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Pahiatua Waste Water Treatment Plant

Discharge of Treated Wastewater

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Prepared By

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Approved for Release By

Dave Watson
Utilities Manager Tararua District

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Contents

PART A

DISCHARGE PERMIT APPLICATION PURSUANT TO SECTION 88 OF THE RESOURCE MANAGEMENT ACT 1991

To:

The General Manager
Horizons Regional Council
Private Bag 11025
Palmerston North

Applicant: Tararua District Council

Proposal: To discharge treated wastewater from the Pahiatua Wastewater Treatment Plant into the Mangatainoka River.

Location: Julia Street, Pahiatua

Legal Description: Part Lot 2 DP 52391 Blk VIII Mangahao SD, Lot 1 DP 52391 (WN44B/616)

Valuation 17390/21100 and 17390/21200

Consent Required: Discharge Permit to discharge treated wastewater to water under Rule 13-27 of the One Plan

Term Sought 15 Years

Attachments: The Assessment of Environmental Effects is attached as Part B of this report. Other attachments include:

Appendix I	Pahiatua Wastewater Treatment Plant Consent Renewal: Assessment of Environmental Effects
Appendix II	Upgrades memo
Appendix III	Land Treatment Reports

Consultation: Please refer to Section 4 of this AEE for information on the consultation undertaken.

On behalf of
Tararua District Council

……………………………………………………………………

Dated

Address for Service:

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Attention: Tabitha Manderson

PART B ASSESSMENT OF ENVIRONMENTAL EFFECTS

1 Introduction

This application has been prepared in accordance with those matters set out in section 88 of, and the Fourth Schedule to, the Resource Management Act 1991. This statement of effects accompanies and forms part of the resource consent application.

The purpose of this application is to obtain resource consent to allow for the ongoing operation of the Pahiatua Wastewater Treatment Plant (WWTP) by Tararua District Council (TDC). This application will replace Discharge Permit 4369.

The Tararua District Council is the territorial authority for a large land area (424,000 hectares) that extends from Mount Bruce at the southern boundary to just north of Norsewood at the northern boundary, and from the Tararua and Ruahine Ranges to the Pacific Coast. The District contains four urban centres and has a total population of 16,854 (Statistics NZ, 2013).

The Manawatu River and five of its major tributaries flow through the district and are highly valued for the resources and recreational opportunities that they provide the wider community and local economy. Numerous smaller tributaries of the Manawatu River also originate within the District, several of which are used by Tararua District Council for water supply purposes and for the discharge of treated wastewater.

The provision of a reticulated sewerage system is integral to the functioning and health of any community and Tararua District Council is therefore committed to providing this service to its residents, whilst ensuring a balance between minimizing adverse effects of domestic wastewater discharges on waterways and not overly burdening the District's ratepayers. Tararua District Council has recently signed the Manawatu River Accord and this has marked a significant shift in focus to Council being committed to working collaboratively with other interested parties and landowners to jointly improve the water quality of the Manawatu River.

TDC have recently investigated a number of upgrade options to improve the performance of a number of its WWTPs. There are some commonalities of design across the sites while still allowing for specific individual site values to be addressed. Improving the treatment of wastewater discharges is a key issue identified by TDCs Vision Statement in its Long Term Plan (2012-2022). The River Accord actions that Council is a signatory to underpin the need to increase the wastewater discharge standards to the Manawatu River system.

1.1 Background

Tararua District Council (TDC) is currently working with the Manawatu Wanganui Regional Council (Horizons) and the Ministry for the Environment (MfE) to undertake upgrades to various wastewater treatment plants in the Manawatu Catchment.

The Pahiatua WWTP is currently operating under Discharge Permit 4369. The existing discharge point is to Town Creek, a small spring fed stream approximately 500m upstream of its confluence with the Managatainoka River.

TDC lodged an application to replace Discharge Permit 4369 in 2004. Application 103246 was publically notified in 2006, three submissions were received. A determination was made to place the application on hold prior to the application going to a hearing.

Since this time TDC have worked to design further upgrades of the treatment that is to be provided at the site. This includes changing the discharge point from Town Creek to the Mangatainoka River and a number of additional treatment systems will be installed. Due to the material changes to the treatment system proposed and moving the discharge point a new application is being lodged.

1.2 The Existing Environment

The resident population for Pahiatua according to the 2013 Census is 2412 people.

The WWTP is accessed from Julia Street, Pahiatua on the north-western edge of town. The WWTP is at the edge of the residential zone of Pahiatua. The land to the north and west of the WWTP is part of the Rural Management Area as defined by the Tararua District Plan.

1.2.1 Mangatainoka River

The Mangatainoka River arises in the north eastern Tararua Ranges with headwaters in the Tararua Forest Park. Below the park the reminder of the river moves from hill country (sheep, deer & beef farming) to more intensive dairy farming in the lowlands.

The Mangatainoka River supports introduced and native fish populations. The National Freshwater Fish Database identifies that shortfin eel, upland bully, common smelt, torrentfish, brown trout, longfin eel, crans bully, koaro, shortjawed kokopu and koura (freshwater crayfish) are found in the River. The Mangatainoka River is also home to the regionally endemic (i.e. known to exist only in this region) freshwater polychaete Namanereis tiriteae.

The Mangatainoka River is identified as a Regionally Significant trout fishery and is also covered by a Local Water Conservation Notice (Mangatainoka River 1991), recognising the fisheries and aesthetic values of the River.

Under the Horizons Regional Council One Plan the following Schedule A/B assessment identifies the following Values:

- Life Supporting Capacity – Hill country mixed geology;
- Aesthetics;
- Mauri;
- Contact Recreation;
- Industrial abstraction;
- Irrigation abstraction;
- Stock water;
- Existing infrastructure; and
- Capacity to assimilate pollution.

Schedule B site specific values that apply to the main stem reach of the stream are:

- Trout Fishery – Regionally Significant Trout Fishery
- Trout Spawning
- Site of Significance – Dotterel

- Flood Control - Drainage

1.3 Existing Treatment System

1.3.1 Domestic Loading

The population of Pahiatua township is approximately 2,500[1] in roughly 1,000 households.

The population decreased slightly between the 2006 and 2013 censuses and no significant population growth is projected.

No data is available on the influent characteristics of the wastewater as there has been no historical sampling of the raw wastewater entering the WWTP. Estimates of the likely loading have been made based on the census data and typical per capita loading rates. These estimates are summarised in Table 1 below.

Table 1: Estimated loading on Pahiatua WWTP

Parameter	Units	Estimated Loading
BOD	kg/day	226
COD	kg/day	603
TSS	kg/day	241
NH_3-N	kg/day	20.6
TKN	kg/day	18.9
TP	kg/day	34.4

1.3.2 Trade Waste

A Fonterra dairy factory and Tui brewery are both located on the outskirts of the town however each has its own wastewater treatment and disposal systems.

There is no other significant industry discharging effluent to the WWTP.

1.3.3 Flow data

In the absence of flow data, flows into the WWTP have been estimated at an average of 550m^3/day. This figure was derived using a flow of 0.220m^3/person/day[2], a conservative figure in order to allow for some inflow and infiltration.

1.3.4 Existing Effluent Quality

Data on the existing effluent quality has been provided in the form of 41 sample results taken between 5/10/2010 and 18/02/2014 and an additional 14 sample results taken between 11/12/2012 and

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[1] 2013 Census recorded 2,412 people

[2] Based roughly on typical residential flows from Metcalf & Eddy

28/01/2104 by HRC. As a portion of the data does not appear reasonable in the absence of tertiary treatment processes at the WWTP, a conservative approach has been taken and the data has been 'cleaned' by removing figures below the threshold of what would be expected from an oxidation pond system like Pahiatua. This cleaning process is fairly arbitrary given that there is no information on the quality or volume of wastewater entering the WWTP. Only results which are not believed to be feasible from the existing plant have been removed from the data set in order to minimise manipulation of the data.

This approach has been taken to ensure a realistic assessment of the future effluent quality once the upgrades have occurred. However it should be noted that the resulting mean concentrations may still represent a higher level of treatment than the plant is realistically achieving as there is insufficient data to draw any conclusions. Collecting additional effluent sample data once the new upgrades are in place, as well as influent data, will assist in refining future effluent quality expectations and give greater certainty.

The filtered and edited data is summarised in Table below.

Table 2: Filtered and edited effluent concentration data (5/10/10-18/02/14)

Parameter	Mean Concentration (mg/L)		Value below which data removed in edited data
	Filtered Data	Edited Data	
Ammoniacal Nitrogen	4	4	1
DRP	0.7	2	0.3
E Coli	284	886	50
Nitrate	2	2	-
Nitrite	0.04	0.04	-
Total Coliforms	19,197	29,417	200
Total Nitrogen	7	7	-
Total Oxidised Nitrogen	2	2	-
Total Phosphate	0.9	3	0.5
Total Suspended Solids	8	36	10
Turbidity	8	8	-
Volatile Matter	6	22	7.5

1.4 WWTP Prior to Upgrades

1.4.1 Description of WWTP Prior to Upgrades

The WWTP, prior to the upgrades commencing, consisted of three oxidation (facultative) ponds and a river discharge. Pond 1 currently has two aerators and Pond 2 has one aerator however an old aerator will be removed from Pond 1 as part of the upgrades, leaving one aerator on each of the first two ponds. There are baffle curtains in Pond 3.

Pahiatua has a 3 pond system and are all Facultative ponds

Facultative ponds rely on biological processes for wastewater treatment. Generally coarse solids will settle in the bottom on the ponds, forming a sludge layer where anaerobic treatment occurs. In the upper layers of the pond aerobic treatment occurs. Various organisms facilitate the treatment process function at different levels in the pond.

Facultative ponds primarily reduce BOD and bacteria. The aerobic stabilization of carbonaceous BOD is primarily dependent on heterotrophic bacterial activity. Heterotrophic bacterial activity is primarily a function of temperature and oxygen availability. Generally good levels of BOD reduction can be achieved in facultative pond system.

Various forms of nitrogen are found in wastewater, most often ammonia, nitrate and organic nitrogen. Typically organic nitrogen is converted to ammonia by bacteria. Ammonia can be removed in an oxidation pond through losses to the atmosphere, being assimilated into bacteria and algal cell and bacterial nitrification (which may be followed by denitrification). Adequate levels of dissolved oxygen (generally levels of 2.0 mg/l is recommended) for nitrification to occur. As the nitrifying bacteria do not compete well with heterotropic bacteria for D.O. and nutrients, before nitrification can take place, BOD levels need to have been reduced to avoid this competition. Accordingly, in a well-functioning pond system nitrification would be expected to occur in the final stages of a pond system. In general, the longer the detention time, the more likely nitrification will occur.

1.5 Effluent Quality Prior to Upgrades

Overall, the WWTP appeared typical of oxidation pond systems in similarly sized towns across NZ and its performance was also comparable or better, even when data that did not appear credible had been filtered.

Mean effluent quality results from Pahiatua WWTP and a number of other similar plants are shown in Table .

Table 3: Mean effluent concentrations from other WWTPs around NZ

Site	Description	cBOD$_5$	TSS	NH_3-N	TKN	DRP	TP	FC	E.coli	Ent
Bulls	2 pond + aerator	13		6			7.3			325
Ratana	2 pond + aerator	15	48	8		1.9				250
Gore	2 pond + aerator	29	56	14	24	3.5	4.8		2301	
Leeston	8 pond + aerator	22	63	17	23					
Queenstown	3 pond + aerator	36	65	31	38		6	44100		
Woodend	2 pond + aerator + UV	10	59	15	27		9	430	430	202
Rangiora	2 pond + aerator	38	78	17		3.8		4350	4285	465
Pahiatua (Filtered data))	3 pond + aerator		36	4	7	2	3.0		866	

1.6 Changes Made to the WWTP in Recent Years

A number of small improvements have been made to the WWTP in recent years:

- The ponds were desludged, lined with clay and refurbished in 2002-2003.
- A single Reliant aerator and a single HPE cage aerator were added to Pond 1 (the old HPE cage aerator will be removed as part of the new upgrades).
- A further aerator was added to Pond 2.
- Mixing walls were installed in Pond 3.

The addition of aeration to the ponds would have reduced BOD and, normally increased ammonia oxidation. Effectively, mechanical aeration increases the oxidation capacity of the ponds beyond what it would be when naturally aspirated by the wind. Desludging and installing mixing walls would have increased the hydraulic retention time, giving a higher probability of increasing nitrification and bacterial and viral removal rates.

An initial assessment of the wastewater discharge indicated that changes that have been made to the wastewater treatment process over the period 2008-2010 have delivered quantifiable improvements to the quality of the wastewater discharge.[3] With two exceptions (nitrate-nitrogen and total organic nitrogen concentrations), the discharge is currently exerting a smaller impact on the Mangatainoka River than was the case in 2009.

1.7 Proposed WWTP Upgrades

A number of upgrades are planned for the Pahiatua WWTP, these are described in more detail below.

1.7.1 WWTP Process Flow Diagram

An annotated aerial image showing the plant, including existing and proposed upgrades, is in Appendix II. The processes are also displayed in the process flow diagram (PFD) in Figure 1 below.

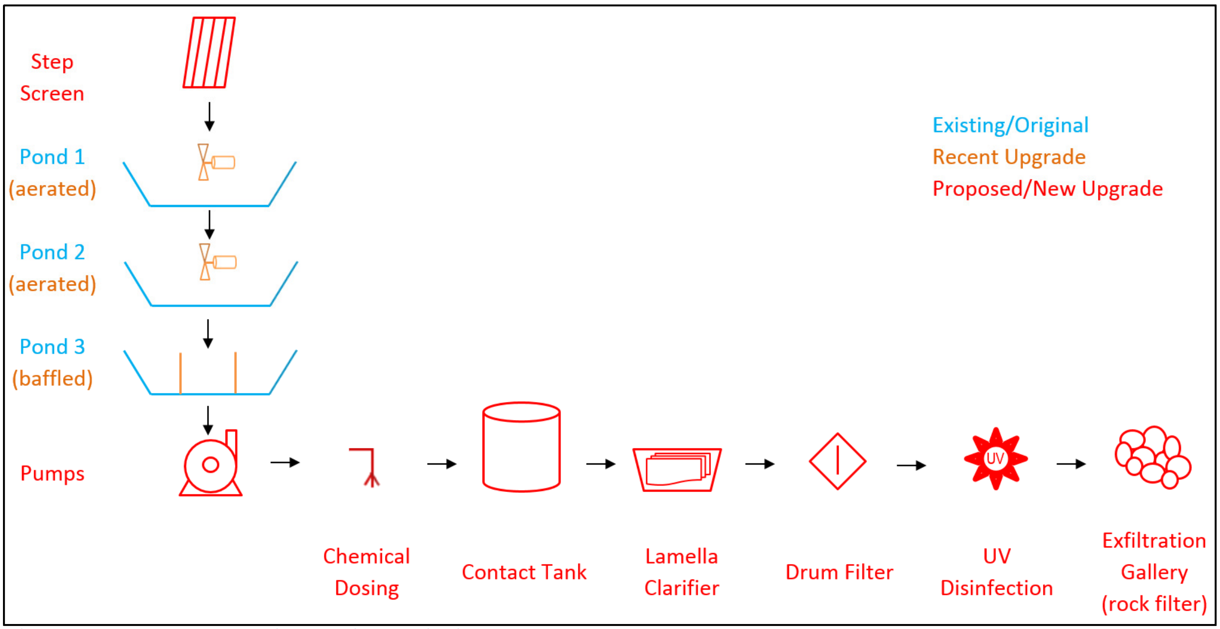

Figure 1 WWTP PFD, including existing and proposed upgrades

1.7.2 Upgrades Underway

Several upgrades are currently underway:

- A new, at grade, Huber Step Screen is being installed currently in 2014 (Figure 2).
- A new Lamella clarifier is been currently being installed (2014), including a contact tank for coagulation and a chemical dosing facility (Figure 3).

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[3] *Pahiatua Wastewater Treatment Plant Consent Renewal: Assessment of Environmental Effects*. Opus, July 2014.

Figure 2: Step screen installed in 2014

Figure 3: Installation of lamella plate clarifier (left) and contact tank (right) in progress

1.7.3 Proposed Further Upgrades

The following upgrades are also either proposed or are in the process of delivery:

- An In-Eko drum filter has been ordered from Brick House

- A UV disinfection system will also be installed.
- A Tephra filter may be installed.

Following UV disinfection, the treated effluent will be back fed into an old water intake line and discharged out to the Mangatainoka River through the old 'Infiltration' Gallery. This will give better dispersion and mixing in the river.

1.8 Effluent Quality Improvements

There is insufficient influent and effluent quality data available to be able to accurately quantify the improvements resulting from the upgrade work undertaken to date.

Anticipated effluent quality improvements resulting from upgrades are described by process in the following sections.

1.8.1 Step Screen

The Huber step screen will remove coarse material from the influent wastewater stream that could damage or clog downstream process equipment and the exfiltration gallery or introduce coarse contaminants to the Mangatainoka River. Although the screen will not dramatically improve the performance of the WWTP, it will slightly reduce the rate at which sludge accumulates in the ponds and it will help mitigate breakdowns in the new, more intensive unit processes.

1.8.2 Lamella Plate Clarifier

Lamella clarification is a counter-current settling process in which a series of inclined plates or tubes enhance the separation and removal of solids from the effluent. The addition of a flocculant in the contact tank before the clarifier promotes the aggregation of small particles into larger particles to further enhance their removal by gravity settlement in the clarifier.

A Filtec Lamella Settler has been purchased from Filtration Technology Ltd. Details are as follows:

Model	Lamella Settler
Max. hydraulic capacity	80m^3/hr (approx. 22L/s)
Proposed flocculant	Unknown

The performance of coagulation and flocculation and therefore of the clarification process, is dependent on a large number of factors, many of which are interrelated. Wastewater characteristics, chemical dose rates, mixing conditions, flocculation times, the selection of chemicals and their order of addition, can all affect performance. Control of pH and alkalinity is also essential to maintain performance. We have approached the suppliers for their comment on the likely performance of their equipment, as supplied for this installation, but have received no response.

The lamella clarifier will be expected to provide improvements in a number of areas of plant performance:

- Total suspended solids via coagulation and settlement
- Total nitrogen via removal organic-N in particulate material

- Dissolved reactive phosphorous

1.8.3 Drum Filter

The drum filter removes additional suspended solids and lowers turbidity by mechanical sieving. This will also increase the effectiveness of the existing UV disinfection system.

An In-Eko Microscreen has been ordered from Brickhouse. Details are as follows:

Model	**In-Eko 4FBO Microscreen Drum Filter**
Max. hydraulic capacity	Design 20L/s up to 50L/s
Filtration cloth	0.020mm
Max TSS loading	150mg/L TSS on inlet at 50L/s

The effectiveness of filtration depends on the filter and filter cloth itself as well as the flow rate and the suspended solids characterisation in terms of concentration, degree of flocculation and particle size distribution. This can be particularly variable following oxidation pond systems.

The In-Eko cloth drum filter proposed will be expected to provide some small incremental benefits over the lamella clarifier. These will principally be gained by 'mopping up' floc. particles that are carried over from the clarifier, particularly during periods of fluctuating flow rates:

- Algae particles less than 20 microns diameter will pass directly through the filter largely unaffected.
- Some improvement in effluent TSS. The quantum will depend on the clarifier performance. Poor clarifier performance will result in better filter performance, in terms of percentage of solids removed.
- Very small improvements could be expected to the TN and TP levels in the effluent but only by virtue of the organic N & P in the filtered particles.

1.8.4 UV Disinfection

Radiation from ultraviolet (UV) light can be an effective bacteriocide and virucide. Since UV light is not a chemical agent, no toxic residuals are produced.

It is understood that TDC intend to purchase TrojanUV3000 PTP UV disinfection system from Trojan Technologies Inc. Details are assumed to be as follows:

Model	**TrojanUV3200K PTP**
Peak hydraulic flow rate	12.3L/s
Validated UV dose	31,023 μWs/cm^2
Total number of lamps	8

The effectiveness of UV disinfection depends on the turbidity and solids content of the effluent as solids can both absorb the ultraviolet energy and shield microorganisms. Further, dissolved organic substances, including colour, can absorb significant proportions of the UV light and further reduce disinfection efficiency. The performance of the UV disinfection is therefore dependant on the performance of the upstream treatment processes, including the lamella clarifier and the drum filter.

Given a minimum effluent UV Light transmissivity (design values are currently uncertain), low effluent suspended solids and service flow rates that are within the design limitations of the selected system, the UV disinfection will inactivate bacteria, viruses and protozoa. The extent of inactivation depends upon the particular microbe (some are much tougher than others) and the dose rate provided.

Treating oxidation pond effluent, with no tertiary treatment of the effluent, a UV system, appropriately designed would be expected to deliver performance of between 1 and 1.5 $\log_{10}$ inactivation of faecal indicator bacteria. With an effective tertiary or set of tertiary unit processes in place, low suspended solids, low dissolved colour, and the dose rate indicated above, an inactivation rate of between 2 and 3 $\log_{10}$ could be expected.

