **This indicates that the export loading is highly seasonal with the majority of losses being in the May to October period**. For SIN 65 -73% of the estimated export is occurring in 30% of the year (May to October). Similarly for DRP 57 -72% of the estimated export is occurring in 30% of the year (May to October).

Table 4: Annual SIN load calculation at Manawatu at Hopelands, for the year 2003. The "Summer" (October to May) loads are in brackets. Numbers in square brackets for the Beale ratios indicate the 95 percentile values.

Method of estimation	NO_3 loads (T/year)	NH_4 loads (T/year)	Annual SIN load (T/year)	Summer SIN Load (T/year)	Percentage of annual load exported in "summer" period
Averaging approach	966 (345)	25	991	345	35%
Regression approach	---	---	--	--	--
Regression approach 2	---	---	--	--	--
Beale Ratio estimator, and 95% confidence interval	1057 [897 ; 1217] (282)	42	1099	282	27%

Table 5: Annual DRP load calculation at Manawatu at Hopelands, for the year 2003. The "summer" (October to May) loads are in brackets. Numbers in square brackets for the Beale ratios indicate the 95 percentile values.

Method of estimation	Annual DRP load (T/year)	"Summer" DRP load (T/year)	Percentage of annual load exported in "summer" period
Averaging approach	20.6	8.79	43%
Regression approach	--	--	--
Regression approach 2	--	--	--
Beale Ratio estimator, and 95% confidence interval	22.99 [3.1 ; 39.9]	6.42	28%

3.1.6 Comparison of export loading estimation methods

The export loading calculations produced very similar estimates of the annual loadings of both SIN and DRP exported from the Manawatu above Hopelands catchment. (Table 6).

For SIN, the loading estimates using water quality and flow data estimated 991 and 1099 tonnes SIN/year, against 1021 tonnes SIN/year calculated using the export coefficients for land use type and characterisation of point source loads.

For DRP, the loading estimates using water quality and flow data estimated 20.6 and 22.99 tonnes DRP/year. The estimate using the export coefficients for land use type and characterisation of point source load was at 26.3, which is slightly higher than the range of the two methods from the water quality and flow methodology.

Table 6: Annual loading estimates for the Manawatu above Hopelands study catchment as estimated by the methodologies used in this report.

	SIN (tonnes/year)	DRP (tonnes/year)
Annual loading estimate		
Screening method		
Non-point source (NPS)	1000	20.99
Point source (PS)	21	5.3
Total Load = NPS + PS	1021	26.3
Water qualityand flow calculations		
Averaging approach	991	20.6
Beale Ratio estimator, and 95% confidence interval	1099 [897 ; 1217]	22.99 [3.1 ; 39.9]
October to May estimate		
Screening method		
Non-point source (NPS)	286	4.5
Point source (PS)	14	3.5
Total Load = NPS+ PS	300	8
Water qualityand flow calculations		
Averaging approach	345	8.79
Beale Ratio estimator, and 95% confidence interval	282	6.42

3.1.7 Conclusions for Manawatu above Hopelands study catchment

In the Upper Manawatu study catchment

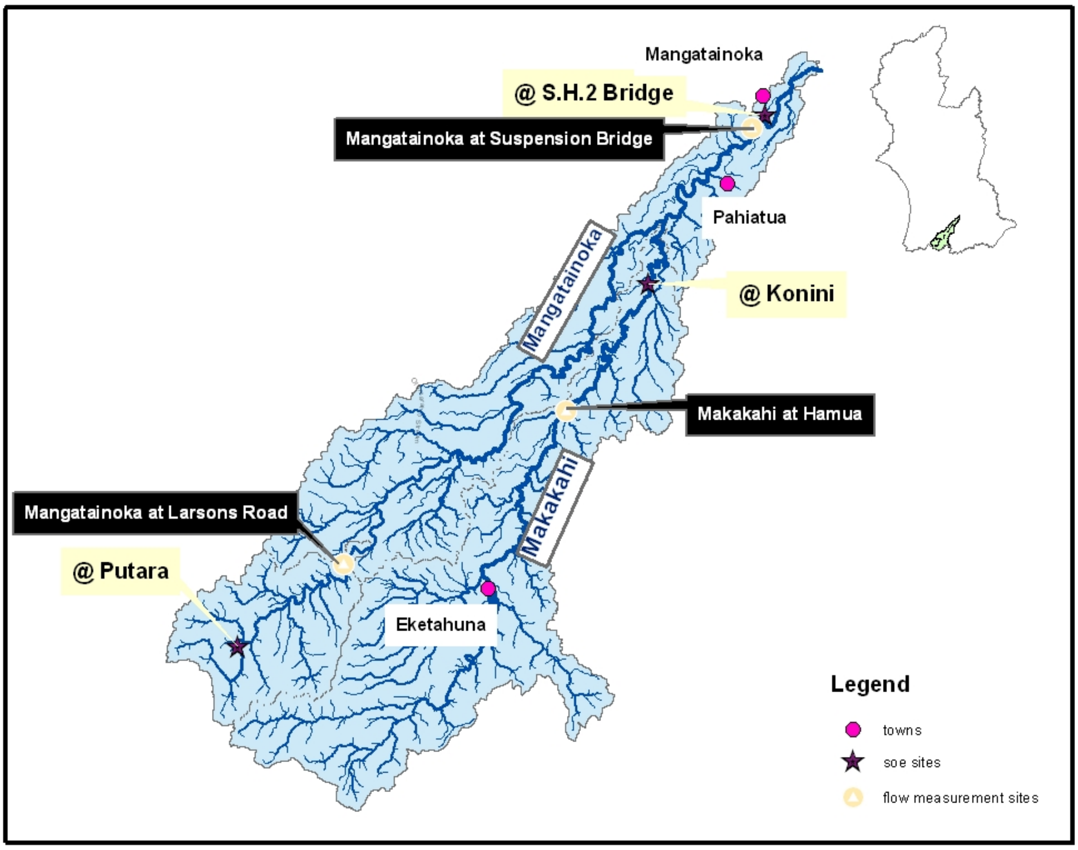
- NPS export rates from the “farmed” part of the catchment were 9.1 kg SIN/ha/yr and 0.19 kg DRP/ha/yr.
- Soluble Inorganic **Nitrogen** (SIN) **in the river predominately (98%) originate from non-point sources**, both on a yearly basis and during the period October to May.
- On an annual basis the DRP load is predominately (80%) sourced from non-point sources.
- However when the 8 month “low flow” period was considered, **Point Sources contribute to nearly half the DRP load**.
- For both SIN and DRP the export loadings appeared to be highly seasonal with a large proportion of the nutrient export occurring in the May to October (winter) period. For SIN 65-73% of the estimated export is occurring in 4 month (30%) of the year (May to October). Similarly for DRP 57-72% of the estimated export is occurring during the May to October period.
- The estimation of SIN loadings via calculation of non-point source and point source contributions were in the range predicted by water quality and flow methods.
- The estimation of DRP loadings via calculation of non-point source and point source contributions (26.3 tonnes/year) was higher than estimates using water quality and flow data (20.6 to 23 tonnes/year).

3.2 The Mangatainoka catchment

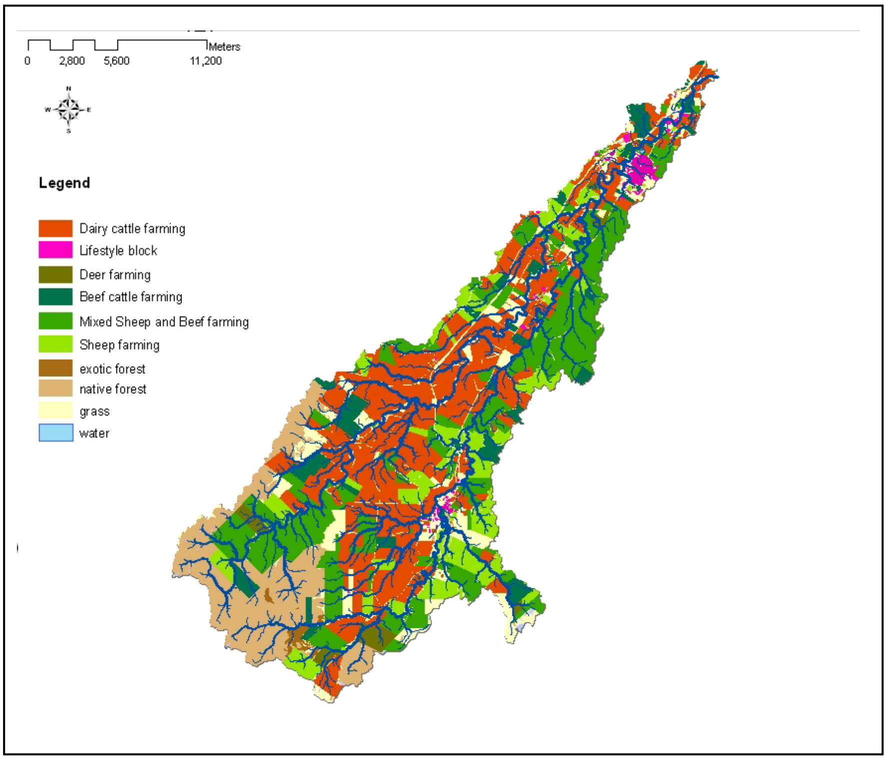
3.2.1 The study catchment

The Mangatainoka catchment is 421 km^2 and is a major tributary of the Tiraumea River which is a tributary of the Manawatu River. Townships in the catchment include Eketahuna and Pahiatua (Map 6). Dominant land uses in the Mangatainoka catchment are sheep and/or beef farming (38%) and dairying (32%) (Map 7).