1.9 Summary of Anticipated Effluent Quality Improvements

Anticipated effluent quality improvements resulting from the upgrades are summarised in Table below.

Table 4 Summary of anticipated effluent quality improvement

Process Upgrade	Affected Effluent Parameters	Anticipated Improvement*	Confidence Rating (1-10, low-high)	Reason for Confidence Rating
Inlet screen	Gross Solids	Protection of downstream mechanical equipment	10	No Numeric
Lamella Clarifier	TSS,	TSS – 60%	4	No pilot results
	TN,	TN – 60% of 3mg/l	4	Filtered data indicates 3mg/l Organic N in SS. But TSS not reliable
	DRP,	DRP to approx. 0.5mg/l**	7	Essentially tunable with coagulant
		Small reduction in faecal indicator bacteria by physical removal.	7	Experience with other solids removal processes.
Drum Filter	TSS, TN, TP	40% of Clarifier carry over. Small TSS particles will go straight through filter.	4	Vague Kaeo pilot trials. No trials on low TSS effluent & therefore no indication of %age less than 20 micron.
UV Disinfection	Bacteria, Viruses, Protozoa	2 - 3 Log_{10} Inactivation	6	Based on a good tertiary effluent but not specified dose.

* Based on Table numbers above

** Depending upon chemical dose rate and clarifier up flow rate.

It is important to note, however, the questions raised about the credibility of the effluent sample results, as outlined in Section 1.4 above. It is of some concern that the effluent quality that we would predict from these combined processes, following the upgrades, could still be worse than the WWTP performance that is currently reported.

1.10 Conclusions and Recommendations

Based on the available effluent quality sample data, performance of the existing Pahiatua WWTP is as good as or better than any other WWTP in New Zealand. Overall, the WWTP appears typical of oxidation pond systems in similarly sized towns across NZ and its performance is also comparable or better, even when data that did not appear credible has been filtered.

It is very difficult to accurately predict the effluent quality following completion of the upgrades, given the number of unknowns about both the influent wastewater and the details of the proposed upgrades. Estimates of the anticipated improvements in effluent quality have been made, based on data from similar plants around the country (refer to Table). Confidence in these estimates is low due to the number of unknowns. In order to calculate potential performance with more certainty, additional monitoring following the installation of the upgrade equipment is recommended.

1.11 Alternatives Considered

1.11.1 Land Disposal

Land Disposal has been considered for the site. TDC commissioned a report for preliminary investigations into land irrigation, this report is contained in Appendix III.

This initial report looked at the feasibility of discharging to land during summer months when the Mangatainoka River was in low flows. A number of factors were considered to calculate how much land area might be required. The report states "*With a likely typical limitation of 150kgN/ha/year, on a nitrogen basis, a minimum of 9.5 hectares of land would be required for effluent irrigation*". It was calculated that this would equate to an application depth of 14.75mm/day which was considered to be high. The report went on to state "*Based on a more conservative hydraulic loading rate of an average of 5mm per day the irrigation area required would increase to 28 hectares*". It was noted that more detailed investigation of soil types and soil moisture deficits could be undertaken and this may reduce the overall irrigation area required.

The report went on to identify some potential irrigation sites, the review identified several constraints due to topography, proximity of small property titles and the proximity of the Mangatainoka River.

A rough order of costs put the establishment of an irrigation network (at one site) as being $535,000 excluding land purchase which was estimated as $1,925,000.

TDC commissioned further work to provide additional comment (where appropriate) to augment the investigation into land disposal. This memo is included in Appendix III.

This report identified that land irrigation of treated effluent would require provision of storage based on the two scenarios examined as follows:

- *Sole discharge of effluent via land irrigation without any parallel discharge to water at minimum would require 96,000m^3 of storage. This storage would need to cater for high load months (January – March), non-irrigation days and emergency storage; and*

- *The parallel discharge to water using Town Creek. This storage would still be required to cater for low flow conditions in the Mangatainoka River and at minimum would be 25,000m^3 (January – March).*

If daily irrigation rates were increased then storage requirements would reduce, as discussed in the memo.

The memo also looked at potential land area requirements, it concluded that a larger land area may be required than was identified in the first report. Total irrigatable area required could be 74-111ha if a seven day rotation using three irrigation sites was designed for.

The memo states that "*In summary we would suggest that the discharge to land is not a cost effective option for this site as this relies on relatively high application rate and this would still require significant temporary storage when any non-irrigation conditions occur (i.e. heavy rainfall occurs).*"

1.11.2 Alternative Treatment Configurations

Option 1

Sewage from Pahiatua passes through a 'Step-screen' before entering Pond 1, Pond 2, and Pond 3. The sewage effluent then passes through a "disk" filter before being discharged into the Mangatainoka River via a diffuser and rock filter.

Option 2

This option proposes to incorporate a UV filter after the "disk" filter before being discharged into the Mangatainoka River via a diffuser and rock filter.

Option 3

This option proposes to incorporate a "Clarifier" before the UV filter before being discharged into the Mangatainoka River via a diffuser and rock filter.

2 Assessment of Environmental Effects

To determine potential effects two reports have been prepared, these are found in full in Appendix I. The first report is a technical assessment of environmental effects on water quality and aquatic ecology prepared by Dr Neale Hudson (Opus Report), a further technical memo has been prepared by Dr Olivier Ausseil (Aquanet Consulting Ltd). The following section uses a summary from the reports.

From the Opus Report the AEE focuses on the impact of the existing wastewater discharge in four inter-related areas: physical variables, nutrient inputs, faecal contaminant inputs, and ecological response. This report includes consideration and analysis relative to the broader Mangatainoka River catchment.

The Aquanet technical memo summarises the key findings of the Opus Report and where possible provides additional clarification on the effects of the discharge in relation to statutory provisions, including Section 107(1) of the RMA and the National Policy Statement for Freshwater management (NPSFM 2014). This report provides some qualitative comments with regards to future effects.

2.1 One Plan Water Quality Targets

The physio-chemical water quality and ecological variable targets defined in the One Plan are shown in the table below. Assessment against these targets is a starting point for determining potential effects. If the numeric targets are met then it is likely that the values assigned to the subzone will be achieved.

Table 5. Water quality targets defined for the Mangatainoka River in the reach between the SH 2 and Pahiatua Town Bridge sites (One Plan Tabe D5.A). Shaded rows indicate region-wide water quality targets (OnePlan Table D.1A). (NB Table 8 in Opus Report)

Water quality variable	Statistic	Value or Range	Units	Allowable change	Flow characteristic	Comment
pH	Instantaneous	7.0 – 8.5	Units	0.5 units	None	
Water temperature	Instantaneous	<19	°C	3 °C	None	
Dissolved oxygen	Instantaneous	>80	% sat.		None	
Soluble cBOD5	Monthly average, flow condition	1.5	mg/L		Flow <20%ile exceedance	
Particulate Organic Matter	Average, flow condition	<5	mg/L		Flow <50%ile exceedance	
Periphyton as Chlorophyll *a*	Instantaneous	<120	mg/m²		none	
Visible periphyton cover	Instantaneous	<30	%		None	
Visible periphyton cover as diatoms or cyanobacteria	Instantaneous	<60	%		None	
Dissolved reactive phosphate	Annual average, flow condition	<0.010	mg/L		Flow <20%ile exceedance	
Soluble inorganic nitrogen	Annual average, flow condition	<0.444	mg/L		Flow <20%ile exceedance	
Proportion deposited sediment cover	Maximum	<20	%		None	SoE reporting only
Macroinvertebrate Community Index (MCI)	Minimum	Not defined	Units		None	SoE reporting only
QMCI		<20% change (reduction)	Units		None	
Ammoniacal-N	Annual average	0.400	mg/L		None	
Ammoniacal-N	Maximum	2.1	mg/L		None	
Toxic contaminants	Maximum	<99%	mg/L		None	Value <ANZECC 99% species protection level
Visual clarity	Minimum according to flow condition	>3	m	<20%	River flow < 50%ile exceedance	
E. coli concentration	Instantaneous maximum, flow condition	260	/100 mL		Flow < 50%ile exceedance	
E. coli concentration	Instantaneous maximum, flow condition	550	/100 mL		Flow < 20%ile exceedance	

2.1.1 Water pH and temperature

The Opus report in pages 22 – 26 presents a summary of the monitoring data in relation to pH and temperature. The summary for these to parameters from this report is as follows –

Summary for pH

10% of sample pairs indicated change in pH greater than 0.5 units during the assessment period.

Less than 10% of upstream samples did not fall within the pH range 7 – 9.5, whereas 17% of downstream samples did not fall into this range.

In general, non-conforming pH happens both upstream and downstream of the discharge, indicating that the pH response occurs generally in the lower catchment, rather than in response to the wastewater discharge specifically.

Summary for Water Temperature

Assessment of the impact of the discharge on the river requires selection of data from appropriate sites – MAN5 (the upstream site) and MAN4 (site closest to the discharge point) should be used for this purpose.

Graphical assessment and formal statistical testing indicates that the discharge does not alter the temperature of the Mangatainoka River measurably.

The technical memo from AquaNet provided further analysis and states:

Non-parametric pairwise testing (Wilcoxon test) does not indicate any overall significant differences between upstream and downstream of the discharge.
On this basis, I conclude that the effects of the discharge on water pH and temperature in the Mangatainoka River are no more than minor.

2.1.2 Visual Clarity

From the Opus Report

Summary for Visual Clarity

Under all flow conditions, visual clarity in the lower Mangatainoka River catchment is generally likely to be lower than 3 m.

25% of visual clarity measurements made at site MAN3 are likely to exceed this target (the highest for all sites between the Town Bridge site and the confluence with the Tiraumea River).

For flows less than the median, more than 75% of all measurements of visual clarity are likely to be lower than 3 m with the exception of the MAN3 site (downstream of the wastewater discharge), where 50% of measurements are likely to be lower than 3 m.

It is possible that the increased clarity apparent for this site is a consequence of the greater number of clarity measurements, rather than water quality improvement. Pairwise comparison (of *measurements made on the same day) indicates that visual clarity is more likely to decrease downstream of the wastewater discharge than increase.*

Further data analysis was undertaken by Aquanet, that analysis did not indicate statistically significant changes in visual water clarity between upstream and downstream of the discharge. From the Aquanet technical memo below:

Reductions in water clarity of more than 20% were measured on 5 out of 27 monitoring occasions (19%), and reductions of more than 30% on 4 out of 27 occasions (15%) (Figure 7: Relative change in visual water clarity in the Mangatainoka River between upstream and downstream of the Pahiatua WWTP discharge (Data source Horizons REgional Council, data from Jan 2008 to Dec 2012) (NB Figure 1 in Aquanet Technical memo)

Three of these were measured in 2010, and one in 2012. Unfortunately, there are no visual clarity data for 2013. Most people are able to detect a change in water clarity of 30% or more.

Effluent quality data indicates that unusually elevated Total Suspended Solids (TSS) concentrations occurred during January to April 2010 (concentrations of 80-110 mg/L against a long-term median of 10 mg/L), suggesting that the discharge was probably the cause of, or a contributor to, the changes in water clarity during these months. The November 2012 change in water clarity was however not associated with elevated TSS concentrations in the discharge however (8 mg/L), and it is doubtful whether the discharge was the cause of the decrease in visual clarity measured that day. TSS concentrations in the effluent have been consistently low (<20 mg/L) since January 2012, indicating that the current discharge presents a low risk of causing significant changes in water clarity or colour.

My conclusion is that the discharge does not appear to cause significant changes in water clarity overall, although conspicuous changes in water clarity have occurred on occasion during three consecutive months in 2010. The current discharge quality presents a low risk of causing significant changes in water clarity or colour.

2.1.3 Microbiological water quality

From the Opus Report:

Summary for E. coli Concentrations

The load of faecal indicator organisms (E. coli) discharged from the WWTP to the Mangatainoka River is likely to have decreased measurably since 2008 (no flow data are available to make this assessment).

The concentration of faecal indicator organisms (E. coli) discharged from the WWTP to the Mangatainoka River has decreased measurably by approximately 4-log units since 2008.

Under median flow conditions, less than 20% of samples have exceeded the HRC target for river water quality since 2011. In 2013, less than 5% of samples exceeded the HRC target.

Since about 2012, the wastewater discharge may actually improve the microbiological quality of the receiving environment by slightly diluting upstream water and associated faecal indicator organism contaminant load.

The Aquanet memo also reviewed available data and reached the following conclusions:

- *I concur with the Opus Report that treated wastewater quality has improved markedly since 2010. The median and 95th percentile E. coli concentrations in the treated effluent for the period 2010-2013 are 4 /100 mL and 1,716 /100 mL respectively, indicating an excellent level of treatment. Median and 95th percentile concentrations during the 2008-2009 period were 74,200 and 367,000 E. coli/100mL respectively;*

- *Assuming a worst-case dilution scenario (river at MALF, wet weather discharge of 16l/s), the above current discharge quality has the potential to raise the in-stream E. coli concentration by 0.04 E. coli/100mL as a median and 17 E. coli/100mL as a 95th percentile. I consider these concentration increases are unlikely to be able to be detected against the existing background (upstream) concentrations;*

- *Based on these figures, it appears unlikely that the discharge would be able to cause any measurable changes in the E. coli concentrations in the Mangatainoka River after reasonable mixing, apart from exceptional circumstances;*

- *However, there is a statistically significant[4] increase in E. coli concentration downstream of the discharge, compared with upstream, leading to slightly more exceedances of the One Plan water quality targets at the downstream site than at the upstream site (Table 7);*

- *There appeared to be no improvement in the level of compliance with the One Plan targets downstream of the discharge when comparing the 2010-2013 period against the 2008-2009 period. This finding also concurs with that of the Opus Report;*

- *Given the effluent quality measured since 2010, the discharge does not appear to be able to give rise to the concentration increases measured between the upstream and the downstream site during that period;*

- *Based on the above findings, it appears likely that the changes in microbiological water quality measured between upstream and downstream of the discharge are influenced, at least in part, by sources other than the discharge of treated wastewater itself. This conclusion is again consistent with that of the Opus Report. It is possible that source of faecal contamination may be present in Town Creek upstream of the discharge point from the Pahiatua WWTP. I am however not aware of any existing data to assess whether this hypothesis is correct.*

Table 6: Summary of E.coli concentractions and compliance with the One Plan water quality targets in the treated discharge from Pahiatua WWTP and in the Mangatainoka River upstream and downstream of the discharge. (NB Table 2 from Aquanet Technical memo)

	2008-2009 period			**2010-2013 period**		
	Discharge	**Upstr.**	**Downstr.**	**Discharge**	**Upstr.**	**Downstr.**
Median (*E. coli*/100mL)	74,200	90	99	4.0	105	154
95th percentile (/100mL)	367,000	739	473	1,716	702	2,263
% compliance with 550 E.coli/100ml at flows below 20th FEP	N/A	93%	93%	N/A	92%	86%
% compliance with 260 *E. coli*/100ml at flows below median	N/A	82%	82%	N/A	76%	62%

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[4]

2.1.4 DRP and SIN

From the Opus Report:

Dissolved reactive phosphate (DRP) is one of the key nutrients that controls or regulates plant growth, including algae and periphyton. Excessive concentration of DRP is likely to promote excessive or nuisance plant and algae growth. The sensitivity of plant growth to DRP concentrations is reflected in the low guideline or target thresholds generally proposed – for example, the ANZECC guidelines indicated a value of 0.01 mg/L (ANZECC & ARMCANZ, 2000), the New Zealand Periphyton Guidelines (Ministry for the Environment (MfE), 2000) recommended values less than approximately 0.02 mg/L to achieve chlorophyll a concentrations lower than 120 mg/m2 (with consideration of accrual period). In-stream plant and nutrient guidelines for New Zealand were recently reviewed (Matheson, 2012). The water quality target proposed for DRP in the Horizons region reflects the desire to minimise nuisance growth and achieve or maintain various values (e.g. nuisance growth of periphyton or chlorophyll a densities maintained below threshold values). The target for the Mangatainoka River is an annual average of 0.01 mg/L for conditions when river flows are less than the 20%ile exceedance value.

The report examines DRP concentrations for all flow conditions in the Mangatainoka River for the period 2008-2013. The summary from the Opus report as follows:

Summary for DRP

*DRP concentrations in the lower Mangatainoka River are subject to catchment-wide influences, as well as the wastewater discharge. In Section 2.6 (of the Opus Report)**Error! Reference source not found.** it was demonstrated that average and median DRP concentrations in the wastewater discharge have decreased from approximately 3 mg/L in 2009 to less than 0.5 mg/L in 2013.*

Although mean DRP concentration is greater downstream of the wastewater discharge than upstream, it is not possible to demonstrate a statistically meaningful increase in DRP concentrations downstream of the wastewater discharge, and any difference may be trivial relative to the +10% to -10% limit used for the assessment.

Trend testing indicates that DRP concentrations in the Mangatainoka River appear to be decreasing over time – this is consistent with the decrease in DRP concentration in the discharge. A more extensive record is required to improve the certainty of this apparent trend.

These trends need to be considered together with trends observed for chlorophyll a and periphyton cover – both metrics are increasing downstream of the wastewater discharge. It is possible that the moderate increase in periphyton growth downstream of the wastewater discharge is evidence of rapid incorporation of the additional DRP as biomass, i.e. this additional nutrient is not transported downstream as un-utilised, bioavailable material.

The limited information available for cyanobacteria indicates that the incidence of these species may be increasing downstream of the discharge. Further increases in DRP concentrations may promote the growth of cyanobacteria.

Consideration of the measured concentration and estimates of the probable load of DRP in the wastewater discharge demonstrates that has decreased substantially since 2009. Currently the concentration of DRP in wastewater is less than 0.1 mg/L. Although this is 10 times larger than *the target for the Mangatainoka River, the small volume of the discharge is unlikely to lead to measurable increases in river concentrations.*

If there is a requirement to further reduce in-stream DRP concentrations, this will be achieved most cost-effectively by introducing mitigation measures at catchment scale.

From the Aquanet Report

With regards to Dissolved Reactive Phosphorus (DRP), the Opus Report concludes that downstream DRP concentrations are greater than upstream, but that the difference is not practically important, again using a formal equivalence testing. My own analysis (using a Wilcoxon test) confirms that the difference between upstream and downstream concentrations is statistically significant.

SIN is defined as the sum of oxidised forms of nitrogen plus ammoniacal-N. A target SIN concentration for the Mangatainoka River has been set at 0.444 mg/L for river flows less than the 20%ile exceedance value (24 200 L/s).

The Opus report examines the SIN concentrations in the Mangatainoka River catchment under all flow conditions, the summary in relation to this is shown below.

Summary for SIN

Although the median concentration of SIN in the discharge exceeds the target concentration by a factor of ten and the 1%ile SIN concentration is approximately twice the target threshold, reducing the concentration of SIN in the discharge is unlikely to have measurable effect on the concentrations of SIN downstream of the Pahiatua WWTP because of the persistently high load of SIN entering the Mangatainoka River upstream of Pahiatua.

From the Aquanet Report:

With regards to Soluble Inorganic Nitrogen (SIN), the Opus Report concludes that the One Plan targets are largely exceeded both upstream and downstream of the discharge, and that the discharge does not result in any practically important differences in concentrations between upstream and downstream of the discharge (using formal equivalence testing).

This is in agreement with my own analysis using a different statistical method (non-parametric pairwise comparison).

In short, the discharge does not appear to cause a more than minor effect on in-stream SIN concentrations, although it should be noted that this is against a background of elevated SIN concentrations upstream of the discharge, making the statistical detection of changes caused by the discharge less likely.

2.1.5 Periphyton

The following is taken from the Aquanet technical memo, which reviewed the information presented in the Opus report but also undertook additional analysis of the available data:

With regards to periphyton growth, the Opus report concludes that:

- *N:P ratios are generally elevated both upstream and downstream of the discharge; and*
- *the Pahiatua WWTP discharge is exerting a mild stimulatory effect on periphyton growth.*

The report does not however provide a clear assessment of how periphyton biomass and cover compare with the One Plan targets upstream and downstream of the discharge. I have thus undertaken my own analysis of the data provided by Horizons and my conclusions are as follows:

- *As reported in the Opus report, there has been an improvement in the quality of the discharge since 2010. I have thus analysed the 2008-2009 and the 2010-2013 periods separately. This is consistent with the analysis I conducted for E. coli;*
- *The periphyton biomass target is generally met both upstream and downstream of the discharge, but with a slight increase in the proportion of exceedances of the periphyton biomass target (from 8 to 9% during 2008-2009 and from 4% to 7% of samples during 2010-2013) (Table 8). It is noted that the difference is due to three samples exceeding the target downstream vs. two upstream, but with a third upstream sample just on 120 mg/m², i.e. only technically compliant;*
- *There appeared to be a significant increase in the number of observations exceeding 30% of cover by filamentous algae between upstream and downstream during the 2008-2009 period. However, the level of compliance with the filamentous cover target has been similarly high both upstream and downstream of the discharge since 2010;*
- *The only exceedances of the target relative to % cover by thick mats were observed upstream of the discharge.*

In conclusion, the discharge from the Pahiatua WWTP causes a moderate, but statistically significant, increase in DRP concentrations downstream of the discharge. It does not however appear to cause any significant changes in SIN concentrations.

It appears to cause a mild stimulatory effect on periphyton growth, which is to be expected given the indication of P-limited periphyton growth conditions indicated by the elevated N:P ratios. However, this mildly increased periphyton growth does not appear to be causing a material increase in the frequency of excessive (defined as exceedances of the One Plan targets) growths of biomass, long filamentous or thick mats downstream of the discharge.

Table 7: Summary compliance with the One Plan water quality targets for periphyton biomass and cover the Pahiatua WWTP and in the Mangatainoka River upstream and downstream of the discharge. (NB Table 3 in Aquanet Technical memo)

	2008-2009 period		**2010-2013 period**	
	Upstr.	**Downstr.**	**Upstr.**	**Downstr.**
Periphyton biomass % compliance with 120 mg Chlo *a*/m²	92%	91%	96%	93%
Periphyton cover % compliance with 30% cover by long filamentous algae	85%	46%	98%	98%
Periphyton cover % compliance with 60% cover by thick mats	92%	100%	100%	100%

2.1.6 Ammonical Nitrogen

Two targets have been established for the lower Mangatainoka River catchment:

- The annual average ammoniacal-N concentrations should not exceed 0.4 mg/L, and
- Ammoniacal-N concentration should never exceed 2.1 mg/L.

No flow conditions apply to either of these target values.

The Opus report summarises the available data for ammoniacal-N. The summary from that report as follows:

Summary for Ammoniacal-N

75th percentile ammoniacal-N concentrations in the Mangatainoka River are below the target concentrations.

The concentration (and presumably load) of ammoniacal-N in the wastewater discharge has decreased substantially since 2008.

There is no measurable increase in the concentration of ammoniacal-N downstream of the wastewater discharge.

Free ammonia-N concentrations are approximately 10 times and five times lower than the ANZECC 95 % and 99% species protection level respectively, and free ammonia concentrations are similar up- and downstream of the discharge.

The Aquanet technical memo also states that existing monitoring data indicates that both targets are met both upstream and downstream of the discharge.

2.1.7 scBOD5 and POM

The Opus report notes that relatively few data are available for cBOD5 in the lower Mangatainoka River. The data are generally at or below the analytical detection limit for this variable. There is a single exceedance of the target value at flows less than the 20%ile below the WWTP, the Opus report considers that there is insufficient evidence to conclude that the discharge causes non-compliance.

Particulate organic matter (POM) is a fraction of total suspended solids (TSS). It is the difference in mass between the result for TSS and the same sample residues after ignition at 500 °C – 600 °C, expressed as a concentration. It is also known as the volatile solids concentration. It is a measure of the amount of organic material in a water sample. This organic material may be derived from point or non-point source inputs to a river, or may be endogenous – produced by biological processes within the river. Elevated POM concentrations is an indication of high productivity - extensive periphyton or algal growth.

The Opus Report presents average POM concentrations at flows lower than 50%ile exceedance summarised on an annual basis for sites along the lower Mangatainoka River, no exceedences occurred. The Opus Report goes on to say that the relatively few data for POM need to be considered together with those for other metrics, such as chlorophyll a concentrations and visual assessment of bed cover by periphyton and cyanobacteria.

In Section 2.6 of the Opus Report trends in concentration of particulate organic matter were considered in terms of Total suspended solids, turbidity and volatile matter. Concentrations of these metrics have decreased appreciably since 2008:

- Median turbidity has decreased from approximately 30 NTU in 2008 to approximately 5 NTU in 2013;

- Median total suspended solids and volatile matter concentrations decreased from approximately 80 mg/L to less than 10 mg/L over this period.

From these data we can conclude that increasing concentrations of soluble and particulate organic matter in the lower Mangatainoka River are not directly attributable to the load of these substances in the discharge. Increases in organic material in the river are most likely related to increases in primary production (i.e. periphyton growth) in the river itself. What needs to be determined however is whether the nutrient input to the river in the wastewater discharge is responsible for increases in periphyton growth in the lower river. This is discussed in Section 3.2.9 and 3.2.10 of the Opus Report.

The Aquanet technical memo notes that having reviewed the Opus report and the actual data that the discharge complies with the One Plan targets for these determinands.

2.1.8 Change in QMCI

One target has been established for the lower Mangatainoka River catchment in terms of macroinvertebrate numbers and species composition, the change in the Quantitative Macroinvertebrate Community Index (QMCI) downstream of a discharge should be less than 20%. The QMCI is an aggregated score derived from the number and types of macroinvertebrates present at the sample location. It was developed specifically to provide a quantitative measure of the impact of point source discharges, particularly in stony-bottomed waters.

The Opus report presents the MCI and QMCI scores derived from State of the Environment Monitoring undertaken in 2013. *Highest MCI and QMCI scores are measured in the upper reaches of the catchment. Lowest MCI scores were measured in the Makakahi River upstream of the confluence with the Mangatainoka River and the Mangatainoka River upstream of the Pahiatua WWTP discharge. Lowest QMCI scores were recorded in the Mangatainoka River immediately upstream and downstream of the Pahiatua WWTP discharge. Both MCI and QMCI scores increase in the reach between MAN4 and MAN3.*

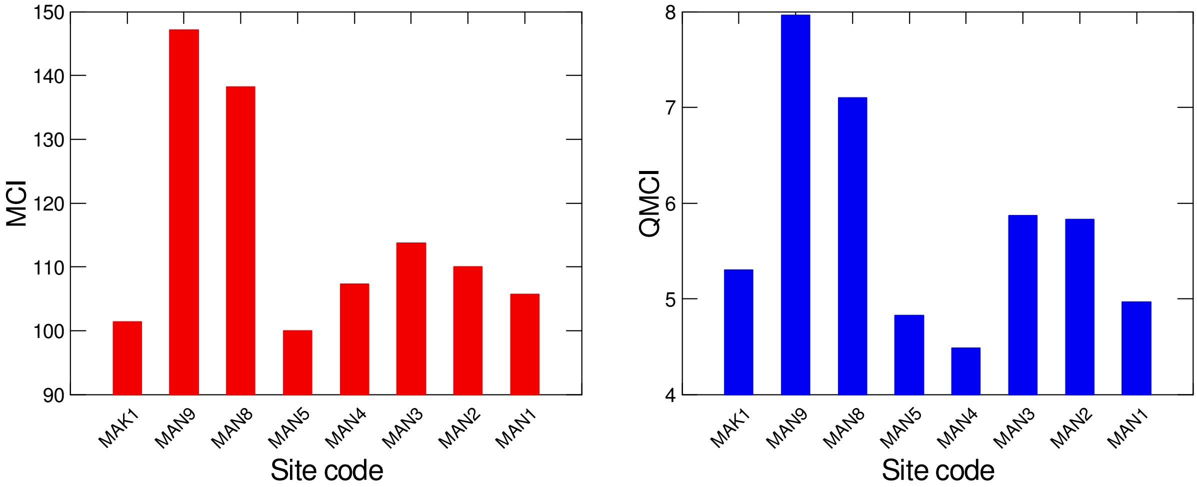

Figure 4: Macroinvertebrate community index scores for the Mangatainoka River Catchment, 2013 (NB Figure 25 in the Opus Report)

Changes in the QMCI score between successive sampling points along the course of the Mangatainoka River in 2013 are summarised in Figure 5: Proportional change in QMCI score between adjacent sites in the lower Mangatainoka River catchment, 2013

None of the decreases in QMCI exceed 20%, and the single increase occurred downstream of the wastewater discharge.

Earlier, chlorophyll *a* and periphyton cover was discussed in terms of increasing primary productivity in response to nutrient inputs from the wastewater discharge. Assessment of the wastewater indicated that relatively little DRP is currently discharged as a consequence of changes to the wastewater treatment process. It is possible however that the limited input of DRP and soluble carbon subtly alters nutrient ratios and stimulates primary productivity immediately downstream of the discharge under summer low flow conditions. This increase in primary productivity causes a slight depletion of available nutrients (particularly P) further downstream (MAN3 and MAN2). It is possible that:

- the decline in QMCI immediately downstream of the discharge is caused by the transient increase in primary productivity, and
- the subsequent increase in QMCI results from a decrease in primary productivity arising from a slight nutrient limitation.

This explanation is speculative and is based on relatively few data – the results of ongoing monitoring should allow this proposal to be confirmed, or provide alternate explanations.

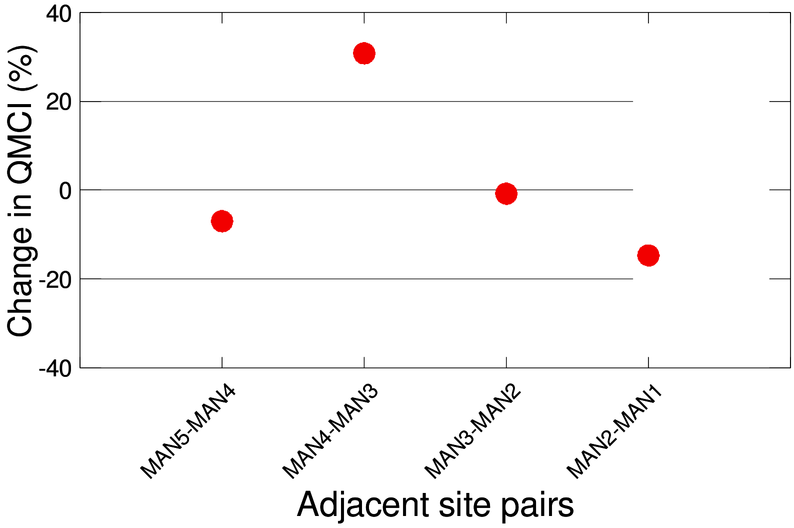

Figure 5: Proportional change in QMCI score between adjacent sites in the lower Mangatainoka River catchment, 2013

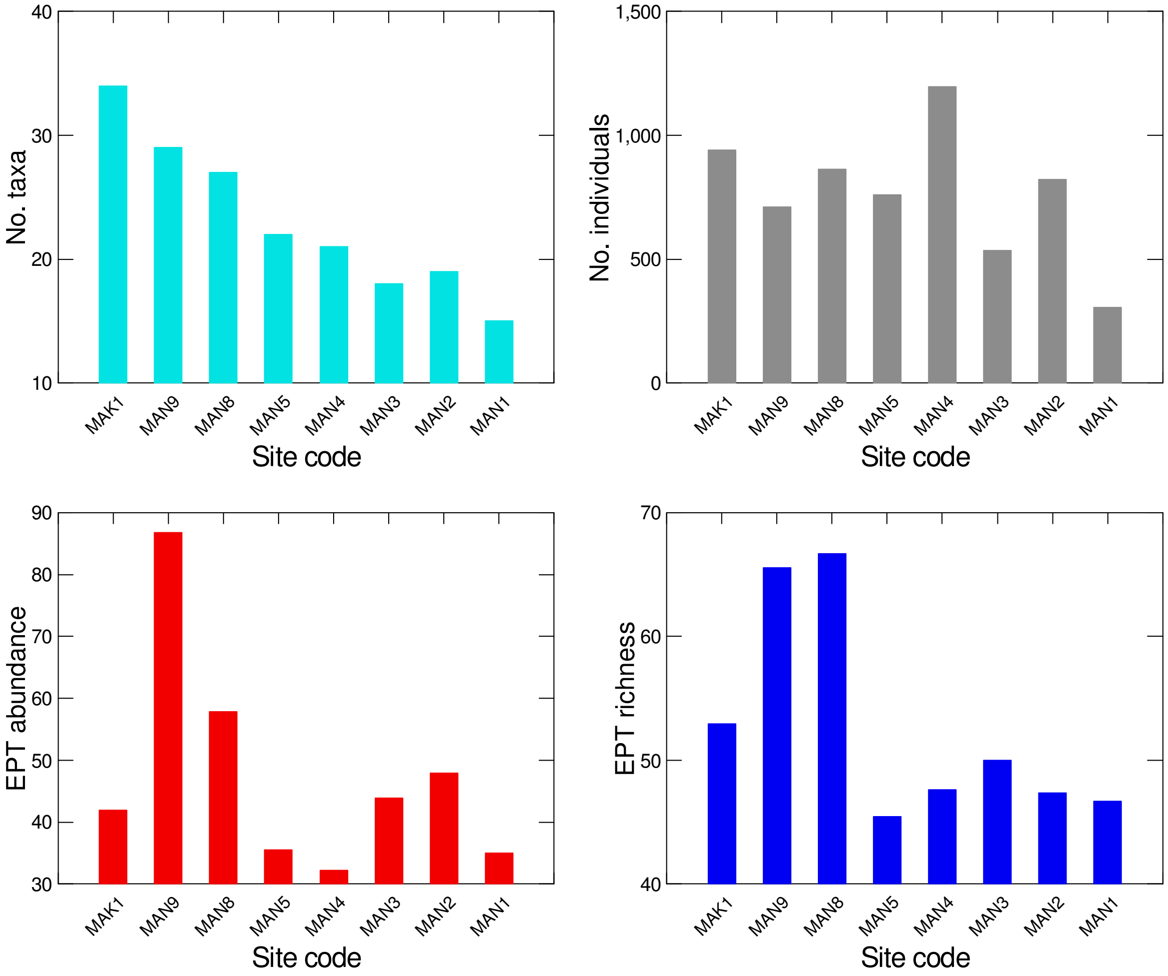

Figure 6: Scores for specific macroinvertebrate metric in the lower Mangatainoka River catchment, 2013.

The Aquanet technical memo provides comment on the effects of the discharge on macroinvertabrate communities, the memo notes:

Based on data collected in 2013, the discharge appears to be causing a slight decrease in QMCI, but of less than 20%, i.e. compliant with the One Plan QMCI change target.

At the time of finalising this memo, I have only just received additional data from Horizons. A cursory look at the data indicates that there was a slight (4%) reduction in QMCI and a moderate (14%) increase in MCI between upstream and downstream, confirming the above conclusions. At the time of writing this memo, I have not been able to access the 2014 data.

2.2 Effects on Air Quality

Potentially odorous compounds include ammonia and hydrogen sulphide. Odour can often result when organic material is being decomposed under anaerobic conditions.

The only odour complains received for the Pahiatua WWTP site occurred when aerators were first installed at the plant, since this time no complaints have been received. The installation of aerators would reduce potential of odours resulting in the treatment ponds. The potential odour effects are considered to be less than minor.

2.3 Effects of future discharge - Summary

The technical memo prepared by Aquanet Consulting (in full in Appendix I) provides a summary, in qualitative terms, as to likely effects of the future discharge. It is noted that further certainty will be able to be provided once additional monitoring has taken place on effluent quality as the upgrades are commissioned on the plant.

The memo notes the following -

- UV disinfection will further reduce the effects of the discharge on the Mangatainoka River's microbiological water quality;
- The installation of a lamella clarifier and drum filter will reduce the concentration of TSS in the discharge, resulting in a reduction (compared with the current low risk) in the risk of the discharge causing effects on water clarity and colour. It is also noted that the proposed discharge via an exfiltration gallery may also provide an additional degree of filtration.
- The proposed upgrades are predicted to result in a reduction in concentration of both the DRP and nitrogen content of the discharge. Currently, the discharge appears to be causing a mild stimulatory effect on periphyton growth. Based on nutrient ratios, it appears likely that the phosphorus content of the discharge is the primary driver of this effect. Qualitatively it is considered that the predicted reductions in nitrogen and phosphorus content of the discharge will result in a reduction in the effects of the discharge on periphyton growth. These effects are currently measurable but within the One Plan targets. It is expected that effects of the future discharge will also be within the One Plan targets.
- The effects of the discharge on macroinvertebrate communities have been reviewed and appear to be within the One Plan targets. Given the predicted improvements in discharge quality it is expected this will remain the case after the proposed upgrades.

3 STATUTORY CONSIDERATIONS

3.1 Resource Management Act 1991

The purpose of the Resource Management Act 1991 is to promote the sustainable management of natural and physical resources.

3.1.1 Part II

Part 2 of the Resource Management Act 1991 sets out the purpose and principles of the Act, to promote the sustainable management of natural and physical resources while enabling people and communities to provide for their social, economic and cultural wellbeing and for their health and safety.

The wastewater treatment plant is a physical resource and provides a vital function by contributing to the health and safety of people and the community of Pahiatua. TDC has duties under the Local

Government Act (2001) and Health Act (1956) to provide wastewater treatment for the Pahiatua community. It is important that these services be provided in a cost effective way, meeting the social and economic aspirations of the community. Improvements to the existing treatment system and imposition of appropriate consent conditions will ensure the sustainable management of the receiving environment.

Section 6 of the Act sets out the Matters of National Importance that need to be recognised and provided for. Those relevant to this proposal are:

> *(a) The preservation of the natural character of the coastal environment (including the coastal marine area), wetlands, and lakes and rivers and their margins, and the protection of them from inappropriate subdivision, use, and development;*
>
> *(e) The relationship of Maori and their culture and traditions with their ancestral lands, water, sites, waahi tapu, and other taonga*

The proposed discharge is an existing discharge, the continuation of the discharge with improved treatment of the wastewater is not considered to be an inappropriate use. The change in discharge point utilises existing infrastructure so no further structures will be placed in the bank of the River.

The preservation of the natural character will be maintained through the imposition of appropriate resource consent conditions.

At the time of preparing this application TDC were awaiting the delivery of a Cultural Impact Assessment report. Receipt of this report will allow for additional assessment of Section 6(e).

Section 7, Other Matters, lists a number of issues Council must consider when assessing applications for resource consents. Those relevant to this proposal include:

> *(b) the efficient use and development of natural and physical resources*
>
> *(c) the maintenance and enhancement of amenity values;*
>
> *(d) intrinsic values of ecosystems; and*
>
> *(f) the maintenance and enhancement of the quality of the environment.*
>
> *(h) the protection of the habitat of trout and salmon*

As noted above the WWTP represents a significant physical resource, the proposed ongoing use of that resource is considered to be an efficient use; the upgrades to the treatment system represent a development of that physical resource.

Both technical AEEs prepared in support of this application conclude that there is little indication that the discharge is having an impact on life-supporting capacity in the River.

The amenity values of the area will be maintained as the effects are no more than minor. The intrinsic values of ecosystems and the quality of the environment will be enhanced with the proposed upgrades.

Section 8 of the Act states that consent authorities must take into account the principles of the Treaty of Waitangi. There are no specific Treaty issues with regard to this application.

3.1.2 Section 104 Assessment

Subject to Part 2 of the Act, in making a decision on this application, Manawatu-Wanganui Regional Council is required, under section 104 (1) of the RMA, to have regard to -

(a) any actual and potential effects on the environment of allowing the activity; and

(b) any relevant provisions of—

(i) a national environmental standard:

(ii) other regulations:

(iii) a national policy statement:

(iv) a New Zealand coastal policy statement:

(v) a regional policy statement or proposed regional policy statement:

(vi) a plan or proposed plan; and

(c) any other matter the consent authority considers relevant and reasonably necessary to determine the application.

The actual and potential effects of the discharge have been considered in section 2 above.

The Technical Memo prepared by Aquanet Consulting Ltd in support of this application provides a technical assessment against the National Policy Statement for Freshwater Management 2014 and is repeated below:

NPSFM (2014)

The assessment below is limited to a technical assessment against the relevant "attribute tables" contained in Appendix 2 of the NPSFM (2014), specifically the following attributes, relevant to rivers: Periphyton (Trophic State), Nitrate (toxicity), Ammonia (Toxicity), and E.coli. I was not able to provide an assessment tin relation to the Dissolved Oxygen (below point sources) Attribute, as it requires continuous dissolved oxygen data. I have made enquiries with Horizons regarding the availability of such data.

The NPSFM (2014) attribute tables are based on four "Bands" with Band A representing the best attribute state, and Band D the worst. The threshold between Band C and Band D constitutes the "national bottom line".

The key output of my assessment presented below is to provide a "grading" assessment for the Mangatainoka River upstream and downstream of the discharge for each Attribute, as presented in Table 6 below.

There is no difference in grading between upstream and downstream of the discharge in relation to periphyton biomass, nitrate (annual median concentration), ammonia (annual median concentration) and E. coli.

There is a shift from band A to band B between upstream and downstream of the discharge in relation to peak (95th percentile) nitrate-nitrogen concentrations. Some growth effects to up to 5% of species may occur within Band B. I note however that under a worst-case scenario, the discharge has the potential to increase nitrate concentrations in the Mangatainoka River by up to 0.020 to 0.026 mg/L (based on median and 95th percentile effluent concentrations), and it thus seems unlikely that the discharge would be the sole cause of the shift from Band A to Band B. Grading for the downstream site in 2013 is A.