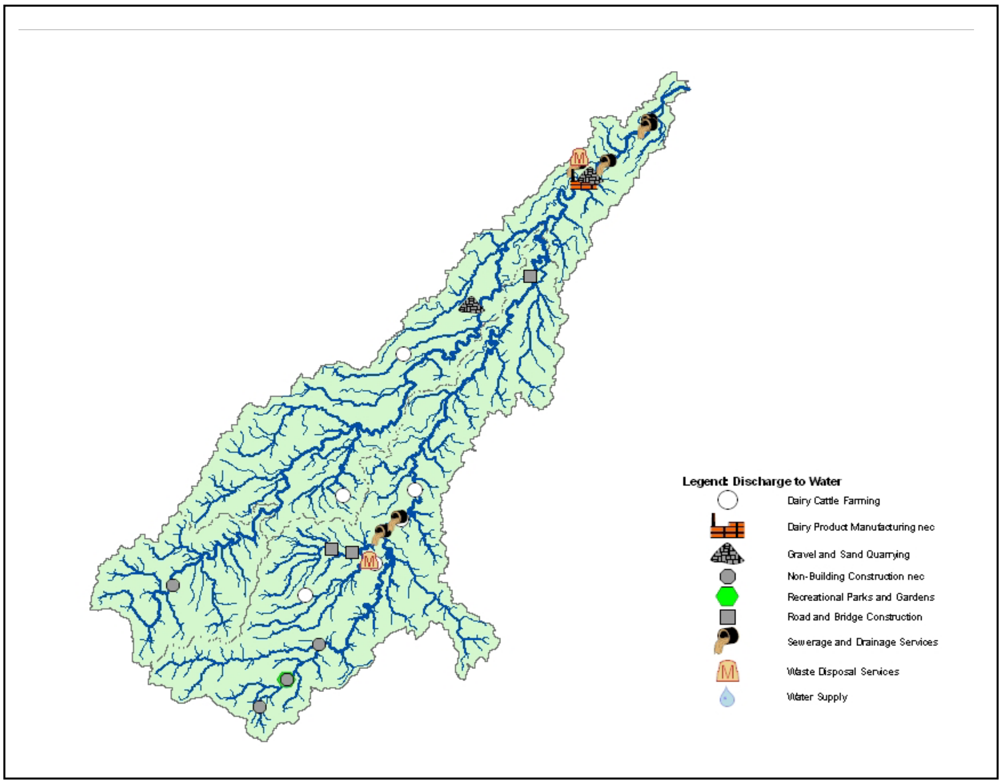
The point source discharges of nutrients in this study catchment (Map 6) are DB Breweries, Fonterra Kiwi Mangamutu, and Pahiatua and Eketahuna oxidation ponds. Note that the Eketahuna and Pahiatua landfills, shown on the map as waste disposal services, are considered non-point source in this study.
Map 8 shows the discharges to land that have been consented in this management zone. These are considered as non-point source contributors by this study.



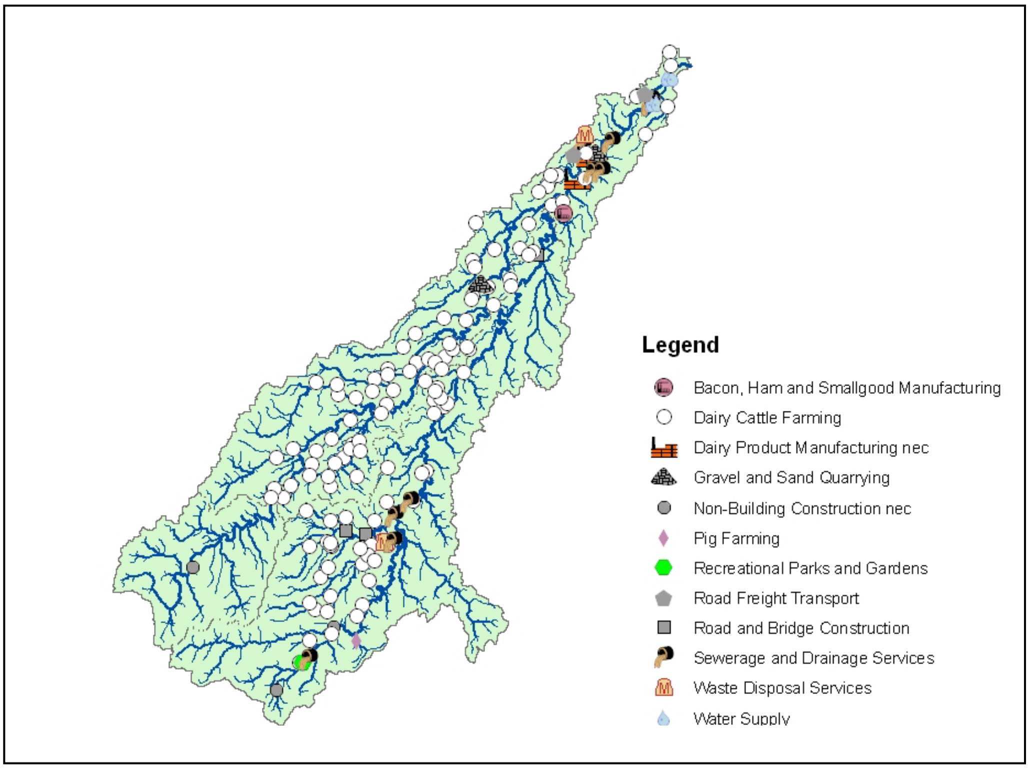
Map 6: Mangatainoka catchment: locations of towns, state of environment water quality monitoring sites (SOE sites) and flow measurement sites.



Map 7: Land cover and land use in the Mangatainoka catchment (data sourced from Agribase and LCDB2. Agribase[TM] data is a product of Agriquality).



Map 7: Consented discharges to water in the Mangatainoka study catchment.



Map 8: Consented discharges to land in the Mangatainoka catchment.

3.2.2 Water quality in the study catchment

The Mangatainoka at SH2 bridge water quality monitoring site is located close to the downstream point of the Mangatainoka catchment. However there are a few kilometres of river length downstream of the site to the confluence with the Tiraumea river, where one significant discharge to water (Tui Brewery) operates. The results of the water quality monitoring undertaken at the "SH2 Bridge" site indicate elevated levels of nitrate, with 97% of samples classified as "poor" or "very poor"[8]. DRP levels were found to be elevated above the threshold values about half of the time (Figure 7).

As with the Upper Manawatu at Hopelands site, the Mangatainoka at SH2 site shows more seasonal trends in nitrate concentration than DRP (
Figure 8).

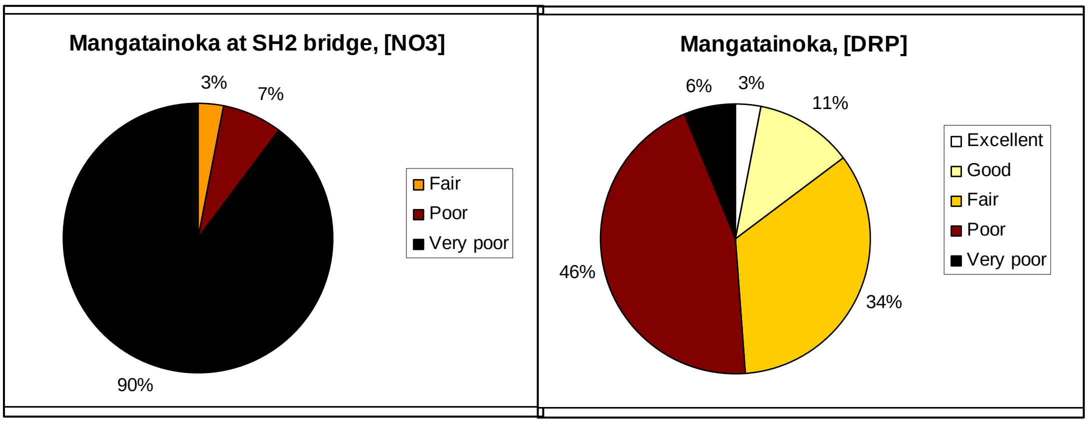


Figure 7: Water quality indicators at Mangatainoka at SH2 Bridge showing the percentage of samples rated in five categories ranging from excellent to very poor [10].

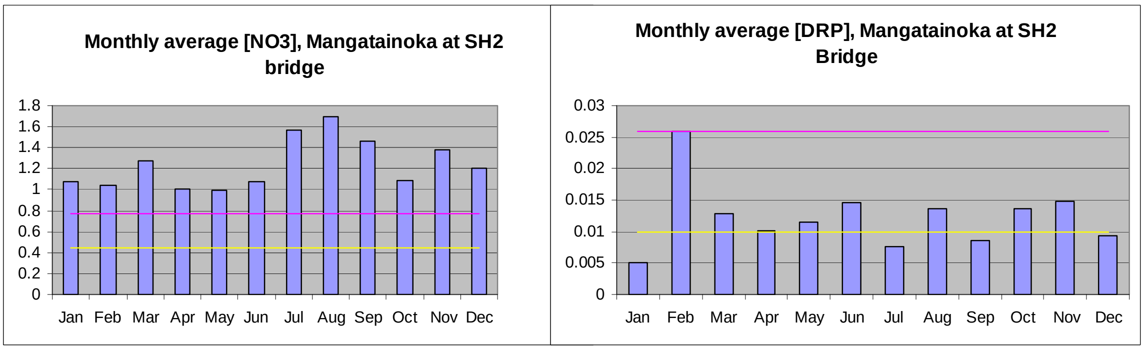


Figure 8: Monthly median concentrations of nitrate and DRP, at Mangatainoka at SH2 Bridge. The yellow and pink thresholds lines indicate the threshold between fair and poor and poor and very poor states respectively.