Similarly, the grading for annual maximum ammonia concentration shifts from Band A upstream of the discharge to Band C downstream of the discharge. This is due to relatively elevated total ammonia-N concentrations recorded downstream of the discharge on two occasions in March and June 2011 (1.8 and 1.4 mg/L respectively) and one occasion in February 2012 (0.57 mg/L). Grading for the downstream site in 2013 is A.

Table 8:Grading assessment of the Mangatainoka River upstream and downstream of the Pahiatua wastewater discharge for River Attirbutes, as per Appendix 2 of the NPSFM(2014). (Data Source, Horizons Regional Council, Jan 2008-Dec 2013). (NB Table 1 in Tech memo)

Attribute	Attribute state (2008-2013 data)		Narrative description
	Upstream	Downstream	
Periphyton biomass	B	B	A: Rare blooms reflecting negligible enrichment and/or alteration of the natural flow regime or habitat B: Occasional blooms reflecting low nutrient enrichment and/ or alteration of the natural flow regime or habitat C: Periodic short-duration nuisance blooms reflecting moderate nutrient enrichment and/or alteration of the natural flow regime or habitat D: Regular and/or extended-duration nuisance blooms reflecting high nutrient enrichment and/or significant alteration of the natural flow regime or habitat
Nitrate-N (Annual median)	A	A	A: High conservation value system. Unlikely to be effects even on sensitive species. B:Some growth effects on up to 5% of species C: Growth effects on up to 20% of species (mainly sensitive species such as fish) D: Impacts on growth of multiple species, and starts approaching acute impact level (ie risk of death) for sensitive species at higher concentrations (>20 mg/L)
Nitrate-N (Annual 95th percentile)	A	B	
Ammonia (Annual median)	A	A	A: 99% species protection level: No observed effect on any species tested B: 95% species protection level: Starts impacting occasionally on the 5% most sensitive species C: 80% species protection level: Starts impacting regularly on the 20% most sensitive species (reduced survival of most sensitive species D: Starts approaching acute impact level (ie risk of death) for sensitive species
Ammonia (Annual Maximum)	A	C	
E. coli Annual Median	A	A	A: People are exposed to a very low risk of infection (less than 0.1% risk) from contact with water during activities with occasional immersion and some ingestion of water (such as wading and boating) B: People are exposed to a low risk of infection (less than 1% risk) from contact with water during activities with occasional immersion and some ingestion of water (such as wading and boating). C: People are exposed to a moderate risk of infection (less than 5% risk) from contact with water during activities with occasional immersion and some ingestion of water (such as wading and boating). People are exposed to a high risk of infection (greater than 5% risk) from contact with water during activities likely to involve immersion. D: People are exposed to a high risk of infection (greater than 5% risk) from contact with water during activities with occasional immersion and some ingestion of water (such as wading and boating).
E. coli (95th percentile)	Below B(a)	Below B	A: People are exposed to a low risk of infection (up to 1% risk) when undertaking activities likely to involve full immersion. B: People are exposed to a moderate risk of infection (less than 5% risk) when undertaking activities likely to involve full immersion. 540 / 100ml is the minimum acceptable state for activities likely to involve full immersion.

(a): The grading system only includes 95th percentile statistics in bands A and B (95th percentile of < 206 and 540 *E. coli*/100mL respectively). The 95th percentile statistic exceeds 540/100mL at both upstream and downstream sites.

The relevant planning provisions are considered and assessed below.

TDC are signatories of the Manawatu River Accord, this is considered to be a relevant other matter. The Accord sets out focus, vision and goals for the Manawatu River.

Specific goals set out in the Accord are:

- *The Manawatu River becomes a source of regional pride and mana.*
- *Waterways in the Manawatu Catchment are safe, accessible, swimmable, and provide good recreation and food resources.*
- *The Manawatu Catchment and waterways are returned to a healthy condition.*
- *Sustainable use of the land and water resources of the Manawatu Catchment continues to underpin the economic prosperity of the Region.*

The renewal of the discharge permit for Pahiatua is identified as one of the tasks for TDC under the Accord Action Plan.

Under 104 (2A) *When considering an application affected by section 124**[**or 165ZH(1)(c)**]**, the consent authority must have regard to the value of the investment of the existing consent holder.*

The current asset value of the WWTP is $2 million the planned upgrades are $1.2 million.

3.1.3 Matters relevant to certain applications

105 Matters relevant to certain applications

(1) If an application is for a discharge permit or coastal permit to do something that would contravene section 15 or section 15B, the consent authority must, in addition to the matters in section 104(1), have regard to—

(a) the nature of the discharge and the sensitivity of the receiving environment to adverse effects; and

(b) the applicant's reasons for the proposed choice; and

(c) any possible alternative methods of discharge, including discharge into any other receiving environment.

The likely effluent quality once upgrades have been installed have been estimated and effects on the environment assessed.

TDC reasoning for the choice of upgrade includes the efficiency of having some commonality across the different WWTPs, allowing for learnings to be shared across the WWTPs.

Alternatives have been considered, including discharge to land, in section 1.5

3.1.4 107 Assessment

Section 107 of the RMA describes that a consent authority shall not grant a discharge permit that, after reasonable mixing, gives rise to any of the following effects:

(c) The production of any conspicuous oil or grease films, scums or foams, or floatable or suspended materials:

(d) Any conspicuous change in the colour or visual clarity:

(e) Any emission of objectionable odour:

(f) The rendering of fresh water unsuitable for consumption by farm animals:

(g) Any significant adverse effects on aquatic life.

The following commentary is repeated from the technical memo prepared by Dr Ausseil, Aquanet Consulting Ltd, in support of this application.

S107(1)d – Conspicuous changes in water clarity or colour

Effects on water clarity are assessed in Sections 3.2.3 (p27) and 4.3 (p71) of the Opus Report. I also undertook some further data analysis, in particular comparing upstream and downstream visual clarity using a statistical test[5] generally considered appropriate[6] for this type of situation. This analysis does not indicate statistically significant changes in visual water clarity between upstream and downstream of the discharge.

Reductions in water clarity of more than 20% were measured on 5 out of 27 monitoring occasions (19%), and reductions of more than 30% on 4 out of 27 occasions (15%) (Figure 7: Relative change in visual water clarity in the Mangatainoka River between upstream and downstream of the Pahiatua WWTP discharge (Data source Horizons REgional Council, data from Jan 2008 to Dec 2012) (NB Figure 1 in Aquanet Technical memo)

Three of these were measured in 2010, and one in 2012. Unfortunately, there are no visual clarity data for 2013. Most people are able to detect a change in water clarity of 30% or more.

Effluent quality data indicates that unusually elevated Total Suspended Solids (TSS) concentrations occurred during January to April 2010 (concentrations of 80-110 mg/L against a long-term median of 10 mg/L), suggesting that the discharge was probably the cause of, or a contributor to, the changes in water clarity during these months. The November 2012 change in water clarity was however not associated with elevated TSS concentrations in the discharge however (8 mg/L), and it is doubtful whether the discharge was the cause of the decrease in visual clarity measured that day. TSS concentrations in the effluent have been consistently low (<20 mg/L) since January 2012, indicating that the current discharge presents a low risk of causing significant changes in water clarity or colour.

My conclusion is that the discharge does not appear to cause significant changes in water clarity overall, although conspicuous changes in water clarity have occurred on occasion during three consecutive months in 2010. The current discharge quality presents a low risk of causing significant changes in water clarity or colour.

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[5] Wilcoxon Pairwise comparison

[6] As recommended in Scarsbrook M. and McBride G (2007). Best practice guidelines for the statistical analysis of freshwater quality data. Prepared for the Ministry for the Environment by the National Institute for Water and Atmospheric Research (NIWA). NIWA client report: HAM2007-088.

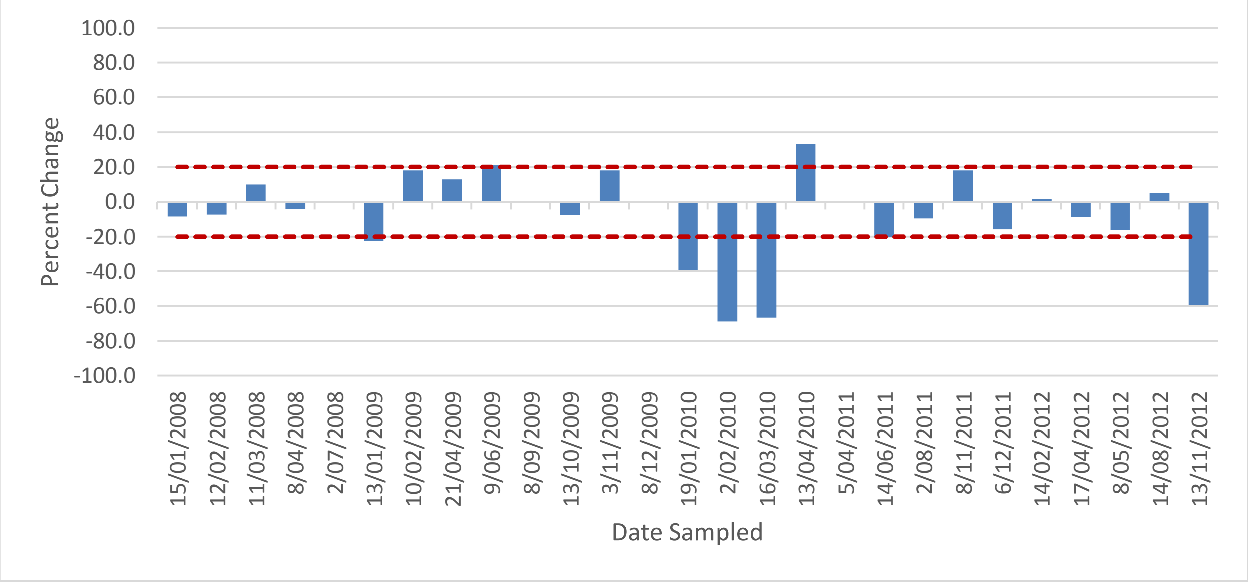

Figure 7: Relative change in visual water clarity in the Mangatainoka River between upstream and downstream of the Pahiatua WWTP discharge (Data source Horizons REgional Council, data from Jan 2008 to Dec 2012) (NB Figure 1 in Aquanet Technical memo)

S107(1)(f) – the rendering of freshwater unsuitable for consumption by farm animals.

There are a range of contaminants relevant to stock drinking water, including pathogens/microbiological water quality, toxicants, and physico-chemical characteristics such as pH.

I comment on aspects relative to microbiological water quality in Section 4.3 of this memo.

I have also reviewed available data relative to total ammonia-nitrogen and nitrate-nitrogen. My conclusion is that the discharge does not cause the stock drinking water guidelines relative to these determinands to be exceeded downstream of the discharge.

I have no information on the discharge content of other water quality determinands relevant to stock drinking standards, such as for example metals, but, based on my experience of a number of other similar WWTPs across the region and in neighbouring regions, I have no reason to believe that these would be present in sufficient concentrations in the discharge to be of significant environmental concern after reasonable mixing.

In conclusion, what information is available indicates that the discharge meets the requirements of S107(1)(f).

S107(1)(g) - Effects on aquatic life

The Opus Report makes an assessment of the effects of the discharge on the life-supporting capacity of the Mangatainoka River (pp74-75). It considers a range of water quality determinands such as water pH, temperature, dissolved oxygen concentrations, and uses indices of macro-invertebrate community health as a direct measure of life-supporting capacity. With regards to the latter, the report concludes that there is little indication that the discharge exerts a deleterious impact on life-

supporting capacity. Having reviewed the data presented in the Opus Report, I concur with this conclusion.

The Opus report indicates that the discharge does not alter the temperature of the Mangatainoka River measurably, and that pH appears to respond to generally in the lower catchment rather than in response to the discharge itself. I generally concur with these conclusions.

With regards to dissolved oxygen (DO), there is a slight, but statistically significant, decrease in DO saturation downstream of the discharge. All DO measurements upstream and downstream of the discharge are well above 5 mg/L and all but one measurement downstream of the discharge are above 80% saturation. On this basis there does not appear to be an indication of significant deleterious effects of the discharge on DO levels in the Mangatainoka. It should be noted however that spot measurements of DO are of limited value, and continuous DO measurements are generally preferable and would be advisable if there was an indication of significant risk of effects on DO concentration or saturation in the Mangatainoka River.

The Opus Report also provides an assessment relative to two toxic contaminants, ammonia and nitrate (pp73-74). The report concludes that:

a. *the discharge does not cause any measurable total ammonia-N concentration increase in the Mangatainoka River downstream of the discharge*[7]*, and*
b. *free ammonia-N concentrations are approximately 10 times lower than the 95% protection species*
c. *The nitrate-nitrogen concentrations in the discharge are well below toxicity thresholds, indicating that the discharge is not a source of nitrate-nitrogen in amounts likely to constitute a toxicity hazard, and that river nitrate-N concentrations are well below both toxicity thresholds.*

On the basis of the above information, my conclusion is that the discharge does not appear to be causing any significant adverse effect on aquatic life, or to be causing more than a low risk of toxic effects to aquatic life.

3.2 Regional Policy Statement

The Horizons Regional Council One Plan is considered to be the relevant planning document. This contains both the Regional Policy Statement (RPS) and Regional Plans.

The objectives and policies of the RPS relevant to the proposal are:

3.2.1 Chapter 3 - Infrastructure

Objective 3-1: Infrastructure^ and other physical resources of regional or national importance

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[7] I note that my own analysis shows that there is a small, but statistically significant increase in total ammonia-N concentrations downstream of the discharge.

Have regard to the benefits of infrastructure^ and other physical resources of regional or national importance by enabling their establishment, operation, maintenance* and upgrading*.*

Policy 3-1: Benefits of infrastructure^ and other physical resources of regional or national importance

(a) The Regional Council and Territorial Authorities^ must recognise the following infrastructure^ as being physical resources of regional or national importance:

> *(viii) public or community sewage treatment plants and associated reticulation and disposal systems*

(c) The Regional Council and Territorial Authorities^ must, in relation to the establishment, operation, maintenance*, or upgrading* of infrastructure^ and other physical resources of regional or national importance, listed in (a) and (b), have regard to the benefits derived from those activities.*

COMMENT

The WWTP at Pahiatua provides ongoing benefits to the residents of Pahiatua by providing functioning wastewater treatment infrastructure. Benefits include providing for social and economic well-beings for the community. It is considered to be appropriate to have regard to Objective 3-1 and Policy 3-1 when making a decision regarding this application.

3.2.2 Chapter 5 - WATER

Objective 5-2: Water^ quality

(a) Surface water^ quality is managed to ensure that:

(i) water^ quality is maintained in those rivers^ and lakes^ where the existing water^ quality is at a level sufficient to support the Values in Schedule B

(ii) water^ quality is enhanced in those rivers^ and lakes^ where the existing water^ quality is not at a level sufficient to support the Values in Schedule B

COMMENT

Objective 5-2 is supported by various Policies which outline how water quality targets must be used to inform the management of surface water. Policies 5-3 to 5-5 set out the policies depending on whether the specified targets are being met for each Water Management Sub-Zone.

In this case it is considered the Policy 5-4 is the most relevant as the water quality targets are not all being met for the sub-zone.

Policy 5-4: Enhancement where water quality targets* are not met

(a) Where the existing water^ quality does not meet the relevant Schedule D water quality targets within a Water Management Sub-zone*, water^ quality within that sub-zone must be managed in a manner that enhances existing water^ quality in order to meet:*

(ia) the water quality target for the Water Management Zone in Schedule D; and/or*

(ii) the relevant Schedule B Values and management objectives that the water quality target is designed to safeguard.*

(b) For the avoidance of doubt:

(i) in circumstances where the existing water^ quality of a Water Management Sub-zone does not meet all of the water quality targets* for the Sub-zone*, (a) applies to every water quality target* for the Sub-zone*

(ii) in circumstances where the existing water^ quality of a Water Management Sub-zone does not meet some of the water quality targets* for the Sub-zone*, (a) applies only to those water quality targets* not met.*

COMMENT

The proposed discharge is located within Mangatainoka (Mana_8) and Lower Mangatainoka (Mana_8c) Water Management Zones and Sub-zones which has zone wide values for: Life Supporting Capacity – Hill Country Mixed geology; aesthetics; Mauri; contact recreation; stockwater; Industrial abstraction; Irrigation; Existing Infrastructure and Capacity to Assimilate Pollution. Schedule AB site specific values for the main stem reach of the River are: Trout Fishery – Regionally Significant Trout Fishery; Trout Spawning; Site of Significance – Dotterel; Flood Control – Drainage.

As summarised in Opus Report (Appendix I) not all of the water quality targets are currently met for the Mana_8c subzone. Assessment of the receiving environment and plant performance indicate that the WTTP does not play a significant role in this, with the exception of DRP. The improvements to the treatment system will see an improvement to water quality in time. An improvement in DRP in effluent quality will assist in enhancing existing water quality.

Overall the proposal is consistent with Policy 5-4.

*Policy 5-9: Point source discharges^ to water^*

The management of point source discharges^ into surface water^ must have regard to the strategies for surface water^ quality management set out in Policies 5-3, 5-4 and 5-5, while having regard to:

*(a) the degree to which the activity will adversely affect the Schedule B Values for the relevant Water Management Sub-zone**

(b) whether the discharge^, in combination with other discharges^, including non-point source discharges^ will cause the Schedule E water quality targets to be breached*

(c) the extent to which the activity is consistent with contaminant^ treatment and discharge^ best management practices

*(d) the need to allow reasonable time to achieve any required improvements to the quality of the discharge^*

(e) whether the discharge^ is of a temporary nature or is associated with necessary maintenance^ or upgrade work and the discharge^ cannot practicably be avoided*

(f) whether adverse effects^ resulting from the discharge^ can be offset by way of a financial contribution set in accordance with Chapter 19

(g) whether it is appropriate to adopt the best practicable option^.

COMMENT

Table 3 compares the performance of the Pahiatua WWTP to a number of other similar plants in NZ. This shows that the current system is performing as well or better than those plants. The addition of tertiary treatment processes is consistent with best management practice.

From the AEE work done to date the discharge of WWTP is not individually responsible for causing water quality targets to be breached, though is likely responsible for some elevated DRP levels downstream of the site based on existing data. The proposed upgrades will improve long term effluent quality, once time is allowed to optimise the plant. The designed upgrades are considered to be the best practicable option for the site.

Policy 5-11: Human sewage discharges^

Notwithstanding other policies in this chapter:
(a) before entering a surface water body^ all new discharges^ of treated human sewage must:
(i) be applied onto or into land^, or
(ii) flow overland, or
(iii) pass through a rock filter, or
(iv) pass though a wetland^ treatment system, or
(v) pass through an alternative system that mitigates the adverse effects^ on the mauri of the receiving water body^, and*

(b) all existing direct discharges^ of treated human sewage into a surface water body^ must change to a treatment system described under (a) by the year 2020 or on renewal of an existing consent, whichever is the earlier date.

COMMENT

The treated wastewater will pass through a rock filter prior to final discharge in to the Mangatainoka River. This is consistent with Policy 5-11.

OVERALL CONCLUSION

The proposal is consistent with the relevant Objectives and Policies from the Regional Policy Statement.

3.3 The Regional Plan

The Summary of consent requirements as follows

Discharge of Treated Wastewater to Water – Rule 14-30, Discretionary Activity

Human effluent storage and treatment facilities – Rule 14-16, Permitted Activity. This rule also covers any ancillary discharge to air pursuant to s15(2A)RMA.

3.3.1 CHAPTER 14 - DISCHARGES TO LAND AND WATER

Objective 14-1 Management of discharges^ to land^ and water^ and land^ uses affecting groundwater and surface water quality

The management of discharges^ onto or into land^ (including those that enter water^) or directly into water^ and land^ use activities affecting groundwater and surface water^ quality in a manner that:

> *(a) safeguards the life supporting capacity of water and recognises and provides for the Values and management objectives in Schedule B,*
>
> *(b) provides for the objectives and policies of Chapter 5 as they relate to surface water^ and groundwater quality, and*
>
> *(c) where a discharge^ is onto or into land^, avoids, remedies or mitigates adverse effects^ on surface water^ or groundwater.*
>
> ***Policy 14-1: Consent decision-making for discharges^ to water^***
>
> *When making decisions on resource consent^ applications, and setting consent conditions^, for discharges^ of water^ or contaminants^ into water^, the Regional Council must specifically consider:*
>
> *(a) the objectives and policies 5-1 to 5-5 and 5-9 of Chapter 5, and have regard to:*
>
> *(b) avoiding discharges^ which contain any persistent contaminants^ that are likely to accumulate in a water body^ or its bed^,*
>
> *(c) the appropriateness of adopting the best practicable option^ to prevent or minimise adverse effects^ in circumstances where:*
>
> > *(i) it is difficult to establish discharge^ parameters for a particular discharge^ that give effect to the management approaches for water^ quality and discharges^ set out in Chapter 6, or*
> >
> > *(ii) the potential adverse effects^ are likely to be minor, and the costs associated with adopting the best practicable option^ are small in comparison to the costs of investigating the likely effects^ on land^ and water^, and*
>
> *(d) the objectives and policies of Chapters 2, 3, 6, 9 and 12 to the extent that they are relevant to the discharge^.*
>
> COMMENT
>
> As there is no significant industry contributing to the WWTP it is not considered there would be any persistent contaminants that would accumulate in the River or its bed.
>
> The proposed discharge from an upgraded treatment system is considered to be the best practicable option taking into account effects on the environment and economics. The existing discharge has been shown to be having minimal impact on the receiving environment. While a quantitative assessment will only be possible once additional data is

recorded once upgrades are installed, the qualitative assessment is that the upgrades will further reduce effects on the Mangatainoka River.

Policy 13-2B: Options for discharges^ to surface water^ and land^

When applying for consents and making decisions on consent applications for discharges^ of contaminants^ into water^ or onto or into land^, the opportunity to utilise alternative discharge^ options, or a mix of discharge^ regimes, for the purpose of mitigating adverse effects^, applying the best practicable option, must be considered, including but not limited to:

(a) discharging contaminants^ onto or into land^ as an alternative to discharging contaminants^ into water^,

(b) withholding from discharging contaminants^ into surface water^ at times of low flow, and

(c) adopting different treatment and discharge^ options for different receiving environments^ or at different times (including different flow regimes or levels in surface water bodies^).

COMMENT

Land treatment has been considered, but not considered to be the best practicable option at this stage. The proposed upgrade is considered to be the best practicable option at this stage.

Policy 13-4: Monitoring requirements for consent holders

Point source discharges^ of contaminants^ to water^ must generally be subject to the following monitoring requirements:

(a) the regular monitoring of discharge^ volumes on discharges^ smaller than 100 m3/day and making the records available to the Regional Council on request,

(b) the installation of a pulse-count capable meter in order to monitor the volume discharged^ for discharges^ of 100 m3/day or greater,

(c) the installation of a Regional Council compatible telemetry system on discharges^ of 300 m3/day or greater, and

(d) monitoring and reporting on the quality of the discharge^ at the point of discharge^ before it enters surface water^ and the quality of the receiving water^ upstream and downstream of the point of discharge^ (after reasonable mixing) may also be required. This must align with the Regional Council's environmental monitoring programme where reasonably practicable to enable cumulative impacts to be measured.*

COMMENT

Flow meters now in place which will be capable of monitoring volumes being discharged.

As most of the proposed upgrades are due to be installed in early 2015, a period of more intensive monitoring of effluent quality is proposed. This more intensive period of monitoring will provide certainty with regards to effluent quality that is likely to be sustained in the longer term.

4 Mitigation

The main form of mitigation for the Pahitua WWTP is the extensive upgrades that are planned for the site.

Additional monitoring is recommended during the commissioning stage in order to help refine the running of the processing and provide further certainty about long term effluent quality.

Below is the indicative sampling that will be done as the new upgrades are installed, it is anticipated this will occur during February and March 2015.

- Influent
  - Take 24 hour composite samples once a week (sampling on a different day) for a month or two, then monthly for the balance of a year.
  - Sample $cBOD_5$, TKN, TP. Alkalinity.
- Commissioning Phase
  - Sample daily or multiple times per day for a duration of two weeks
  - Sample TSS, DRP and UVT at the Pond 3 outlet and after the clarifier and the filter in order to confirm the improvement across each new tertiary process
  - Sample full list of analytes at discharge (after UV disinfection)
- Trial Operation Phase
  - Sample three times a week (Monday, Wednesday and Friday) for a duration of four weeks
  - Sample full list of analytes at discharge (after UV disinfection)

The full list of effluent analytes to be sampled (except in between unit processes as detailed above) is as follows:

- Composite Samples
  - $cBOD_5$
  - Ammonia
  - TKN
  - TN
  - DRP
  - TP
  - TSS

- Grab Samples
  - UVT%
  - pH
  - E.coli

In addition, once the commissioning phase is completed a management plan will be prepared by TDC. This will ensure that the optimised plant performance can be continued, even if staff changes occur.

5 Consultation

TDC have led consultation with a number of interested parties.

Representatives from Rangitane and Water and Environmental Care Association Inc (WECA) were invited in Nov 2014 to visit the Pahiatua site to discuss with TDC the upgrades prior to commissioning. Both parties were on site prior to any of the proposed upgrades being finalised. Both parties have indicated they are available for a site visit in Jan 2015.

Onsite visits have recently (November 2014) taken place with representatives from Ngati Kahununu and Fish and Game.

TDC have had discussions with the landowner around the pond area Mr. Phillip Morrison

6 Summary

The resource consent application to discharge treated wastewater to water under Rule 13-27 of the Proposed One Plan, addresses the actual and potential effects arising from this activity and assesses the activity against the Resource Management Act 1991 and the relevant Regional Plans. The proposal is consistent with the objectives and policies listed in this application, and given the proposed upgrades to the treatment plant the effects of the activity are considered to be no more than minor.

APPENDIX I –

APPENDIX II –

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Tararua District Council

Pahiatua Wastewater Treatment Plant Consent Renewal: Assessment of Environmental Effects

OPUS

Tararua District Council

Pahiatua Wastewater Treatment Plant Consent Renewal:

Assessment of Environmental Effects

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Executive Summary

Data obtained from monitoring river water quality and the wastewater discharge over the period 2009 – 2013 (inclusive) was used to assess the impact of the Pahiatua Wastewater Treatment Plant (WWTP) on the lower Mangatainoka River.

Wastewater quality

An initial assessment of the wastewater discharge indicated that changes that have been made to the wastewater treatment process over the period 2008-2010 have delivered quantifiable improvements to the quality of the wastewater discharge. The improvements in wastewater quality are summarised in terms of concentrations of key variables in Table i) below. The Table also indicates the likely effect of the change on water quality in the receiving environment (the lower Mangatainoka River):

Table i: Change in wastewater quality, 2009-2013 and assessment of likely impact on river water quality.

Water quality variable (units)	**Median Concentration**		**Proportional change in concentration/ metric (%)**	**Likely effect on receiving environment**
	2008	**2013**		
E. coli (cfu/100 mL)	4362.5	0	-100[c]	Improvement in quality, Reduced impact
Enterococci (cfu/100 mL)	8015.5	0	-100[c]	Improvement in quality, Reduced impact
Total suspended solids (mg/L)	71.5	1	-98	Improvement in quality, Reduced impact
Suspended solids (mg/L)	3.5[A]	1[A]	-71	Improvement in quality, Reduced impact
Turbidity	29.8	5.2	-83	Improvement in quality, Reduced impact
Volatile matter (mg/L)	65	0.5	-99	Improvement in quality, Reduced impact
Ammoniacal-N (mg/L)	6.07	1.7765	-71	Improvement in quality, Reduced impact
Nitrite-N (mg/L)	0.056[B]	0.006[B]	-89	Improvement in quality, Reduced impact
Nitrate-N (mg/L)	**0.086[B]**	**1.991[B]**	**2203**	**Increase in concentration, Possible increased impact**
Total organic nitrogen (mg/L)	**0.350**	**2.001**	**471**	**Increase in concentration, Possible increased impact**
Total nitrogen (mg/L)	14.95	3.945	-74	Improvement in quality, Reduced impact
Dissolved reactive phosphate (mg/L)	2.517	0.027	-99	Improvement in quality, Reduced impact
Total phosphorus (mg/L)	4.225	0.107	-97	Improvement in quality, Reduced impact
Carbonaceous BOD$_5$ (mg/L)	2.25	1	-55	Improvement in quality, Reduced impact

The Table indicates that with two exceptions (nitrate-nitrogen and total organic nitrogen concentrations), the discharge is currently exerting a smaller impact on the Mangatainoka River than was the case in 2009.

Receiving water quality

The improvements in wastewater quality are in most cases evident in the receiving environment as reduced impact. In some cases the large mass load of variables of concern in the river upstream of the discharge do not allow a change in impact to be determined. The impact of the wastewater discharge on surface water quality is summarised in Table ii):

Table ii: Impact of wastewater discharge on receiving water quality (data for period 2012 - 2013). The impact is assessed in terms of compliance with water quality targets identified in the Horizons OnePlan (bold text). In some cases existing water quality is described in terms of median or other concentrations (non-bold text). Abbreviations are defined in Table 3 of the main body of the report. Data with superscript ^{A} use site MAN3 as downstream assessment site.

Water quality variable	Statistic or measurement	Flow condition	Measured concentration or value of water quality variable at each site		Proportion noncompliant, 2012-2013 (%)
			Upstream (MAN5)	Downstream (MAN4)	
pH	**Instantaneous (7.0 – 8.5 units)**	**All flows**	**7.6 (median)**	**7.6 (median)**	**-**
		All flows	pH 7 = 5th % ile	pH 7.2< 5th %ile	5 - 10
		All flows	pH 8.5 = 95th %ile	pH 8.5 > 90th %ile	
pH	**Instantaneous change (<0.5 units)**	**All flows**	**-**	**-**	**10**
Water temperature	**Instantaneous (<19 °C)**	**All flows**	**19 ≅ 85th %ile**	**19 ≅ 85th %ile**	**~15**
		All flows	14.7 (median)	13.9 (median)	-
Water temperature	**Instantaneous change (<3 °C)**	**All flows**	**-**	**-**	**0**
Dissolved oxygen	**Instantaneous (>80 %sat.)**	**All flows**	**86.4 = 1st %ile**	**88.4 = 1st %ile**	**<1**
		All flows	104.1 (median)	100.8 (median)	-
Soluble cBOD$_5$	**Monthly average, flow condition (<1.5 mg/L)**	**Flow <20%ile exceedance**	**0.78 (mean)**	**0.8 (mean)**	**-**
		Flow <20%ile exceedance	1 < 99th %ile	1 < 99th %ile	-
Particulate Organic Matter	**Average, flow condition (<5 mg/L)**	**Flow <50%ile exceedance**	**1.13 (mean)**	**1.7 (mean)**	**0**
			3.4 = 99th %ile	5 ≅ 94th %ile	-
Periphyton as Chlorophyll *a*	**Instantaneous (<120 mg/m^2)**	**All flows**	**96th %ile**	**92nd %ile^A**	**~4% (u/s) - ~8% (d/s)**
			13.6 (median)	37 (median)	-
			13.6 (median)	33.5 (median)^A	-
Visible periphyton cover	**Instantaneous (<30%)**	**All flows**	**92% (median)**	**~96% (median)**	**~85% (u/s) – 95% (d/s)**
Visible periphyton cover as diatoms or cyanobacteria	**Instantaneous (<60%)**	**All flows**	**3.5 % (median)**	**~ 2% (median)**	**4% (u/s) - ~1% (d/s)**
Dissolved reactive phosphate	**Annual average, flow condition (<0.010 mg/L)**	**Flow <20%ile exceedance**	**0.009 (mean)**	**0.013 (mean)**	**~30**

Water quality variable	**Statistic or measurement**	**Flow condition**	**Measured concentration or value of water quality variable at each site**		**Proportion noncompliant, 2012-2013 (%)**
			Upstream (MAN5)	**Downstream (MAN4)**	
			0.010 ≅ 84th %ile	0.010 = 70th %ile	
Soluble inorganic nitrogen	**Annual average, flow condition (<0.444 mg/L)**	**Flow <20%ile exceedance**	**0.773 (mean)**	**0.920 (mean)**	**0**
QMCI	**Change (reduction) (<20%)**	**All flows**	**4.83**	**4.49**	**-7%**
Ammoniacal-N	**Annual average (0.400 mg/L)**	**All flows**	**0.012 (mean)**	**0.035 (mean)**	**0**
Ammoniacal-N	**Maximum (2.1 mg/L)**	**All flows**	**0.005 (max)**	**0.57 (max)**	**0**
Toxic contaminants	Maximum (<99% Species protection level)	All flows	-	-	-
Toxic contaminants – Nitrate-N	Annual median (<2.4 mg/L)	All flows	**0.81**	**0.85**	**0**
Toxic contaminants – Nitrate-N	95th percentile (3.5 mg/L)	All flows	**1.24**	**1.95**	**0**
Toxic contaminants – Ammoniacal-N	Maximum (0.32 mg/L)	All flows	0.005	0.011	0
Visual clarity	**Minimum according to flow condition (>3 m)**	**River flow < 50%ile exceedance**	**3.05 = 75th %ile**	**3.04 = 40th %ile**	**~70% (u/s) – 80% or 40%[A] (d/s)**
Visual clarity	**Change (<20%)**	**River flow < 50%ile exceedance**			**45%[A]**
***E. coli* concentration**	**Instantaneous maximum, flow condition (260 /100 mL)**	**Flow < 50%ile exceedance**	**2000 (max)**	**4045 (max)**	**-**
			260 ≅ 78th %ile	260 ≅ 45th %ile	12% (u/s) - 55% (d/s)
	Instantaneous maximum, flow condition (260 /100 mL)	**Flow < 50%ile exceedance**	**2000 (max)**	**2421 (max)[A]**	**-**
			260 ≅ 78th %ile	260 ≅ 85th %ile[A]	12% (u/s) – 15% (d/s)
***E. coli* concentration**	**Instantaneous maximum, flow condition (550/100 mL)**	**Flow < 20%ile exceedance**	**2000 (max)**	**4045 (max)**	**-**
			550 ≅ 91st %ile	550 ≅ 82nd %ile	9% (u/s) – 18% (d/s)
	Instantaneous maximum, flow condition	**Flow < 20%ile exceedance**	**2000 (max)**	**2421 (max)[A]**	**-**
			550 ≅ 91st %ile	550 ≅ 92nd %ile[A]	9% (u/s) – 8% (d/s)

The quality of surface water in the Mangatainoka River was also assessed in terms of whether the values identified for the river in the OnePlan were likely to be impaired. It was identified that where values were impaired, it would be necessary to address these issues in a catchment-wide manner, rather than by focusing on one or two point sources (including the Pahiatua WWTP).

This assessment demonstrates that water quality in the reach where the Pahiatua WWTP treated wastewater is discharged is subject to upstream point source and land use impacts. Currently these are the principal determinants of surface water quality in the Mangatainoka River both upstream and downstream of the discharge.

In terms of impacts on the values specifically identified for the lower Mangatainoka River, the Pahiatua WWTP does not in itself compromise these. It is one of a range of point-source and diffuse pollution sources that exert a cumulative impact on river water quality. Where specific water quality improvement is required to achieve an identified value, a catchment-wide response will be required that identifies and addresses the specific contributions from various sources. It will be insufficient and in most cases inappropriate to focus on point source discharges such as the Pahiatua WWTP alone.

1 Introduction

Tararua District Council owns and operates the Pahiatua Wastewater Treatment Plant (WWTP), which treats the mainly domestic wastewater arising from Pahiatua. Wastewater is treated in a series of three unlined ponds. Treated wastewater is discharged to the Town Creek, which conveys the wastewater approximately 500 m prior to discharge into the Mangatainoka River to the north of Pahiatua.

Since 2010, the wastewater treatment process has been progressively upgraded to now include:

- Primary screening to remove gross solids
- Chemical dosing (to facilitate phosphorus removal)
- Clarification within a clarifier (to remove phosphorus and other particulate materials)
- A maturation pond (12,500 m3 capacity), with a high-flow bypass system
- UV sterilisation of the clarified effluent
- Discharge to the Town Creek via a rock filter.

Over the time since the previous consent was granted, the Horizons OnePlan has been adopted. It provides clear direction regarding the quality of water required to meet a range of stakeholder values (or uses). A series of water quality targets are integral to the OnePlan – they define the concentrations of key nutrient species (among other variables), which will allow the identified fresh water values to be achieved. The OnePlan identifies that meeting the water quality targets for surface waters in the region will require improvement in the quality of wastewater discharged to surface waters, as well as changes to land use practices. The OnePlan clearly signals an intention to maintain good water quality, and improve the quality of water where necessary.

Tararua District Council engaged Opus International Consultants to lodge the application to renew the wastewater discharge consent. One of the key requirements for the application is an Assessment of Environmental Effects (AEE) of the proposed discharge. This document provides this assessment as a desk-top exercise, using data derived from Horizons Regional Council monitoring activity, supported with limited additional data from other sources where necessary.

The AEE focuses on the impact of the wastewater discharge in four inter-related areas:

- Physical variables
- Nutrient inputs
- Faecal contaminant inputs, and
- Ecological response.

2 Methods

2.1 Data Used for Evaluation

Water quality and hydrometric data were retrieved from Horizons Regional Council (HRC)[1]. These data were derived from the HRC routine monitoring programme. Data were provided for a number of sites located in the Mangatainoka River catchment, including State of Environment monitoring sites and compliance monitoring sites. The latter were located upstream and downstream of significant point source discharges.

Precipitation data were derived from the National Climate Database (CliFlo[2]), managed by NIWA. Data were retrieved from the Pahiatua EWS station (DO5591).

Ecological data were provided by HRC in the form of Monthly periphyton data, weekly periphyton and cyanobacteria data and invertebrate scores. Reports were also provided that summarised routine macroinvertebrate data (Stark, 2011, 2012), as well as an officer report associated with an earlier consent application (Ausseil, 2007).

2.2 Data Manipulation

Data were stored and manipulated in Microsoft Excel. Data were checked for missing and duplicate records, censored data and obvious errors. Data were stored as “raw” (as received) and processed data files, with explanatory notes describing specific actions and an audit trail.

The following modifications were made to the dataset:

a. Censored data reported as less than an analytical method detection limit were converted to half the detection limit value. Although the rationale for this practice is questionable, it allows these data to be used as numeric values, rather than being excluded as text.
b. Censored data reported as greater than an analytical result were used as that value. Results of this nature were limited to microbiological tests, and reflect the nature of the test.
c. For use of the LOADEST software, flow data were converted to cubic feet per second values (cfs) using the relationship Q (L/s) × 0.03531 = Q (cfs).
d. Flow data for the Mangatainoka River immediately applicable to the Pahiatua WWTP were available for the Pahiatua Town Bridge site, approximately 1.8 km upstream of the confluence of the Town Stream with the Mangatainoka River main stem. Inflow between the Town Bridge site and SH2 (approximately 2.8 km downstream from the confluence with the Town Stream) is limited, allowing flow to be estimated for ungauged stations using estimates for the inflow from the wastewater site. No flow data exist for the wastewater discharge, so estimates derived from Ausseil were used. Ausseil considered that 626 m^3/d was a reasonable estimate of average dry weather flow (7.2 L/s). Earlier estimates of dry, wet weather and peak wet weather flows were 1000, 4000 and 8000 m^3/d respectively. The latter two values were adjusted according to the estimate of dry weather flow by Ausseil to provide estimates of wet weather and peak weather flows of 16 and 40 L/s respectively. Flows in the Mangatainoka River downstream of the WWTP were adjusted using the daily rainfall record as follows:

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[1] Provided by email and FTP by Maree Clark, Senior Water Quality Scientist on 13/05/2014

[2] http://cliflo.niwa.co.nz/

i. If rainfall was less than 12 mm within the 24 h period, the flow downstream of the discharge was increased by 8 L/s.
ii. If rainfall was greater than 12 mm but less than 30 mm, flow in the river was increased by 16 L/s.
iii. If rainfall was greater than 30 mm within the 24 h period, flow in the river downstream of the discharge was increased by 40 L/s.

The effects of these somewhat arbitrary adjustments were less than minor in terms of increases to river flows or comparison of upstream and downstream loads and assessment of the impact of the discharge.

2.3 Assessment of Data

Quantitative assessment was undertaken using Systat v12, LOADEST[3] and TimeTrends[4].

The assessment of the water quality data took three principal forms:

1) **Exploratory data assessment**, to determine spatial relationships in water quality and trends in water quality at individual sites over time. Summary statistics, time series graphs and box and whisker plots were prepared to assist with visual assessment.
2) Formal **trend assessment**, to determine whether apparent trends were statistically significant and meaningful from a resource management perspective.
3) **Load calculations**, to determine the mass load and flux of material within the river at various locations and over time.