3.2.3 Estimation of non-point source export loading

The total non-point source loading estimated to be exported from the Mangatainoka catchment is 423 tonnes/year for SIN and 7.7 tonnes for DRP (Table 6). This equates to 1158 kg/day for SIN and 21 kg/day for DRP.

This study shows that, in the Mangatainoka catchment, mixed sheep and beef farming which comprise 22% of the catchment contribute approximately 16% of the non-point source SIN load and 18% of the phosphorous load. By comparison **dairy farming which comprises 32% of the catchment contributes approximately 62% of the non-point source SIN load** and 39% of the DRP reflecting the higher export coefficients for dairying.

10 Water quality samples were classified in 5 categories. For DRP (mg/m^3): Excellent< 3; Good 3 to 6; Fair: 6 to 10; Poor: 10 to 26; Very Poor >26. For Nitrates (mg/m^3): Excellent< 75; Good 75 to 167; Fair: 167 to 444; Poor: 444 to 667; Very Poor >667.

Table 6: Non-point source nutrient load estimation in the Mangatainoka catchment.

	Area (Hectares)	%age of the catchment	Nitrate load (T/year)	% of the SIN NPS load	DRP load (T/year)	% of the DRP NPS load
Dairy cattle farming (including dairy shed effluents[11])	13531	32.1%	270.62 (73.5)	64% (17%)	4.1 (3.15)	53% (41%)
Mixed Sheep and Beef farming	9522.	22.6%	68.558	16%	1.9	25%
Sheep farming	4234.	10.1%	30.485	7%	0.8	11%
Beef cattle farming	2394.	5.7%	47.880	11%	0.7	9%
Deer farming	699.	1.7%	5.033	1%	0.1	2%
Forestry	213.	0.5%	0.320	0%	0.0	0%
Other	11500	27%				
Total of NPSs contribution			423		7.7	
Total farmed area (ha)	30593	72.7				
Total loading from farmed area (kg/ha/year)			13.83		0.25	

Non-point source export rates after attenuation from the "farmed" part of the catchment were estimated to be 13.83 kg SIN/ha/yr and 0.25 kg DRP/ha/yr. This is significantly higher than the numbers estimated in the Upper Manawatu catchment: 9.1 kg SIN/ha/yr and 0.19 kg DRP/ha/yr. The higher rates may be attributed to a higher percentage of dairy farming in the Mangatainoka catchment (32% compared to 17%). It is noted that the Mangatainoka has 13,531 ha of dairying compared to the Upper Manawatu above Hopelands 20,724 ha.

The **Pahiatua landfill** leachate is discharged to a farm drain and the data suggests it has a minimal contribution to nitrogen loads. The concentration of monitoring samples for the discharge (which are collected from a detention pond) were multiplied by the discharge volume (maximum consented volume) to get an indicative annual load: the results of this show

- Nitrates loadings of 5.7 kg/year (average concentration) and 3.5 kg/year (median concentration)
- Ammonia loadings of 40.5 kg/year (average cc) – 47.4 kg/year (median cc)
- DRP loadings of 26 g/year (average concentration) or 19.4 g/year (median concentration)

Data for **Eketahuna landfill** has indicates no measurable impact on the nitrate, ammonia or DRP concentration of the receiving water body (Ngatahaka Creek).

3.2.4 Estimation of point source export loading

3.2.4.1 Point sources of SIN

The monitoring of the point sources (concentration measurements downstream and upstream) indicates that:

- **Kiwi Mangamutu** condensate water discharge has minimal impact on NO_3 and NH_4 and DRP. It is noted this is based on very limited data.

[11] The dairy farm export coefficients take into account the different types of nitrate loss related to dairy farms: nitrate leaching and runoff from the pasture, dairy shed effluents, etc. An estimate of the dairy shed effluent contribution to the total load is given here, using the regional council consents database (number of cows per dairy shed and treatment of the effluent).

- **Totaranui Ltd** (Sheep killing shed effluents, treated in an oxidation pond system) has no measurable impact of the nitrate load in the river. There appears to be minimal discharge to land due to evaporation.
- **Eketahuna sewage oxidation pond** has a measurable impact on soluble inorganic nitrogen in the river. The load can be estimated at 1.7 tonnes N/year (600 people minus 90 connected to a Imhoff tank, 4.2 kg N/person/year, 20 % removed by the oxidation pond).
- **Pahiatua sewage oxidation pond** has an impact on soluble nitrogen in the river. The load can be estimated at 11.15 tonnes N/year (2650 people, 4.2 kg P/person/year, 20 % removed by the oxidation pond).
- **DB Breweries** have no measurable impact on nitrate and ammonia concentration in the river (monitoring from November to April).
- **DB Breweries** irrigation of the wastewater treatment plant effluents to land. Monitoring downstream and upstream the irrigation area show that the irrigation has an impact on nitrogen concentrations in the Mangatainoka River, but not quantifiable due to insufficient data.

Summary
The total point source loading of SIN that is estimated to be exported from the Mangatainoka study catchment is 12.85 tonnes/year. This equates to 35 kg/day. This is predominately sourced from the Pahiatua sewage oxidation pond discharge (11.2 tonnes/year).

3.2.4.2 Point sources of DRP

The DB Breweries consents discharge downstream of the Mangatainoka at SH2 site. In contrast to SIN, the DRP output from this discharge has a major impact on instream nutrient loadings. To enable a comparison between methods for calculation loadings using water quality and flow data, an assessment of loading to the Mangatainoka at SH2 site was completed for DRP. To enable a calculation of total point source loading in the catchment a further analysis including the DB breweries consent was also completed for DRP.

The monitoring of the point sources (DRP concentration measurements downstream and upstream) indicates:

- **Kiwi Mangamutu** condensate water discharge has no or minimal impact on DRP concentration in the river. It is noted this is based on very limited data.
- **Totaranui Ltd** (Sheep killing shed effluents, treated in an oxidation pond system) has no measurable impact of the DRP load in the river. There appears to be minimal discharge to land due to evaporation.
- **Eketahuna sewage oxidation pond** has a measurable impact on DRP concentrations in the river. The load can be estimated at 0.52 tonnes DRP/year (600 people minus 90 connected to a Imhoff tank, 1.5 kg P/person/year, 20 % removed by the oxidation pond, 85 % of DRP).
- **Pahiatua oxidation** pond has an impact on DRP in the river. The load can be estimated at 2.7 tonnes DRP/year (2650 people, 1.5 kg P/person/year, 20 % removed by the oxidation pond, 85 % of DRP).
- **DB Breweries** have an impact on DRP concentration in the river. The DRP load is estimated at 6 tonnes DRP-P, for the months of Nov-Dec 2000, Jan-Mar-Apr 2001 (estimated with an averaging approach, using the flow data of Mangatainoka at SH2). DRP peaks were identified downstream of DB Breweries in February, in March and in November, each year leading to high calculated loading. DB Breweries discharge is

located downstream of “Mangatainoka at SH2”. Consequently, this load will be added to the load at SH2.

- **DB Breweries** irrigation of the wastewater treatment plant effluents to land. Monitoring downstream and upstream of the irrigation area show that the irrigation has an impact on DRP concentrations in the Mangatainoka River, but not quantifiable, due to insufficient data.

Summary:
The total point source loading of DRP that is estimated to be exported from the Mangatainoka catchment (above the monitoring site at SH2 Bridge) was estimated to be 3.2 tonnes/year. This equates to 8.8 kg/day. This is predominately sourced from Pahiatua sewage oxidation pond 2.7 tonnes/year.

The total point source loading of DRP that is estimated to be exported from the Mangatainoka catchment (to the confluence with the Tiraumea River, thus including the DB breweries discharges) was estimated to be 9.2 tonnes/year. This equates to 25.2 kg/day. This includes DB breweries’ contribution of 6 tonnes DRP/year.

3.2.5 Estimation of the total export nutrient loading using non-point source and point source estimations

The annual loadings for SIN in the Mangatainoka catchment are estimated at 436 tonnes/year. This is predominately (97%) from non-point sources with sheep, beef farming contributing 16% of the NPS load from 22% of the catchment. By contrast dairy farming contributed 62% of the NPS load from 32% of the catchment (Figure). Point source inputs of SIN totalled 12.85 tonnes N/year 3% of the total loading and were predominately sourced from Pahiatua sewage (11.2 tonnes N/year).

The annual loadings for DRP in the Mangatainoka catchment to the State Highway 2 bridge estimate a total DRP loading of 10.92 tonnes/year. This is mostly (71%) from non-point sources with sheep, beef farming contributing 18% of the NPS load from 22% of the catchment. By contrast dairy farming contributed 39% of the NPS load from 32% of the catchment (Figure 12). Point source inputs of DRP totalled 3.22 tonnes N/year (29% of the total loading). This was predominately sourced from Pahiatua sewage (2.7 tonnes N/year) which made up 83% of the point source contribution of DRP.

The annual loadings for DRP in the Mangatainoka catchment to downstream of the DB breweries discharge, estimate a total DRP loading of 16.92 tonnes/year. This is 6 tonnes/year higher than the SH2 estimate. This changes the predominate contributor of DRP from 71% being from non-point source at the upstream SH2 site to being only 46% from NPS at the downstream DB breweries discharges. Point source inputs of DRP totalled 3.22 tonnes N/year at the upstream SH2 site increase to a total of 9.22 tonnes/year downstream of the DB breweries site.

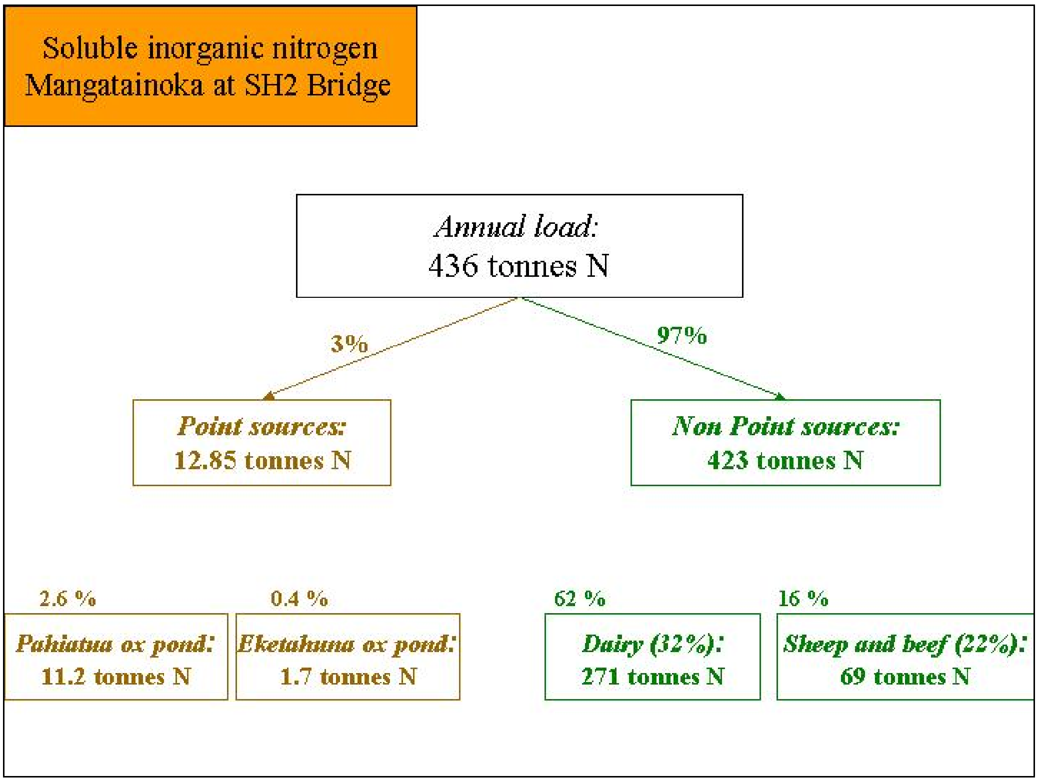


Figure 9: Annual Soluble Inorganic Nitrogen load at Mangatainoka at SH2 Bridge, and major sources. Percentage of land in the catchment used for dairying (32%) and sheep and beef farming (22%) are indicated in brackets.

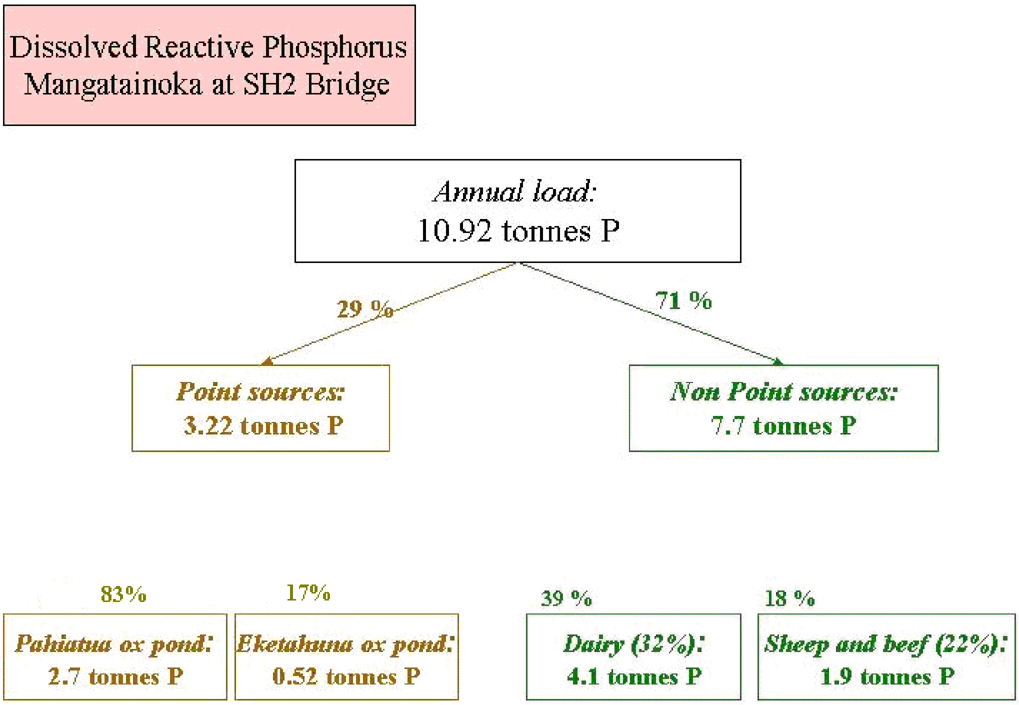


Figure 10: Annual DRP load in the Mangatainoka River at SH2 Bridge, and major sources. Percentage of land in the catchment used for dairying (32%) and sheep and beef farming (22%) are indicated in brackets.

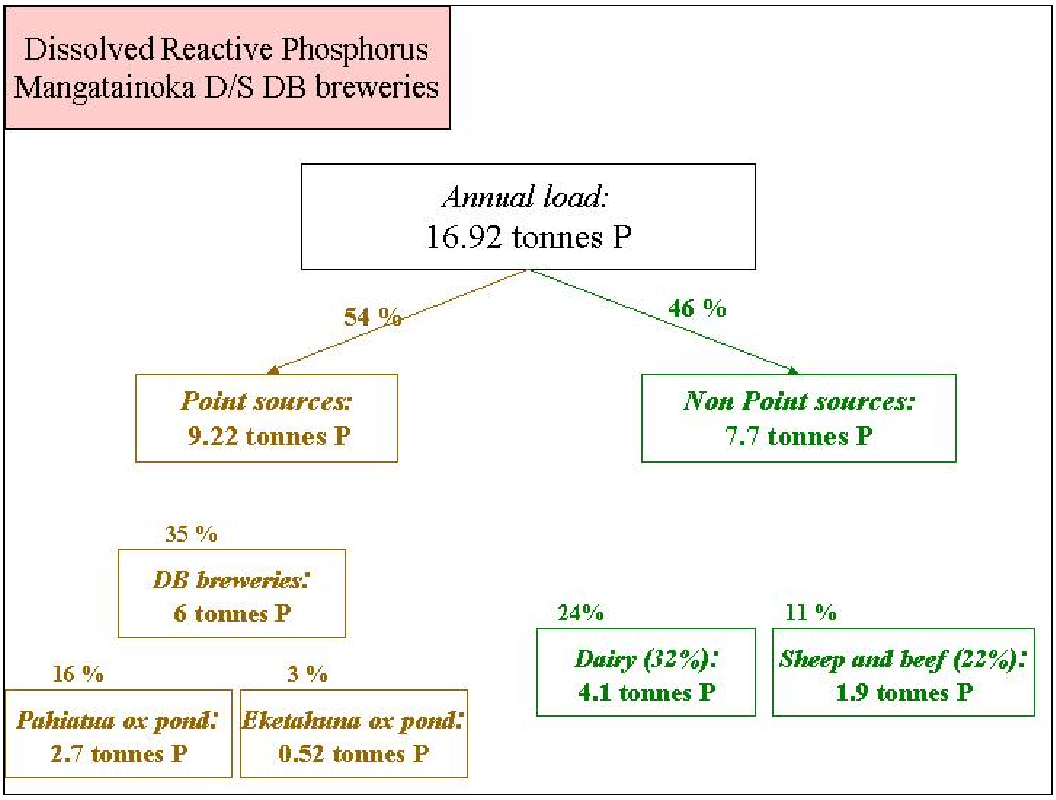


Figure 11: Annual DRP load in the Mangatainoka River downstream DB breweries, and major sources. Percentage of land in the catchment used for dairying (32%) and sheep and beef farming (22%) are indicated in brackets.

3.2.6 Nutrient load calculations

As was the case in the Upper Manawatu catchment, nitrate, ammonia, and DRP concentrations in the Mangatainoka river at SH2 have low correlation coefficients with flow (ie. the correlation coefficients were between 0.5 and -0.5). The averaging approach and the Beale ratio estimator were therefore considered the most appropriate approaches, as explained in Appendix 1. Nutrient loadings calculated via these methods are shown in Table 7.

Total export loading estimates for he Mangatainoka at SH2 were calculated for three individual years using the river flow and water quality data. Variability between years was found to be high. By contrast the averaging approach and Beale ratio estimator methods provided similar estimates for annual loadings by year. For example for 2000, 2002 and 2003 the annual export loadings for SIN were 463 to 960 using the averaging approach. However for 2000 the average approach estimated 638 tonnes/year and the Beale ratio estimator method estimated 665 tonnes/year. It is noted that 2003 was a dry year in the Horizons Region.