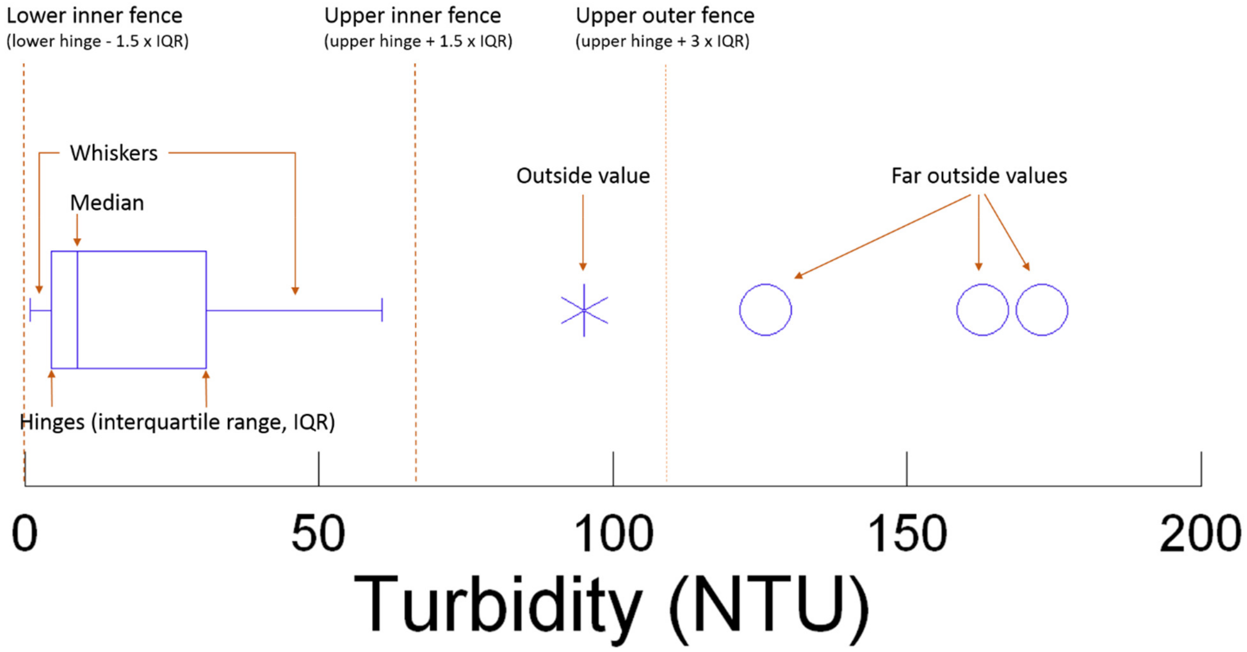

Figure 1: Explanation of a box plot derived from SYSTAT

Although various software packages produce box and whisker plots that appear similar, they may differ significantly. In a box plot produced with the SYSTAT software package (refer to Figure 1):

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[3] http://water.usgs.gov/software/loadest/
[4] http://www.jowettconsulting.co.nz/home/time-1

- the vertical line within the box marks the median of the sample data
- the length of each box shows the range of the central 50% of data, with the box edges (called hinges) at the first and third quartiles (i.e. define the interquartile range (IQR))
- the whiskers show the range of values that fall within the inner fences (but do not necessarily extend all the way to the inner fences)
- values between the inner and outer fences are plotted with asterisks
- values outside the outer fence are plotted with empty circles. The fences are defined as follows:

  - » Lower inner fence = lower hinge – (1.5 × (IQR))
  - » Upper inner fence = upper hinge + (1.5 × (IQR))
  - » Lower outer fence = lower hinge – (3 × (IQR))
  - » Upper outer fence = upper hinge + (3 × (IQR))

2.4 Water Quality and Hydrometric Monitoring Sites

Water quality monitoring sites within the Mangatainoka River catchment are listed in Table 1, where HRC site names are related to those used in this report.

Continuous hydrometric monitoring occurs at the Mangatainoka River at Pahiatua Town Bridge and at the Makakahi River at Hamua, operated by HRC. Water levels are measured continuously and these are converted to flow after gauging and application of a site-specific water height-area-flow volume relationship. Data collection accords with recognised hydrological monitoring practice. The location of these sites is indicated in Figure 2 and Figure 3 and as a schematic in Figure 4.

Table 1. Relationship between HRC site names and codes and sample codes used in this report

Catchment	CATCH$	Site name	SITE$	CODE$
Brechin	BRE	Brechin at d/s Fonterra Pahiatua	Brechin d/s Fonterra	BRE1
	BRE	Brechin at u/s Fonterra Pahiatua	Brechin u/s Fonterra	BRE2
Makakahi	MAK	Makakahi at Hamua	Makakahi at Hamua	MAK1
	MAK	Makakahi at d/s Eketahuna STP	Makakahi d/s Eketa WWTP	MAK2
	MAK	Makakahi at u/s Eketahuna STP	Makakahi u/s Eketa WWTP	MAK3
Mangatainoka	MANGA	Mangatainoka at u/s Tiraumea Confluence	Manga u/s Tiraumea	MAN1
	MANGA	Mangatainoka at d/s DB Breweries	Manga d/s DB	MAN2
	MANGA	Mangatainoka at Brewery - S.H.2 Bridge	Manga at SH2	MAN3
	MANGA	Mangatainoka at d/s Pahiatua STP	Manga d/s Pahi WWTP	MAN4
Wastewater	WW	Pahiatua STP at Tertiary oxpond waste	Pahiatua TP discharge	WW
	MANGA	Mangatainoka at u/s Pahiatua STP	Manga u/s Pahi WWTP	MAN5
	MANGA	Mangatainoka at Pahiatua Town Bridge	Manga at Pahiatua TB	MAN6
	MANGA	Mangatainoka at Scarborough Konini Rd	Manga at Scarboro	MAN7
	MANGA	Mangatainoka at Larsons Road	Manga at Larsons	MAN8
	MANGA	Mangatainoka at Putara	Manga at Putara	MAN9

Table 2. Water quality and hydrometric monitoring stations (shaded grey) operated by HRC

Site Name	Grid reference		Life supporting capacity class	Water mgt. sub-zone	Start of water quality record	Biological sampling		Continuously measured variables				
	NZ TM X	NZTM Y				Invert.	Periphyton Monthly	Temp.	pH	EC	DO	Turb./TSS
Brechin at u/s Fonterra Pahiatua	1839594.0	5518393.0	Hill Mixed Geology	(Mana_8c)	2007							
Brechin at d/s Fonterra Pahiatua	1839594.3	5518393.1	Hill Mixed Geology	(Mana_8c)	2007							
Makakahi at Hamua	1832392.0	5505889.0	Hill Mixed Geology	(Mana_8d)	2005	Y	Y	Y				
Makakahi at d/s Eketahuna STP	1829591.0	5498487.0	Hill Mixed Geology	(Mana_8d)	2007							
Makakahi at u/s Eketahuna STP	1828591.0	5496386.0	Hill Mixed Geology	(Mana_8d)	2007							
Pahiatua STP at Tertiary oxpond	1840853.9	5519231.1	N/A	(Mana_8c)	2007							
Mangatainoka at Brewery - S.H.2 Bridge	1842795.0	5521394.0	Hill Mixed Geology	(Mana_8c)	1993	Y	Y					
Mangatainoka at Larsons Road	1820788.0	5497887.0	Upland Hard Sedimentary	(Mana_8a)	2005	Y		Y				
Mangatainoka at Pahiatua Town Bridge	1840094.0	5518493.0	Hill Mixed Geology	(Mana_8c)	2009			Y	Y	Y	Y	Y
Mangatainoka at Putara	1815287.0	5493586.0	Upland Hard Sedimentary	(Mana_8a)	2008	Y	Y					
Mangatainoka at Scarborough Konini Rd	1836993.6	5515692.2	Hill Mixed Geology	(Mana_8b)	2011							
Mangatainoka at d/s DB Breweries	1843495.6	5521794.4	Hill Mixed Geology	(Mana_8c)	2007	Y	Y					
Mangatainoka at d/s Pahiatua STP	1841094.9	5519693.0	Hill Mixed Geology	(Mana_8c)	2007	Y	Y					
Mangatainoka at u/s Pahiatua STP	1840895.0	5519593.0	Hill Mixed Geology	(Mana_8c)	2007	Y	Y					
Mangatainoka at u/s Tiraumea confluence	1844631.0	5523563.1	Hill Mixed Geology	(Mana_8c)	2010		Y					

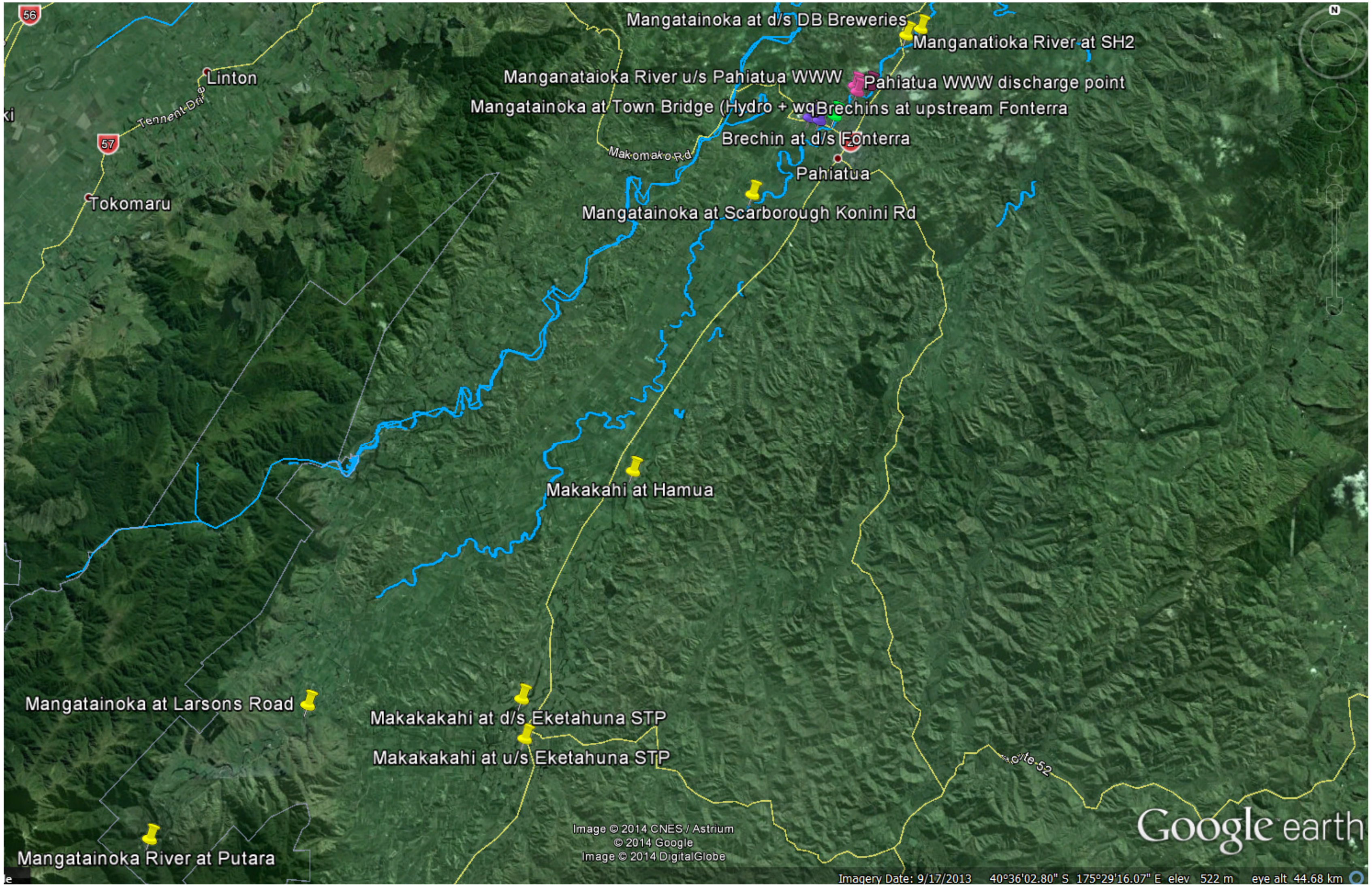


Figure 2. Location of water quality sampling points and hydrometric monitoring stations

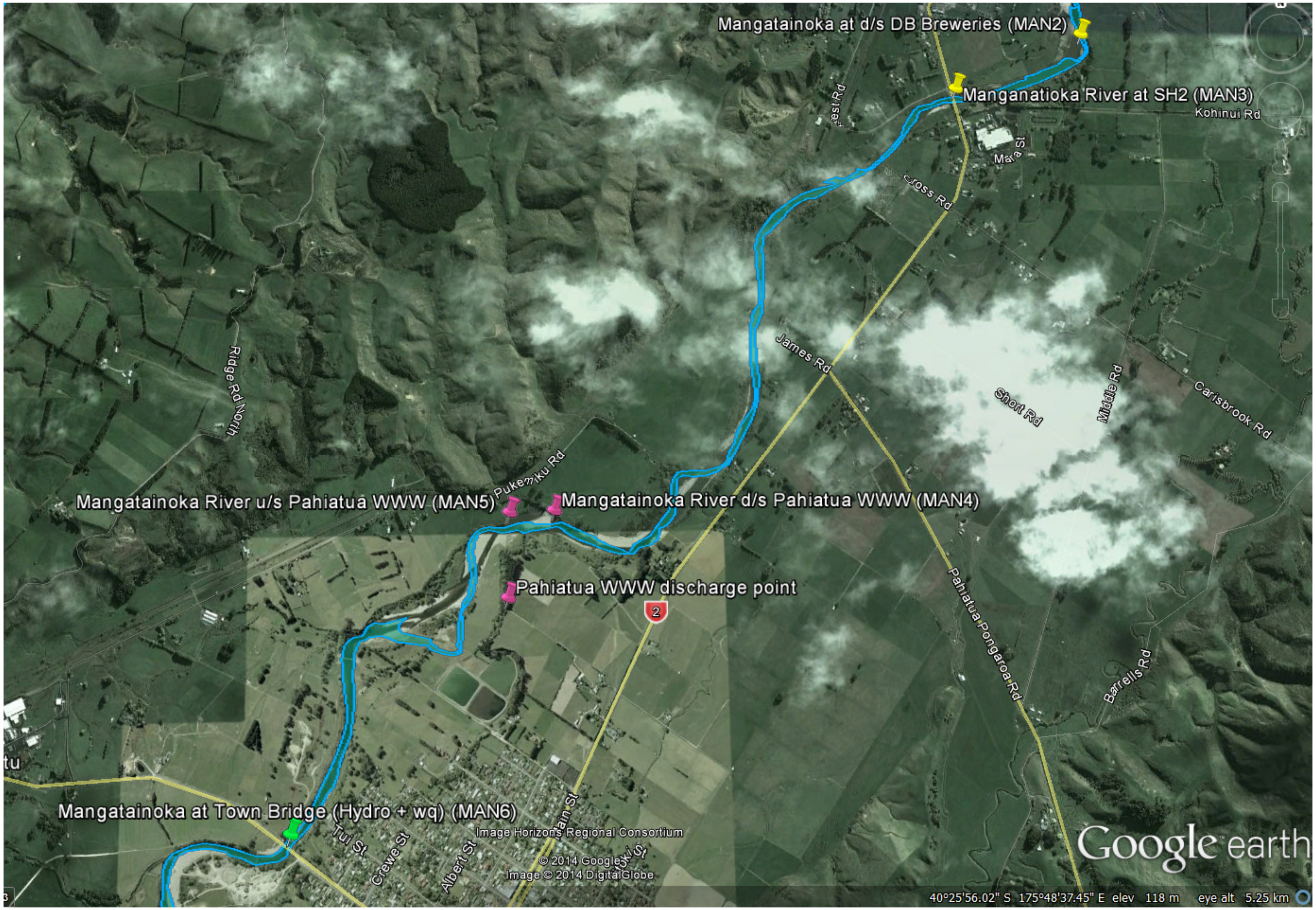


Figure 3. Location of water quality sampling points closely related to the wastewater discharge and Town Bridge hydrometric monitoring station

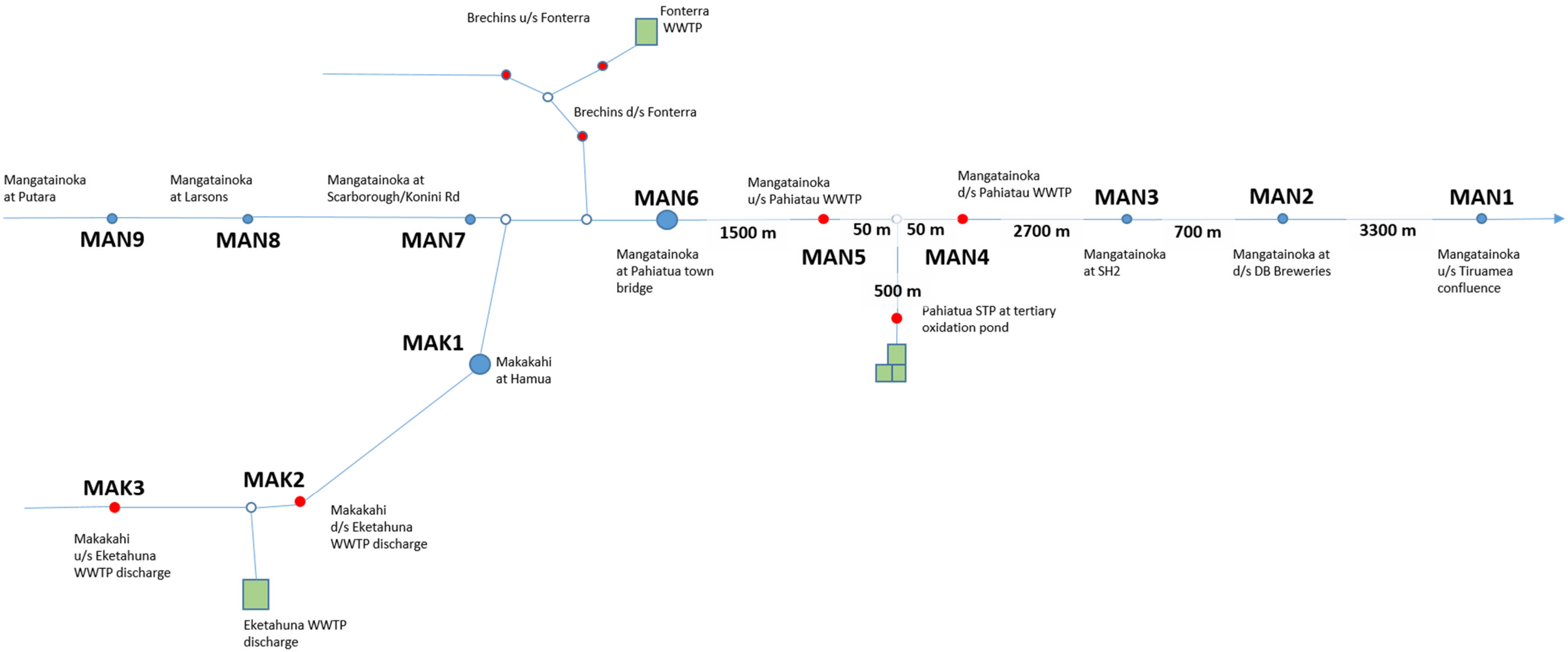


Figure 4. Relative location of water quality sampling points and hydrometric monitoring stations. Small blue dots – water quality sampling points, large blue dots – water quality and hydrometric monitoring points, red dots – water quality sampling points associated with wastewater discharges. Distances between sample points are approximate

2.5 Water Quality Data

Water quality data were retrieved for the points identified in Figure 2 and Figure 4 and as described in Table 2. Sample points were recoded for convenient presentation – the relationship between HRC sample site codes and the codes used in this report are summarised in Table 1.

Data were obtained for the variables listed in Table 3.

Table 3. Data for water quality variables routinely measured by HRC

Water quality variable	Abbreviation	Laboratory detection limit (post-Sept 2012)	Units
Ammoniacal-N		0.01	g/m^3
Black Disc (Visual water clarity)			m
Dissolved reactive phosphate	DRP	0.005	g/m^3
E. coli by MPN		1	/100 mL
Enterococci		1	CFU/100 mL
Field Barometric pressure	BP		mbar
Field Conductivity	EC		µS/cm
Field DO concentration	DO		g/m^3
Field DO saturation	DOsat		% Sat
Field pH	pH		pH units
Field temperature			°C
Nitrate-N		0.002	g/m^3
Nitrite-N		0.002	g/m^3
Soluble five-day biochemical oxygen demand	sCBOD$_5$	1	g/m^3
Soluble Inorganic Nitrogen	SIN	0.002 (Sum of concentrations of nitrate-N, nitrite-N and ammoniacal-N)	g/m^3
Carbonaceous suspended solids	SSC	1	g/m^3
Total dissolved phosphate	TDP	0.005	g/m^3
Total-N	TN	0.05	g/m^3
Total organic N	TON	0.005	g/m^3
Total coliforms		Not measured post-Sept 2012	/100 mL
Total phosphorus	TP	0.005	g/m^3
Total suspended solids	TSS	3	g/m^3
Turbidity EPA		0.01	NTU
Volatile matter	VM	3	g/m^3

Note:
The concentration units g/m^3 are identical to mg/L.

2.5.1 Hydrology Statistics

A selection of flow statistics are included in the Appendix in Section 6.1. These provide a selection of statistics for each calendar year of the assessment period. A number of the water quality targets defined by HRC apply under specific flow conditions, notably the median flow and 20th percentile exceedance flow (i.e. the flow exceeded by the upper 20% of flow conditions). These flows are summarised in Table 4.