Applying the river flow and water quality method for the Mangatainoka study catchment estimates export loadings from 427 to 960 tonnes/year for SIN and from 5 to 9.5 tonnes for DRP (Table 7). **The indication from the data is that annual loads are highly variable from year to year.**

Table 7: Nutrient load calculation at Mangatainoka at SH2 Bridge for 2000, 2002 and 2003. Numbers in square brackets for the Beale ratios indicate the 95 percentile values.

Method of estimation		NO_3 load (T/year)	NH_4 loads (T/year)	SIN Load (T/Year)	DRP loads (T/year)
Averaging approach	2000	638	---	638	9.5
	2002	960	---	960	7.5
	2003	463	---	463	5
Average of 2000, 2002, 2003		687	---	687	7.3
Beale Ratio estimator, and [95% confidence interval]	2000	665 [540 ; 790]	---	665 [540 ; 790]	9.5 [5.5 ; 13.5]
	2002	830 [677 ; 983]	---	830 [677 ; 983]	10.2 [8.2 ; 12.2]
	2003	427 [348 ; 507]	---	427 [348 ; 507]	5.8 [4.2 ; 7.3]
Average of 2000, 2002, 2003		640.6	---	640.6	8.5

3.2.7 Comparison of export loading estimation methods

In the Mangatainoka study catchment the SIN export loading calculations produced by the screening method provided an estimate (436 tonnes/year) which was in the low end of the range predicted by the water quality and flow method (427 to 960 tonnes/year). By comparison for DRP the screening method produced an estimate (10.92 tonnes/year) just higher than the range predicted by the water quality and flow method (5.0 to 10.2 tonnes/year).

Table 6: Annual loading estimates for the Manawatu above Hopelands study catchment as estimated by the methodologies used in this report.

	SIN (T/year)	DRP (T/year)
Screening method		
Non-point source (NPS)	423	7.7
Point source (PS)	13	3.22
Total Load = NPS+ PS	436	10.92
Water quality and flow calculations		
Averaging approach	463 to 960	5.0 to 9.5
Beale Ratio estimator, and 95% confidence interval	427 to 830	5.8 to 10.2

3.2.8 Conclusions for Mangatainoka study catchment and comparisons to the Upper Manawatu above Hopelands study catchment

In the Mangatainoka study catchment:

- Non-point source export rates after attenuation from the “farmed” part of the catchment were estimated to be 13.83 kg SIN/ha/yr and 0.25 kg DRP/ha/yr. These rates are higher than the figures for the Upper Manawatu catchment, which may be attributed to a higher percentage of dairy farming in the Mangatainoka 32% than in the Upper Manawatu (17%).
- **SIN in the river predominately (97%) come from non-point sources**, a similar result to the Upper Manawatu (98%),
- DRP is mostly (71%) sourced from non-point sources for the catchment upstream of the water quality monitoring site at the SH2 bridge.
- Downstream of the SH2 site the DB breweries discharges significantly contributes DRP to the river changing the loading estimate to a 44% point source/56 % non-point source split.

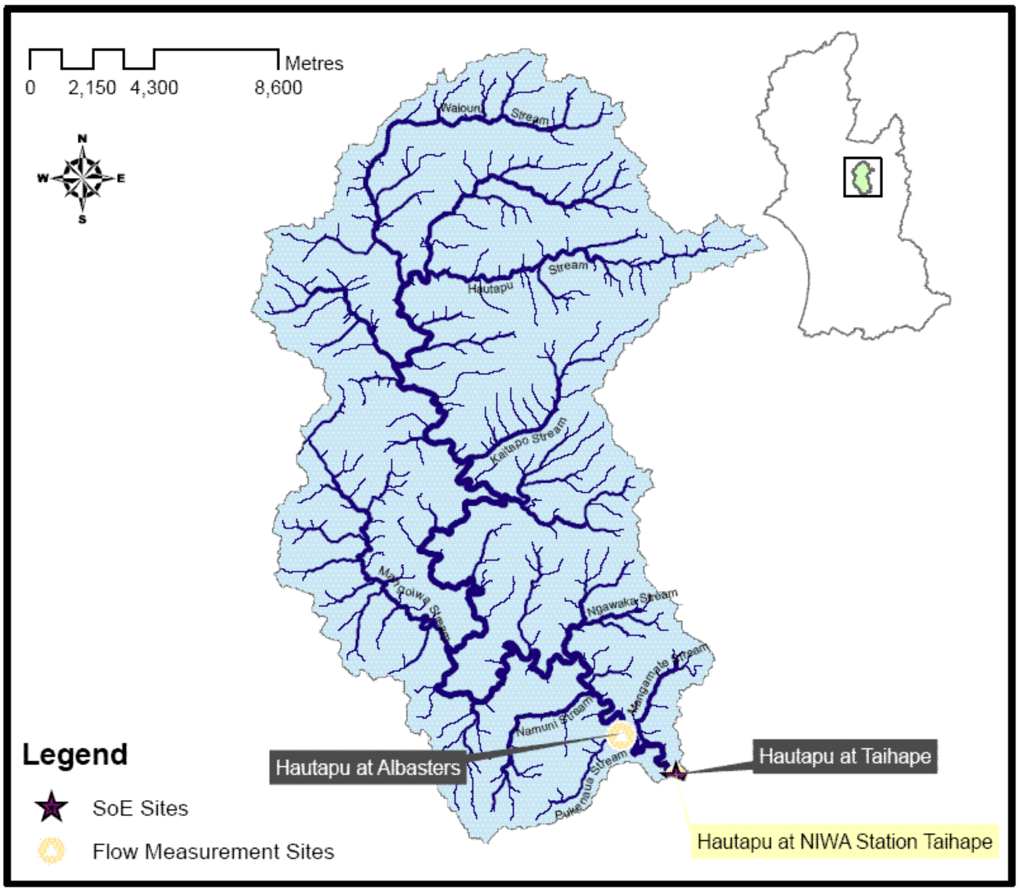
- For both SIN and DRP the export loadings appeared to be highly variable between years.

3.3 The Upper Hautapu catchment

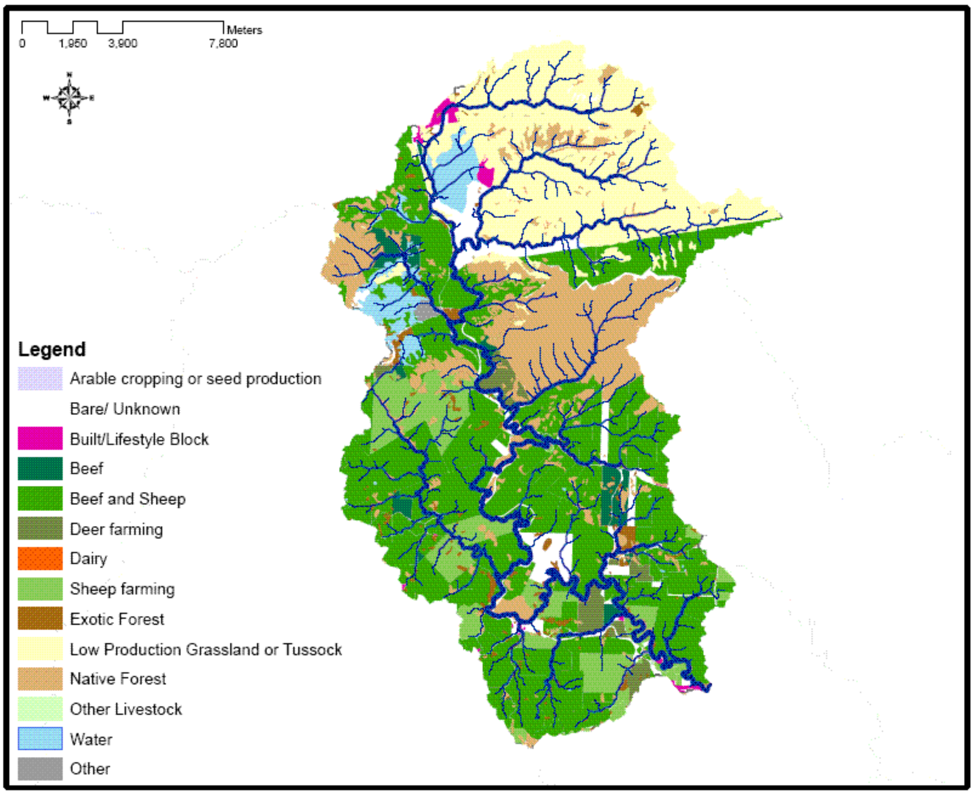
3.3.1 Brief introduction to the study catchment

The Hautapu River is a major tributary of the Rangitikei River. The study catchment is the Upper Hautapu catchment (290 km^2), from its source to just upstream of Taihape township (Map 9).

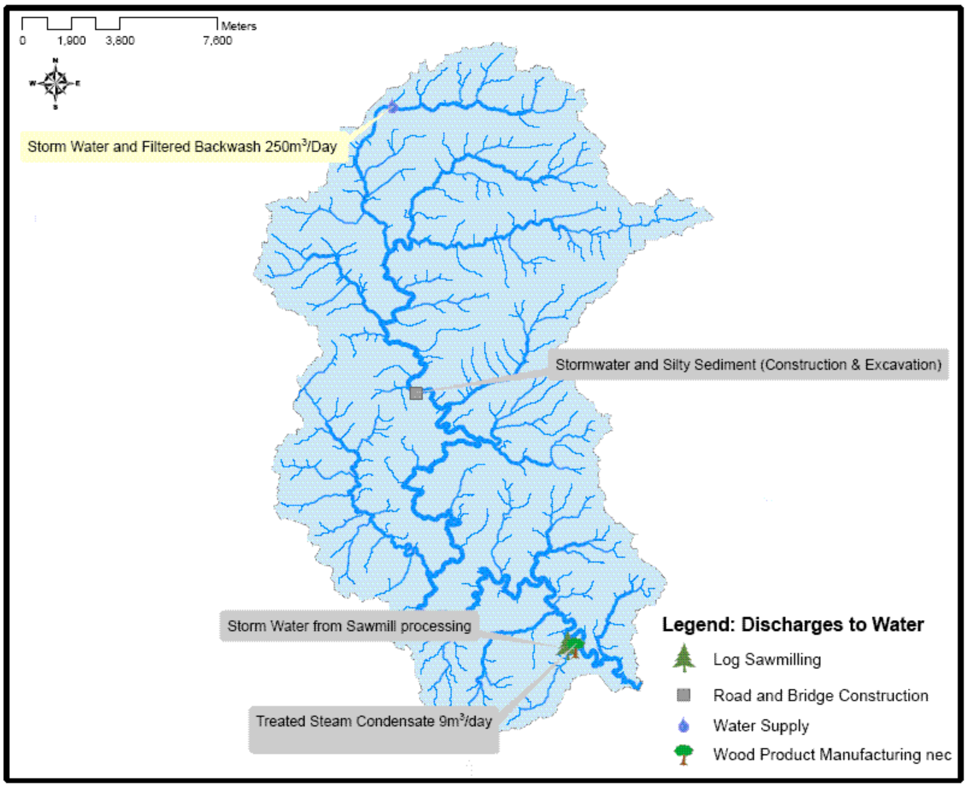
About 30 percent of the catchment is covered in tussock grassland or native bush and receives little or no human pressure. The rest of the catchment's land use is predominantly (46%) sheep and beef farming (Map 10). There are only currently consented discharges to water in the study catchment, none of them likely to significantly contribute to nutrient loads (Map 11). It is noted that the Taihape Sewage discharge to water is downstream of this zone.



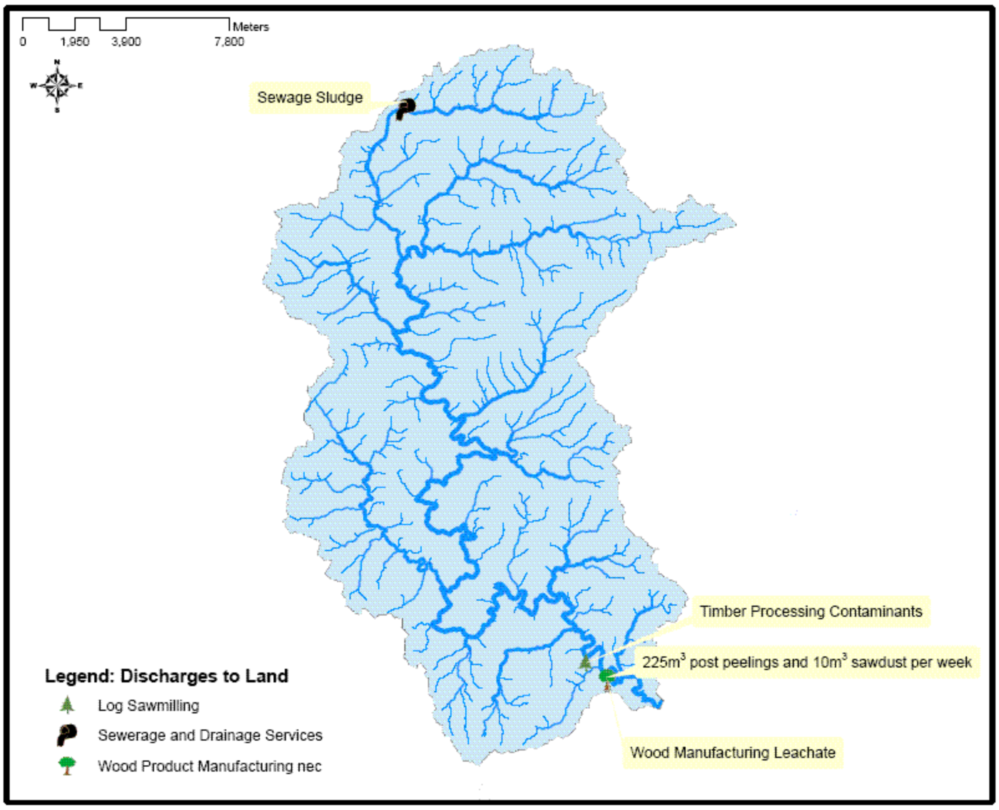
Map 10: Location of towns, state of environment water quality monitoring sites (SOE sites) and flow measurement sites in the Upper Hautapu study catchment.



Map 11: Land cover and land use in the Upper Hautapu study catchment (Data source from Agribase and LCDB2 Agribase™ data is a product of Agriquality)



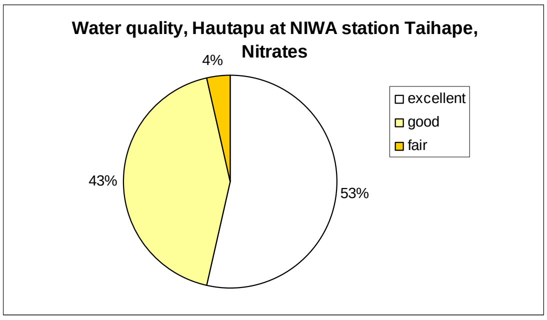
Map 12: Consented discharges to water in the Upper Hautapu study catchment.



Map 12: Consented discharges to land in the Upper Hautapu study catchment.

3.3.1 Water quality in the study catchment

The Hautapu at Taihape water quality monitoring site at the most downstream point of the study catchment shows elevated levels of DRP about half of the time, while the nitrate levels were nearly always satisfactory when compared to the standards (Figure 12).



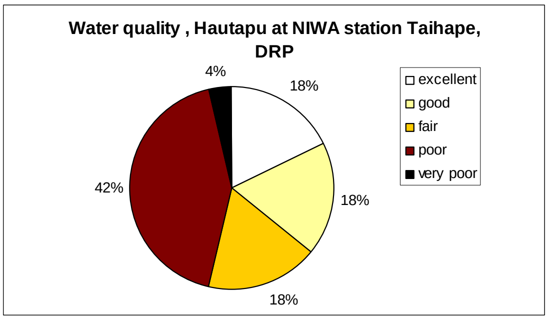


Figure 12: Water quality indicators at Hautapu at Taihape showing the percentage of samples rated in five categories ranging from excellent to very poor [12]. Data from 1997 to 2005.

[12] Water quality samples were classified in 5 categories. For DRP (mg/m^3): Excellent< 3; Good 3 to 6; Fair: 6 to 10; Poor: 10 to 26; Very Poor >26. For Nitrates (mg/m^3): Excellent< 75; Good 75 to 167; Fair: 167 to 444; Poor: 444 to 667; Very Poor >667.

3.3.2 Estimation of non-point source export loading

The total non-point source loading estimated to be exported from the Hautapu study catchment is 131 tonnes/year for SIN and 3.2 tonnes for DRP (Table 8).

Non-point source export rates after attenuation from the “farmed” part of the catchment were estimated to be 7.56 SIN/ha/yr and 0.19 kg DRP/ha/yr. For comparison the Upper Manawatu above Hopelands catchment had estimated rates of 9.1 kg SIN/ha/yr and 0.19 kg DRP/ha/yr. The Mangatainoka catchment has estimated rates of 13.83 kg SIN/ha/yr and 0.25 kg DRP/ha/yr. The lower rates in the Hautapu are attributed to the predominance of sheep and beef farming and the absence of dairy farming in this study catchment.

Table 8: Non-point source load estimation, on the Upper Hautapu catchment.

Agribase Description	Area (Ha)	% of catchment	SIN load (T/year)	% of the SIN NPS load	DRP load (T/year)	% of the DRP NPS load
Mixed Sheep and Beef farming	13296	46.4	95.7	73%	2.66	83%
Sheep farming	2395	8.4	10.1	8%	0.12	4%
Beef cattle farming	1050	3.7	21	16%	0.32	10%
Deer farming	600	2.1	4.3	3%	0.12	4%
Forestry	11.1	0.04	0.017	0%	0	0%
Other	11296	39.4				
Total catchment area (ha)	28649					
Total NPS contributions			131.1		3.21	
Total farmed area (ha) (excludes “Other category)	17353	60.6				
Total Loading from farmed area (kg/ha/yr)			7.56		0.19	

3.3.3 Estimation of point source export loading

The Upper Hautapu zone does not contain any point source discharges likely to contribute to nutrient loading in the river.

3.3.4 Estimation of the total nutrient export loading using non-point source and point source estimations

The total loading for the Upper Hautapu zone is estimated to be the loading for the non-point source estimates (Table 8).

It is noted that the catchment contains a significant area of land that is not used for production. These calculations provide no allowance for the losses from this land in the total loading estimate.

3.3.5 Estimation of nutrient load calculations using flow and water quality data

Load calculation, at NIWA station Taihape was calculated for data from July 2001 to June 2002. Nitrate concentration in the River was strongly correlated (Figure 13) to the river flow, enabling the use of the regression approach (Appendix 1) as well as the Beale Ratio estimator.