Values estimated for the entire assessment period have been rounded to nearest 100 L/s.

Table 4: Key flow metrics associated with water quality targets, aggregated according to calendar year and entire assessment period

Period over which metric was estimated	**Key flow metrics associated with water quality targets (L/s)**	
	50th percentile exceedance flow (median flow)	**20th percentile exceedance flow**
2008	6820	24630
2009	11300	29950
2010	10200	26950
2011	10900	23750
2012	8355	19330
2013	7940	20400
Entire assessment period	9300	24200

2.5.2 Water Quality Data Summary Statistics

Summary statistics were calculated for all variables at all sites for the period 2008-2013 inclusive. These statics are tabulated in the Appendix in Section 6.2.

2.6 Characterisation of the Pahiatua Wastewater Discharge

No flow data exists for the discharge. In Section 2.5 the correction of river flows with assumed wastewater discharge values was described. Estimates of dry, wet weather and peak wet weather discharge were 7.2 L/s, 16 and 40 L/s respectively.

Data are currently collected for 15 water quality variables (previously data were collected for Total coliforms as well, but this was discontinued in 2012). Statistics for water quality data are included as Section 6.3, in the Appendices; these data are presented graphically as a series of box and whisker plots in Figure 5.

Key points to note from the individual graphs in Figure 5 include:

- The concentrations of 11 variables have decreased over time, most notably during 2010;
- For two of these 11 variables (turbidity and $cBOD_5$), values appear to have increased slightly during 2013;
- The concentrations of two variables have increased (total organic nitrogen and nitrate-N), most notably during or around 2010;
- The concentrations of the latter two variables appear to have plateaued during 2012.
- The data indicate:
  - a reasonably consistent effluent was discharged in 2008 and 2009 (e.g. *E. coli*, TSS and DRP)
  - a reasonably consistent wastewater was being discharged in 2012 and 2013, but of a significantly higher quality (e.g. approximately four-log reduction in median *E. coli* numbers, almost 70 times reduction in TSS concentrations and ten-fold reduction in turbidity, relative to 20108 and 2009)
  - Less variable effluent quality for almost all variables in 2012 and 2013, indicated by the shorter boxes and whiskers for most variables.

Although it is possible to reduce the concentrations of all variables in a discharge through dilution, this is not the reason for the change in wastewater quality observed. The concentrations of two variables (TON and nitrate-N) have increased – this has occurred because of changes to the treatment process. A greater proportion of ammoniacal-N is being nitrified (indicated by decrease in ammoniacal-N and increase in nitrate-N concentration), and a greater proportion of nitrogen is being incorporated in biomass (increase in TON). Solids removal is effectively removing these particulate forms of N from the discharge (indicated by approximately four-fold reduction in median TN concentration, 2009 vs. 2013).

While solids removal is directly reducing the amount of suspended material in the discharge, it is also reducing the concentration of phosphorus in the discharge. DRP is either being incorporated in biomass and removed through filtration, or is being removed directly through chemical dosing, flocculation and filtration. TP is also being effectively removed from the wastewater. Median concentrations of DRP and TP have decreased approximately three-fold, 2008 vs. 2013.

Trends in estimated discharge loads are summarised in Discharge loads of selected variables were estimated from measured concentrations and estimated wastewater flow rates – values of 7.2 L/s, 16 and 40 L/s were used for dry, wet weather and peak wet weather conditions respectively. Median, 80th percentile and 95th percentile concentrations were associated with these three flow conditions to calculate daily and monthly estimates, summarised in Table 5 and Table 6.

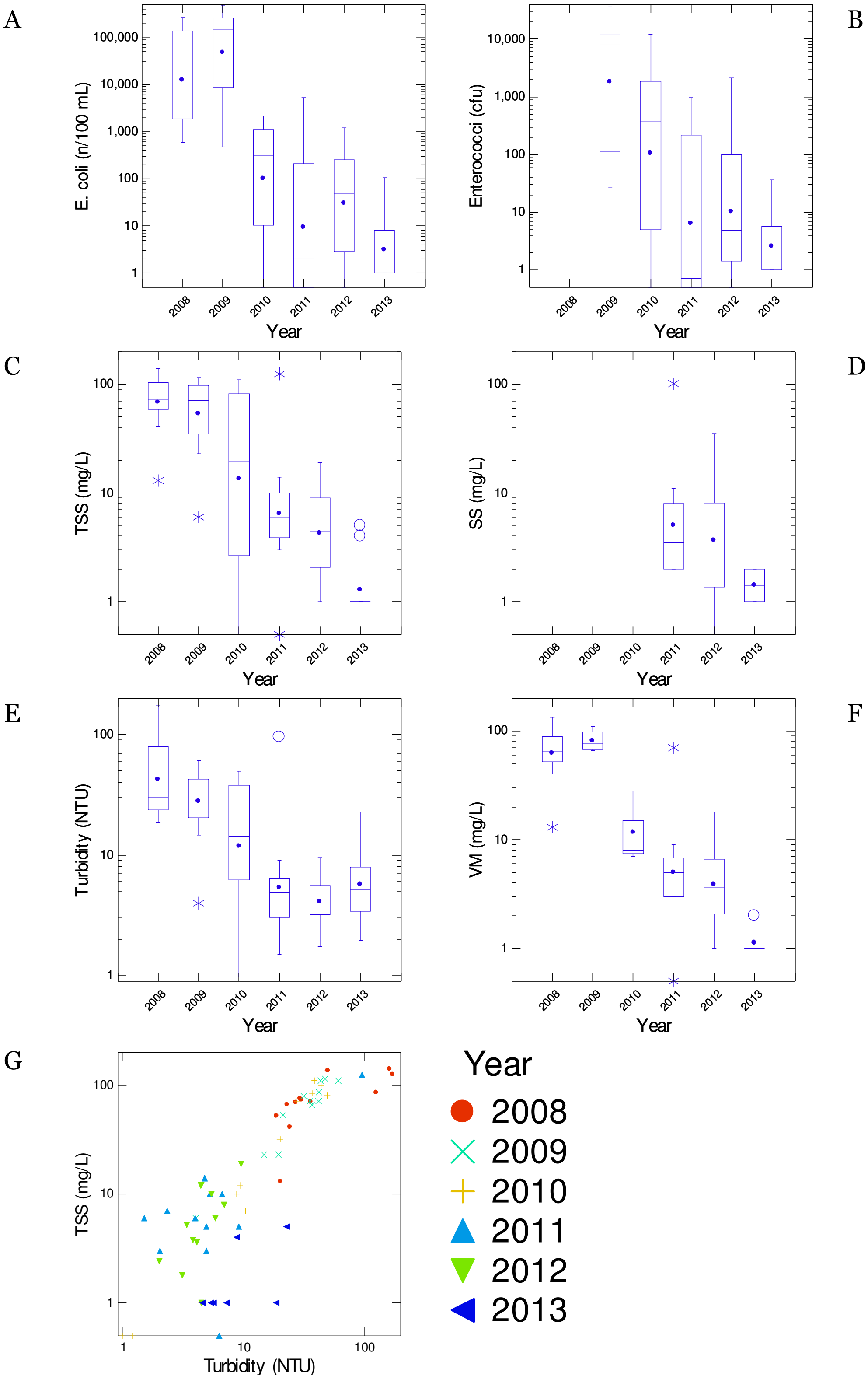


Figure 5: Full caption on next page

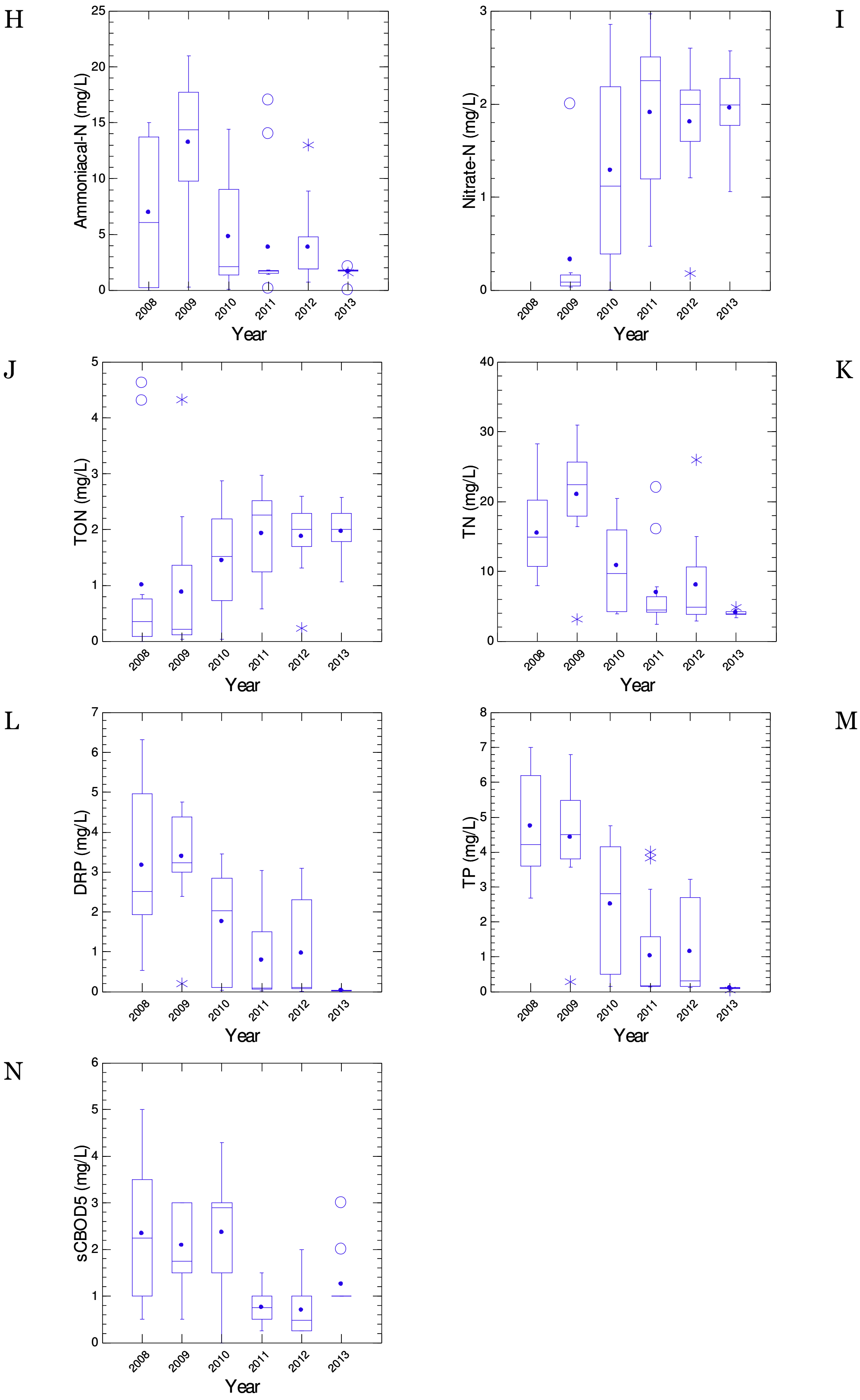


Figure 5. Trend in concentrations of water quality variables in the Pahiatua WWTP discharge over time (A-F and H-N). G indicates the relationship between TSS and turbidity. Note some axes have a $\log_{10}$ scale. For *E. coli* and enterococci, results of zero were replaced with 1 to better represent the data set

Discharge loads of selected variables were estimated from measured concentrations and estimated wastewater flow rates – values of 7.2 L/s, 16 and 40 L/s were used for dry, wet weather and peak wet weather conditions respectively. Median, 80th percentile and 95th percentile concentrations were associated with these three flow conditions to calculate daily and monthly estimates, summarised in Table 5 and Table 6.

Table 5. Estimated daily loads of selected variables discharged from Pahiatua WWTP under three flow conditions. D = dry weather conditions (7.2 L/s), W = wet weather conditions and S = storm conditions

Year	TSS (kg/d)			Nitrate-N (kg/d)			TN (kg/d)			DRP (kg/d)			TP (kg/d)		
	D	W	S	D	W	S	D	W	S	D	W	S	D	W	S
2008	44	152	482	-	-	-	9.3	24.5	95	1.5	7	21.7	2.6	24.1	24.1
2009	44	133	395	0.05	0.22	6.9	13.9	32.1	106	2	5.4	16.4	2.8	6.9	23.2
2010	13.7	103	277	0.7	2.7	9.7	6	19.7	70	1.3	3.6	11.8	1.7	5.3	16.3
2011	3.7	12.6	390	1.4	3.1	10.1	2.7	10.4	74	0.05	3.5	10.4	0.1	3.7	13.7
2012	2.8	12.3	63.2	1.2	2.7	9	3	14.4	86	0.06	3.4	10.6	0.2	3.6	11.1
2013	0.6	1.6	16.7	1.2	2.8	8.8	2.4	5.2	16.8	0.01	0.05	0.15	0.06	0.14	0.4

Table 6. Estimated monthly loads of selected variables discharged from Pahiatua WWTP under three flow conditions. Abbreviations and flow conditions as described in the caption for Table 5

Year	TSS (kg/m)			Nitrate-N (kg/m)			TN (kg/m)			DRP (kg/m)			TP (kg/m)		
	D	W	S	D	W	S	D	W	S	D	W	S	D	W	S
2008	1335	4572	14460	0	0	0	279	735	2850	45	210	651	78	723	723
2009	1323	3990	11850	1.5	6.6	207	417	963	3174	60	162	492	84	207	696
2010	411	3090	8310	21	81	291	180	591	2100	39	108	354	51	159	489
2011	111	378	11700	42	93	303	81	312	2220	1.5	105	312	3	111	411
2012	84	369	1896	36	81	270	90	432	2580	1.8	102	318	6	108	333
2013	18	48	501	36	84	264	72	156	504	0.3	1.5	4.5	1.8	4.2	12

Although the selection of flow values and concentration conditions are subjective and open to criticism, the estimates summarised in Table 5 and Table 6 indicate the likely trends in the magnitudes of discharge loads. These are quite reasonable:

- The flow discharged from the wastewater treatment plant is unlikely to have altered appreciably over the assessment period
- Refinements to the wastewater treatment process have reduced the concentration of materials discharged from the treatment works, as indicated graphically in Figure 5.

As a consequence of changes made to the wastewater treatment process, the WWTP discharge is having a smaller impact on the receiving environment:

- Lower numbers of faecal indicator organisms downstream after mixing;
- Smaller loads of particulate material are currently being discharged, causing less deposition on the river bed;
- Much smaller loads of DRP, a bioavailable plant nutrient, as well as TP, which may be made bioavailable in the river channel as a consequence of biogeochemical processes, are being discharged currently, and
- Reduced loads of total nitrogen are being discharged, and

- Reduced discharge of ammoniacal-N occurs currently (which under naturally occurring temperature and pH conditions may contain free ammonia in amounts able to exert toxicity).

Although the concentration and load of nitrate-N in the discharge has increased, the increase is insignificant in the context of concentrations of nitrate-N in the upstream receiving water. This is discussed further in Section 3.2.10.

3 Assessment of Effects

3.1 Policy Context Provided by the OnePlan

The OnePlan identifies a range of surface water values for management zones and sub-zones in the Region (Table D.2A). Values applicable to the Mangatainoka River (Water Management Zone Mangatainoka (Mana_9) in the reach that includes the Pahiatua WWTP discharge [Sub Zone Lower Mangatainoka (Mana_8c)] are summarised in Table 7.

Table 7. Water quality management objectives established for surface water in the Horizons Region (shaded cells and the Lower Mangatainoka River catchment and associated values.

Value Group	Individual Values	Management Objective
Ecosystem Values	LSC: Life-supporting Capacity – Hill Country Mixed (Zone Wide Value)	The water body and its bed support healthy aquatic life / ecosystems
	SOS-R: Sites of Significance – Riparian (Site Specific Value)	Sites of significance for indigenous riparian biodiversity are maintained or enhanced
Recreational and Cultural Values	CR: Contact Recreation (Zone Wide Value)	The water body and its bed are suitable for contact recreation
	AM: Amenity (Site Specific Value)	The amenity values of the water body and its bed (and its margins where in public ownership) are maintained or enhanced
	Mau: Mauri (Zone Wide Value)	The mauri of the water body and its bed is maintained or enhanced
	TF: Trout Fishery – Regionally Significant (Site Specific Value)	The water body and its bed sustain healthy rainbow or brown trout fisheries
	TS: Trout Spawning (Site Specific Value)	The water body and its bed meet the requirements of rainbow and brown trout spawning and larval and fry development
	AE: Aesthetics (Zone Wide Value)	The aesthetic values of the water body and its bed are maintained or enhanced
Water Use	IA: Industrial Abstraction (Zone Wide Value)	The water is suitable as a water source for industrial abstraction or use, including for hydroelectricity generation
	I: Irrigation (Zone Wide Value)	The water is suitable as a water source for irrigation
	SW: Stock water (Zone Wide Value)	The water is suitable as a supply of drinking water for livestock
	WS: Water Supply (Site Specific Value)	The water is suitable, after treatment, as a drinking water source for human consumption
Social/Economic Values	CAP: Capacity to Assimilate Pollution (Zone Wide Value)	The capacity of a water body and its bed to assimilate pollution is not exceeded
	FC/D: Flood Control and Drainage. (Site Specific Value)	The integrity of existing flood and river bank erosion protection structures and existing drainage structures is not compromised and the risks associated with flooding and erosion are managed sustainably
	EI: Existing *Infrastructure* (Zone Wide Value)	The integrity of existing infrastructure is not compromised

The OnePlan also identifies how these values may be achieved in terms of numeric targets for a range of key physico-chemical water quality and ecological variables, which are listed in Table 8:

Table 8. Water quality targets defined for the Mangatainoka River in the reach between the SH 2 and Pahiatua Town Bridge sites (OnePlan Table D5.A). Shaded rows indicate region-wide water quality targets (OnePlan Table D.1A).

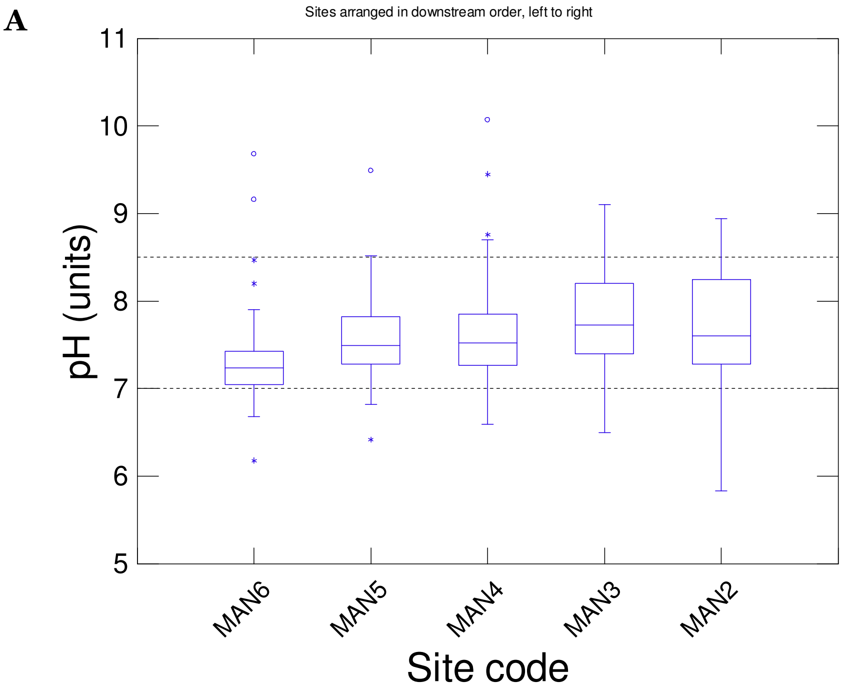
Water quality variable	**Statistic**	**Value or Range**	**Units**	**Allowable change**	**Flow characteristic**	**Comment**
pH	Instantaneous	7.0 – 8.5	Units	0.5 units	None	
Water temperature	Instantaneous	<19	°C	3 °C	None	
Dissolved oxygen	Instantaneous	>80	% sat.		None	
Soluble cBOD5	Monthly average, flow condition	1.5	mg/L		Flow <20%ile exceedance	
Particulate Organic Matter	Average, flow condition	<5	mg/L		Flow <50%ile exceedance	
Periphyton as Chlorophyll *a*	Instantaneous	<120	mg/m²		none	
Visible periphyton cover	Instantaneous	<30	%		None	
Visible periphyton cover as diatoms or cyanobacteria	Instantaneous	<60	%		None	
Dissolved reactive phosphate	Annual average, flow condition	<0.010	mg/L		Flow <20%ile exceedance	
Soluble inorganic nitrogen	Annual average, flow condition	<0.444	mg/L		Flow <20%ile exceedance	
Proportion deposited sediment cover	Maximum	<20	%		None	SoE reporting only
Macroinvertebrate Community Index (MCI)	Minimum	Not defined	Units		None	SoE reporting only
QMCI		<20% change (reduction)	Units		None	
Ammoniacal-N	Annual average	0.400	mg/L		None	
Ammoniacal-N	Maximum	2.1	mg/L		None	
Toxic contaminants	Maximum	<99%	mg/L		None	Value <ANZECC 99% species protection level
Visual clarity	Minimum according to flow condition	>3	m	<20%	River flow < 50%ile exceedance	
E. coli concentration	Instantaneous maximum, flow condition	260	/100 mL		Flow < 50%ile exceedance	
E. coli concentration	Instantaneous maximum, flow condition	550	/100 mL		Flow < 20%ile exceedance	

If the numeric targets identified in Table 8 are achieved, it is likely that the values or uses of water described in in Table 7 will be achieved. If the numeric targets identified are not achieved, management actions will be required at property and point source discharge level. The values in the lower Mangatainoka River sub-management zone (8c) are likely to be determined by a range of activities, including pastoral farming, intensive grazing and cropping, urban stormwater discharge and the point source discharge from the Pahiatua WWTP. This assessment focuses specifically on the impact of the wastewater discharge on surface water quality in terms of compliance with the target values identified in Table 8.