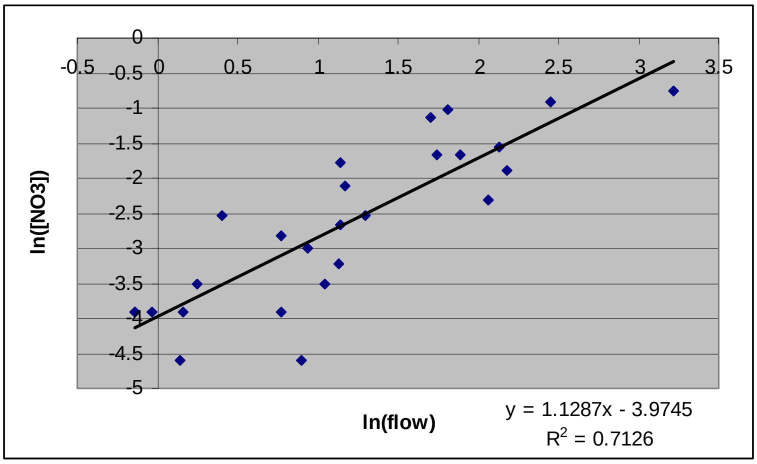


Figure 13: Correlation between flow and nitrate concentration for the Hautapu above Alabasters study catchment

As with the other catchments of this study, DRP concentrations was found to have a low correlation coefficient with river flow.. The averaging approach and the Beale ratio estimator were therefore taken as the most appropriate approaches as explained in Appendix 1.

Table 9: Total load calculation, at NIWA station Taihape. Numbers in square brackets for the Beale ratios indicate the 95 percentile values.

	SIN load tonnes/year	DRP load tonnes/year
Averaging approach		1.25
Regression approach - 1	66.8	
Regression approach - 2	88.7	
Beale ratio estimator	52.5 [24.6 ; 80.4]	1.25 [0.87 ; 1.64]

On an annual basis, the total loading that is estimated to be exported from the Upper Hautapu catchment using the water quality and flow data range from 52.5 to 66.8 tonnes/year for SIN and both methods estimate 1.25 tonnes/year for DRP.

3.3.6 Comparison of export loading estimation methods

Export loadings from the estimation of non-point source losses from the productive land in the catchment provided estimates that were considerably higher than the estimates using water quality and flow data for both SIN and DRP. The total non-point source loading estimated to be exported from the Hautapu study catchment is 131 tonnes/year for SIN and 3.2 tonnes for DRP

(Table 9). By comparison estimates from the water quality and flow data range from 52.5 to 66.8 tonnes/year for SIN and both methods estimate 1.25 tonnes/year for DRP. The sheep and beef farming in the Upper Hautapu is of relatively low intensity, compared to the two other study catchments. This may explain the discrepancy between the calculated loads “observed” in the river (Water quality and flow data) and “predicted” (screening model.).

3.3.7 Conclusions for the Upper Hautapu study catchments and comparisons to the Upper Manawatu above Hopelands and Mangatainoka study catchments

In the Upper Hautapu study catchment

- Non-point rates of export after attenuation from the “farmed” part of the catchment were estimated to be 7.56 SIN/ha/yr and 0.19 kg DRP/ha/yr. For comparison the Upper Manawatu above Hopelands catchment had estimated rates of 9.1 kg SIN/ha/yr and 0.19 kg DRP/ha/yr. And the Mangatainoka study catchment estimates were be 13.83 kg SIN/ha/yr and 0.25 kg DRP/ha/yr. The lower rates in the Hautapu were attributed to the absence of dairy farming in the catchment.
- There are no point source discharges in the study area.
- Export loadings from the estimation of non-point source losses from the productive land in the catchment provided estimates that were considerably higher than the estimates using water quality and flow data for both SIN and DRP.

4 Summary of findings

The three study catchments show

- On an annual basis it is estimated that instream SIN is predominately (97–100%) from non-point sources.
- On an annual basis the proportion of DRP loading is highly influenced by the presence of direct discharges to water of treated domestic or industrial wastewater. On an annual basis estimates of the percentage of DRP in the river sourced from non-point sources ranged from (56–80%) in the two catchments with point source discharges.
- Seasonality of loadings was tested in the Upper Manawatu above Hopelands catchment. On an annual basis the DRP load is predominately 80% sourced from non-point sources. However when the 8 month "summer" period was considered the DRP load contributions of non-point source and point source was close to even.
- For both SIN and DRP the export loadings appeared to be highly seasonal with a large proportion of the nutrient export occurring in the May to October (winter) period. For SIN 65-73% of the estimated export is occurring in 30% of the year (May to October). Similarly for DRP 57-72% of the estimated export is occurring in 30% of the year (May to October).
- Annual variability in loadings was tested using the data for the Mangatainoka study catchment, both SIN and DRP export loadings appeared to be highly variable between years.
- The estimation of SIN loadings via calculation of non-point source and point source contributions were generally in the range predicted by water quality and flow methods. However for the Hautapu catchment the water quality and flow estimates were considerably lower.
- The estimation of DRP loadings via calculation of non-point source and point source contributions were generally higher than estimates using water quality and flow data.

4.1 A note on the extrapolation of the findings

The three study catchments were selected to be representative of the Region's land cover, land use and pressures associated with human activity. However, **extrapolating these results to other catchments in the Region, or generalising them to the rest of the Region should not be done without due caution. In particular, on needs to give consideration to**:

- the land cover and land use mix in the catchment: the relative contributions of dairy over sheep and beef farming may be very different from the study catchment, which in turn will affect the results,
- the presence of land uses seldom or not covered in this study, eg. market gardening, cropping or urban catchment. These have been shown to have the potential to lose significant amounts of nutrients into the environment, and their presence in a catchment could change the results,
- the influence of sources that have not been assessed in this study, eg. concentration of septic tanks in coastal/urban subdivision,
- the fact that the model provides annual or seasonal estimates. In no way the NPS/PS ratio should be extrapolated to daily loads or specific scenario (eg. low flow conditions).

5 Recommendations for further work

This study provides a first approach to identifying sources of pollution at the catchment scale. It provides useful information and guidance in a context of new policy development.

Further work is however required to refine and extend the findings of this study, in particular:

- extent the methodology to other contaminants, such as BOD, *E. coli*;
- investigation of the seasonality and annual variability of loadings,
- develop a methodology to reduce the temporal or spatial scale of the model, ie. estimate daily or monthly contaminant loads, at the sub-catchment or farm scale.

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Appendix 1

1 Nutrient export load calculation methods

The task of load calculation is to get an annual amount of pollutant running through the downstream point of a study catchment (in tonnes/year for example) out of measurement of concentration and flow.

If continuous measurements of the flow and of the pollutant concentrations were available, the loads would be simple to evaluate:

$$Load(year_i) = \int_{01/01/year_i}^{31/12/year_i} [Pollut](t) \cdot Flow(t) \cdot dt$$

Continuous flow measurement is available for many sites in the Manawatu-Wanganui Region. However, water quality samples are usually measured only once a month. That is why we have to approximate this integral formula.

We use three different approaches in this study to estimate the loads. The choice of the estimator depends on the correlation between concentration and flow data.

1.1 Averaging approach: If pollutant concentration and flow are independent variables

If pollutant concentration and flow are independent variables, an estimate of the monthly load is estimated by the monthly average concentration times the average flow for the month (Richards, 1998 and Ferguson, 1985)

$$Load(month_i) = [Pollut](month_i) \cdot \int_{01/month_i}^{31/month_i} Flow(t) \cdot dt$$

This leads to the estimator

$$Load\,(year_i) = \sum_i [\,pollut\,]_{monthi} \cdot Monthly\_average\_flow_{monthi} \cdot \Delta t$$

The precision of this estimator can be estimated with the following formula (Hoare, 1982):

$$\Pr ecision = \frac{S\tan dardDeviation(Concentration)}{\sqrt{NbOfObservationsInTheYear}} + Flow\Pr ecision$$

Little relationship between two variables is assumed when their correlation coefficient is between -0.5 and 0.5.

1.2 Regression approach: If pollutant concentration and flow are not independent variables

If the correlation is good enough (ie. outside the range where correlation coefficients are between -0.5 and 0.5) then the flow rates can be used to estimate concentrations, by deriving a linear regression equation. The regression is often better if concentrations and flow are log-transformed (this reduces the influence of the highest concentrations/flows).

Time may be used to account for possible linear trends, and seasonal variation.

Often, the regression is of the form:

$$\ln([pollut]) = \lambda_0 + \lambda_1 \cdot t + \lambda_2 \cdot \sin(2\pi t) + \lambda_3 \cdot \cos(2\pi t) + \lambda_4 \cdot \ln(q) + \lambda_5 \cdot \ln(q)^2$$

where t is decimal time, so that $\lambda_1 t$ accounts for linear trends and $\lambda_2 \sin(2\pi t) + \lambda_3 \cos(2\pi t)$ approximate seasonal variations (Smith *et al*., 1997)

To get pollutant concentration, an exponentiation is required. This transformation creates a bias. Ferguson suggested this bias correction (Ferguson, 1986):

$$[pollut] = e^{\overline{\ln[pollut]} + \frac{\sigma^2}{2}}$$

where $\overline{\ln[pollut]}$ is the log-concentration estimated from the regression model, and σ^2 is the variance of the residuals of the regression model (this correction is valid if the residuals are normally distributed, (Ferguson, 1986)).

Then, there are two options to estimate the annual load:

- derive a daily concentration from the regression equation, multiply it by the average flow of the flow for this day, and sum up
- derive a pollutant flux duration curve from the flow duration curve, using the regression equation. Integrate it over a year to get the annual load (Hoare, 1982 and Schouten et al, 1981)

NB: When using a linear regression, there is no use in trying to do a regression of ln(flux) = ln([pollut]*flow) on ln(flow). The regression seems to be better than a regression of ln[pollut] on ln(flow) (R^2 is higher) but this is artificial. The regression is exactly the same in both cases. R^2 may be higher in case of a regression of ln(flux) because variance (ln(flux)) is higher than variance (ln([pollut]). This statistical phenomena is called “spurious self-correlations” by B.C Kenney (Kenney B.C, 1982), but it is not agreed by all statisticians.

1.3 Ratio approach: If there is a positive linear relationship between pollutant flux, which passes through the origin

“If pollutant flux is proportional to the magnitude of the flow, the ratio estimator is known to be the best linear unbiased estimator, ie. the most precise among the class of estimators which assume a linear relationship” (Richards, 1998)

Ratio estimators give an average daily pollutant load over the year. They assume that the ratio of load to flow for the entire year should be the same as the ratio of load to the flow on the days concentration was measured.

$$\frac{Average\_daily\_load_{year}}{Average\_daily\_flow_{year}} = \frac{Average\_daily\_load_o}{Average\_daily\_flow_o}$$

where the subscript “year” refers to an average for the year, and o refers to an average over the days on which concentration was observed.

However, as daily load and daily flow are correlated variables, this ratio estimator is biased and a bias correction factor must be used.
The Beale Ratio estimator is one way to correct the bias:

$$Average\_daily\_load_{year} = Average\_daily\_load_{o} \cdot \frac{Average\_daily\_flow_{year}}{Average\_daily\_flow_{o}} \left[\frac{1+\left(\frac{1}{n}-\frac{1}{N}\right)\frac{s_{lq}}{\overline{l_o q_o}}}{1+\left(\frac{1}{n}-\frac{1}{N}\right)\frac{s_{qq}}{\overline{q_o}^{2}}} \right]$$

S_{lq} is the covariance between flow and pollutant flux, s_{qq} is the variance of the flow based on the days on which concentration was measured. N is the expected population size (365), and n is the number of concentration measures (12, as we have one measure for each month). lo and qo represent the average daily flux and flow respectively on the days concentrations were measured.

1.4 References for Appendix 1

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2 Export coefficients

This appendix presents some of the summary data used in defining the export coefficients for this study.

In the "Lake Manager's Handbook" (MfE 2002) a review of export coefficients was presented for New Zealand. The MfE study gives total nitrogen and total phosphorus export coefficients. For the purpose of this Horizons study nitrate and DRP export coefficients were sought. To do this it was assumed that:

- 85% of the total nitrogen is in the form of nitrate or ammoniacal nitrogen (as in the example of (Wilcock et al, 1999)).
- 10% of total phosphorus is DRP in case of sheep and sheep and beef farming. The majority (perhaps 80%) of P exported to waterways that drain pasture catchments in New Zealand is as PAP (Gilligham, Thorrold, 2000).
- 30% of total phosphorus is DRP in case of dairy farming (as shown in Smith and Monaghan, 2003).

Consequently, the nitrate and DRP export coefficients were developed as shown in Table 2.

Table 1: Export coefficient of total nitrogen and total phosphorus for different land uses, adapted from (MfE, 2002) and (Wilcock et al., 1999)

Land use	Agricultural practices, location	Nitrogen export coefficient, or specific yield (kg/ha/y).	Total Phosphates export coeff, (kg/ha/y)	Reference
Dairy pasture	High density of cattle Waikato Region Extensive farm drainage	35.0 (NO_3: 29.3 ; NH_4: 1.08)	1.16	Wilcock and al, 1999
	Average Range	25.0 10.7 – 35.3	1.00 0.6 – 1.30	Ministry for the Environment, 2002
Sheep and beef or sheep, on Hill pasture	Average Range	9.0 2.6 – 19.5	1.98 0.60 – 3.40	Ministry for the Environment, 2002
Low intensity pasture	Average Range	5.2 2.8 – 8.8	0.46 0.30 – 0.60	Ministry for the Environment, 2002

Table 2: Nitrate and DRP export coefficient used in this study

Land use	Agricultural practices, location	Nitrate export coefficient, or specific yield (kg/ha/yr)	DRP export coefficient, (kg/ha/yr)
Dairy pasture	Average	80 % * 25.0 = 20.0	30 % * 1.00 = 0.3
Sheep and beef or sheep on hill pasture	Average	80% * 9.0 = 7.2	10% * 1.98 = 0.20
Low intensity pasture	Average	80 % * 5.2	10 % * 0.46

		= 4.2	= 0.05

When export coefficient estimations were unavailable, it was necessary to use nutrient loss figures, and to estimate the attenuation within the catchment. Of course, this attenuation depends on the physical characteristics of the catchment, but in a first approximation, it is considered to be uniform.

2.1 Estimation of the missing nitrate export coefficients

Comparing the typical figure of nitrate leaching losses with nitrate export coefficients, it can be seen that nitrate export coefficients are always half of nitrate leaching losses (Table 3). Consequently, a 50% ratio has been used to estimate the export coefficients, which would otherwise be unavailable (Table 4).

Table 3: Nitrate leaching losses for different land uses, adapted from Menneer *et al.*, 2004, Steele *et al.*, 1984, Ledgard *et al.*, 1999, Houlbrooke *et al.*, 2003 and Monaghan *et al.* 2002.

Land use	Agricultural practices, location, Soil properties	Nitrate leaching losses, (kg/ha/y)	Reference
Dairy Pasture	Eastern Southland Naturally poorly drained soils Mole and Tile drainage No N fertilizer used	25 kg/ha/year	Monaghan et al, 2002
	Massey University, Palmerston North Naturally poorly drained soil Fertilized according to farm's normal management program Aerobic pond effluent	Loss in winter drainage 24.5 26.4	Houlbrooke et al, 2003
	Waikato No fertilizers N fertilizer (200 kg/ha/y) N fertilizer (400 kg/ha/y)	 29 kg/ha/year 67 130	Ledgard et al, 1999
	Typical figure for NZ	**40**	Menneer et al, 2004
	Average Range	65 15-115	
Steers/Cattle grazing	Northland No fertilizers N fertilizer (170 kg/ha/y)	 88 kg/ha/year 193	Steele et al, 1984
	Average Range (high rates of N fertilizers)	65 15-115	Menneer et al, 2004
	Typical figure for NZ	**40**	Menneer et al, 2004
Sheep and beef grazing	Typical figure for NZ	**10 – 20**	Menneer et al, 2004
Sheep farming	Average for NZ Range	**21** 6-66	Menneer et al, 2004
Sheep farming on hill country (low intensity pasture)	Range	**2-11**	
Arable farming	Typical figure for NZ	**30 – 60 (Autumn-Spring)**	Menneer et al, 2004
Vegetable cropping/Market gardening	Average Range	**177** 80 – 292 Up to 321 in NZ	Menneer et al, 2004
Forestry	Average Range	**3** 3-28	Menneer et al, 2004

Table 4: Estimation of the missing nitrate export coefficients

Land use	Agricultural practices, location	Nitrate export coefficient, or specific yield (kg/ha/y)
Cattle grazing	Average	50 % * 40 = 20.0
Arable farming	Typical figure for NZ	50% * 30-60 = 15 -30
Vegetable cropping	Average	50 % * 177 = 88.5
Forestry	Average	50% * 3 = 1.5

2.2 Estimation of the missing drp export coefficients

Table 5: Total P loss in runoff water, adapted from (Gillingham and Thorrold, 2000) and (Menneer *et al.* 2004)

Land use	Agricultural practices, location	Total Phosphate loss, (kg/ha/y)	Reference
Sheep and beef pasture	Range in New Zealand National average	Range: 0.11 to 1.67 1.3	Gillingham A.G, Thorrold B.S, 2000
	11 stock units/ha Silt loam soils, some sheet, rill and stream bank erosion	1.6, 76 %PAP	
Sheep grazing	15 stock units/ha	0.29, 62% PAP	Gillingham A.G, Thorrold B.S, 2000
	Silt loam soils	0.11	
	19 stock units/ha, volcanic ash derived soils	0.75, 80% PAP	
	Silt loam soils from tertiary sandstone, silt stone and mudstone	0.70, 85% PAP	
Beef grazing	Cattle rotational grazing	1.5, 91% in PAP	Gillingham A.G, Thorrold B.S, 2000
Forestry		0.01 to 0.10 kg P/ha/year about 80 % PAP	Menner et al, 2004
Cropping and horticultural systems	Lack of data	Up to 2 kg P/ha/year, in the PAP form	Menner et al, 2004

It can be seen that the ranges of total P loss given in Table 5 are comparable to the export coefficients given in table 1. These total phosphate losses were therefore used as export coefficients.

It was assumed that 10 % of the phosphorus loss is in the DRP form. The DRP export coefficients were therefore calculated as shown in Table 6.

Table 6: Estimation of the missing DRP export coefficients

LAND USE	DRP EXPORT COEFF, (OR SPECIFIC YIELD)
Cropping and horticultural systems	10 % * 2.5 = 0.25
Forestry	10% * 0.05 = 0.005

2.3 References for Appendix 2

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