3.2 Comparison of Observed Water Quality with Water Quality Targets Identified in the OnePlan

3.2.1 pH Limits and Changes in pH

Spatial trend in pH is summarised along the lower Mangatainoka River in the reach between Pahiatua Town Bridge and SH2 in Figure 6 (A), and the change in pH upstream and downstream of the wastewater discharge over the period of record is summarised in Figure 6 (B).



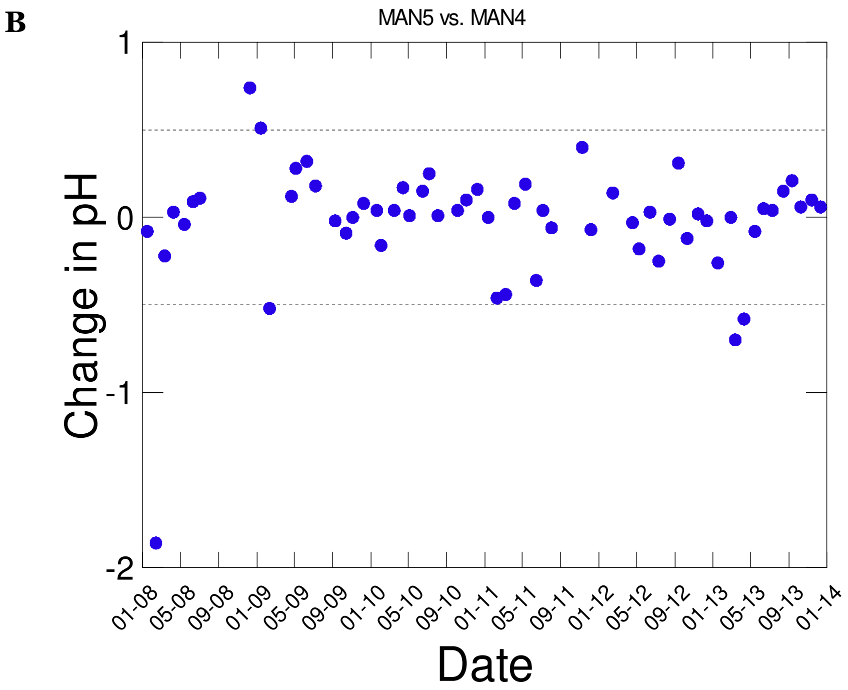


Figure 6. Spatial trend in pH along the lower Mangatainoka River (A), and difference in pH upstream and downstream of Pahiatua WWTP discharge (MAN5 vs MAN4). In A) the stippled lines indicate the pH target identified in the OnePlan, and in B) the stippled lines indicate changes of ±0.5 pH unit

Figure 6 (B) indicates that pH increased downstream of the discharge on four occasions, whereas pH decreased downstream of the discharge on two occasions (overall 10% of sample pairs).

Table 9. Comparison of pH upstream and downstream of the wastewater discharge by year. "%n/c" is the proportion of non-compliant sample results

Year	pH upstream of wastewater discharge (MAN5)						pH downstream of wastewater discharge (MAN4)				
	No. samples	Results <7	% n/c	Results >8.5	% n/c		No. samples	Results <7	% n/c	Results >8.5	% n/c
2008	8	3	38				8	3	38	1	13
2009	10	1	10				11	4	36		
2010	12			1	8		12			1	8
2011	10						10				
2012	12			1	8		12			1	8
2013	12						12			1	8

pH measurements falling outside of the range from pH 7 – 8.5 are summarised graphically in Figure 7 (A) and in Table 9. Two upstream and four downstream samples had pH greater than 8.5, and seven downstream and four upstream samples had pH less than 7. These data are shown in Figure 7 (B) in terms of time of sampling (fewer data are shown – sample times were not recorded for all samples). Overall 9% of upstream and 17% of downstream samples did not comply with the target values.

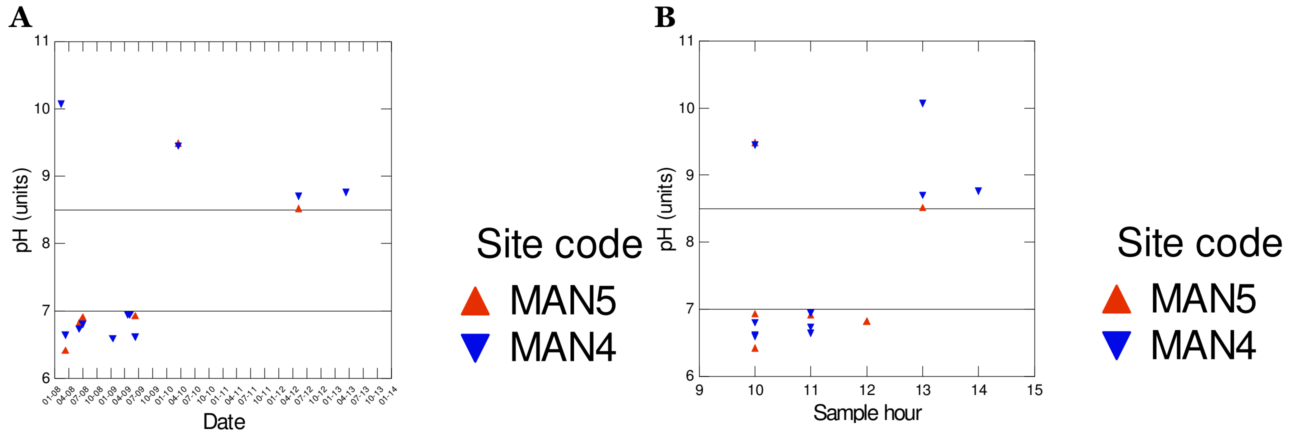


Figure 7. Relationship between pH and date (left) and time of sampling (right), upstream and downstream of Pahiatua WWTP discharge (MAN5 vs MAN4).

There were a greater proportion of non-compliant samples with low pH values than non-compliant samples with high pH, and coincidence of non-compliance both up and downstream of the discharge indicate generally high productivity in the lower Mangatainoka River, unrelated to changes in pH caused by the wastewater discharge. No wastewater pH data were available to directly estimate the impact that the effluent may have had on river pH values.

pH values vary naturally over daily and seasonal cycles in response to photosynthesis. As plants photosynthesise, they consume carbon dioxide (CO_2) raising water pH, whereas production of CO_2 during respiration increases the concentration of carbonic acid, reducing the pH. Daily pH minima occur in the morning, prior to the onset of photosynthesis, and daily maxima in the evening, prior to the cessation of photosynthesis. This pattern is pronounced in rivers that are subject to periphyton growth. As Figure 7 indicates, high pH values were generally measured in the afternoon, whereas all low pH values were measured in the morning. For the obvious exception (high pH measured at 10:00), the measurements were made in March 2010. It is likely that these coincided with a period of warmer weather, low flows and good water clarity – conducive to photosynthesis, i.e. by 10:00 am sufficient photosynthesis had occurred to deplete CO_2 in the water column.

Summary for pH

10% of sample pairs indicated change in pH greater than 0.5 units during the assessment period.

Less than 10% of upstream samples did not fall within the pH range 7 – 9.5, whereas 17% of downstream samples did not fall into this range.

In general, non-conforming pH happens both upstream and downstream of the discharge, indicating that the pH response occurs generally in the lower catchment, rather than in response to the wastewater discharge specifically.

3.2.2 Water Temperature

Water temperature data for sites in the lower Mangatainoka River are summarised in Figure 8. Water temperatures at all sites are strongly seasonal and exceed the target water temperature at most sites in most years. Water quality is monitored more intensively at MAN3, downstream of the wastewater discharge. The increased data better defines the seasonal minimum and maximum values at this site, particularly during 2012 and 2013.

The water quality target also indicates that there should be less than 3°C increase in water temperature as a consequence of a discharge. As Figure 9 indicates, the difference in temperature between MAN5 and MAN4 is always less than 3°C, and is generally less than 1°C. There is no statistically significant or practical difference between the temperatures at sample sites MAN5 or MAN4. The temperature differences are generally scattered evenly on either side of the zero line, confirming that there is no statistically significant difference between the two sites.

Greater temperature differences exist between MAN3 and MAN5. These sites are approximately 3.4 km apart. One temperature difference exceeded 3 °C (indicating a decrease of water temperature downstream of the wastewater discharge), while one increase of 3°C and one decrease of 3°C also occurred. Similar temperature differences exist between MAN5 and MAN6, which are 1.5 km apart. This indicates that the change in temperature is related to distance and the heat budget of the river, rather than input of wastewater or other surface water.

No temperature data exists for the wastewater discharge itself, which makes calculation of the thermal load of the discharge and prediction of temperature change using a mixing and dilution model impossible.

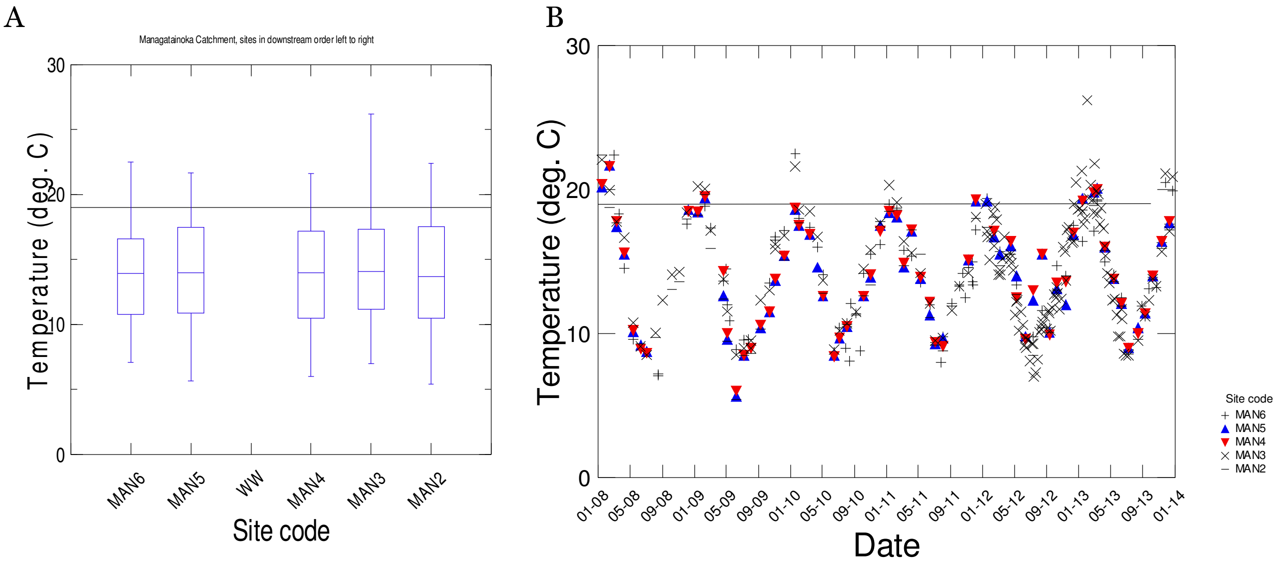


Figure 8. Spatial trend in water temperature (left) and trend in water temperature over time (right). The stippled line indicates the water temperature target

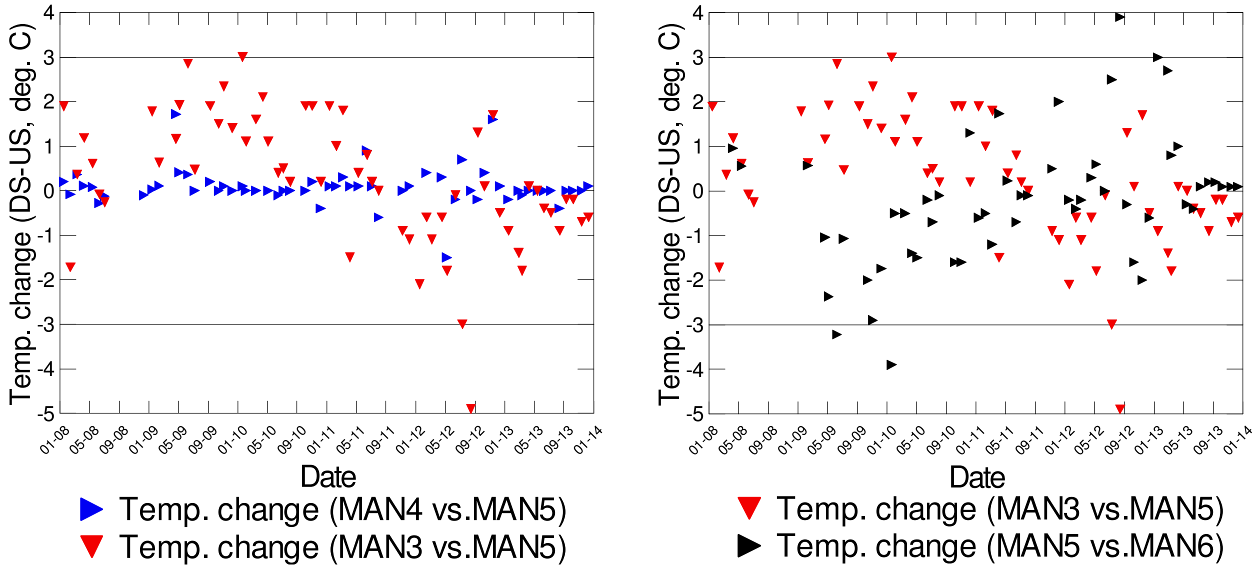


Figure 9. Difference in water temperature between MAN5 and MAN4 over time

Summary for Water Temperature

Assessment of the impact of the discharge on the river requires selection of data from appropriate sites – MAN5 (the upstream site) and MAN4 (site closest to the discharge point) should be used for this purpose.

Graphical assessment and formal statistical testing indicates that the discharge does not alter the temperature of the Mangatainoka River measurably.

3.2.3 Visual Clarity

Two targets have been established for visual clarity:

- Clarity should exceed 3 m when river flows are less than median flow
- Clarity should change by less than 20% as a consequence of discharge to water.

Visual clarity across the lower Mangatainoka River under all flow conditions are summarised in Figure 10. There is a general decrease in visual clarity in a downstream direction, particularly along the main-stem of the Mangatainoka River. The 75%ile values of visual clarity at all sites in the lower Mangatainoka River are less than 3 m.

Visual clarity under flow conditions less than the median are summarised in Figure 11. Median clarity at site MAN3 is the same as the water quality target, and the upper quartile values at sites MAN6 and MAN5 increase to 3 m.

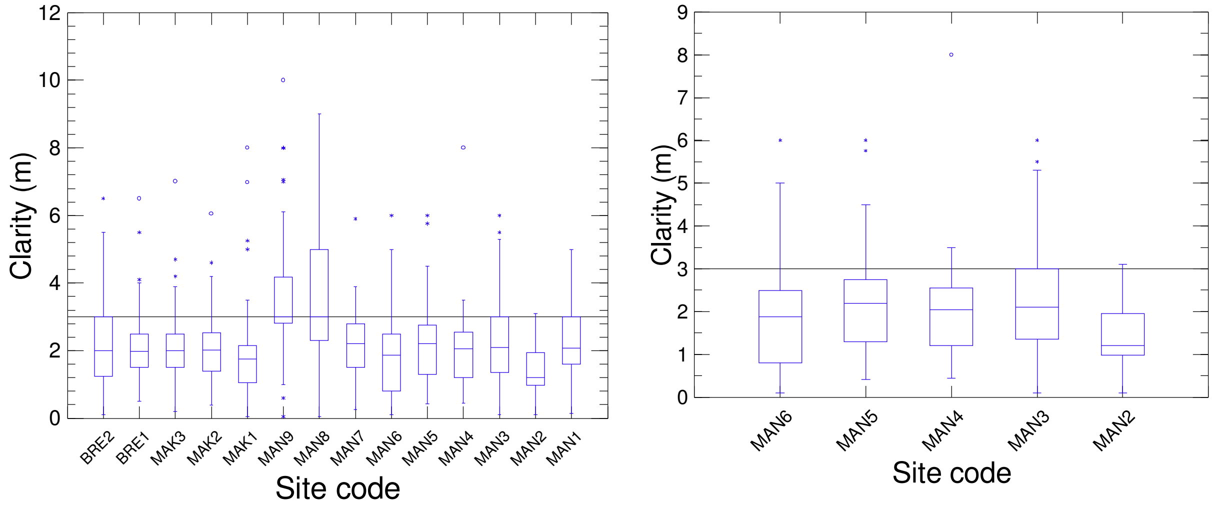


Figure 10. Comparison of visual clarity results in the Mangatainoka River under all flow conditions, 2008-2013

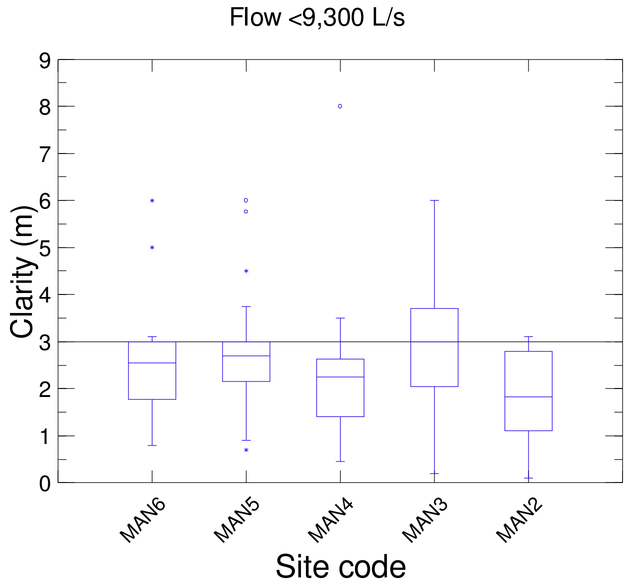


Figure 11. Comparison of visual clarity results in the Mangatainoka River when flows are less than median (9,300 L/s), 2008-2013

The impact of the wastewater discharge on visual clarity is summarised in Figure 12. This figure shows the change in visual clarity associated with the wastewater discharge in terms of the difference between measurements at MAN5 vs. MAN4 and MAN5 vs. MAN3 respectively. The number of measurements of visual clarity at MAN5 (45) is greater than at MAN4 (23), but smaller than at MAN3 (66). This limits the numbers of pair-wise comparisons that are possible.

Figure 12 indicates:

- Under all flow conditions, visual clarity:
  - decreases by more than 20% on six occasions (MAN5 vs. MAN4) and on 19 occasions (MAN5 vs. MAN3),
  - decreases by less than 20% on 12 occasions (MAN5 vs. MAN4) and a similar number for MAN5 vs. MAN3,
  - increases on nine occasions (MAN5 vs. MAN4) and on 14 occasions (MAN5 vs. MAN3) respectively.
- For flows < 9300 L/s, visual clarity:
  - decreases by more than 20% on four occasions (MAN5 vs. MAN4) and on 11 occasions (MAN5 vs. MAN3),
  - decreases by less than 20% on six occasions (MAN5 vs MAN4) and a similar number of occasions for MAN5 vs. MAN3,
  - increases on six occasions (MAN5 vs. MAN4 and MAN5 vs. MAN3).

In section 2.6 it was demonstrated that median suspended solids concentrations in the wastewater discharge have decreased 70 mg/L to approximately 1 mg/L. Suspended solids have a direct adverse impact on visual clarity (e.g. (Ministry for the Environment, 1994)) – the decrease in suspended solids concentrations in the discharge is likely to improve the quality of water downstream of the discharge. Formal statistical testing indicates that there is no practically important difference in visual clarity upstream and downstream of the Pahiatua WWTP however. The relatively small volume of wastewater relative to the river flow is likely to make any improvement in clarity difficult to measure.

Formal trend testing indicates that there is no statistically significant trend in visual clarity.

Both Figure 10 and Figure 11 indicate that visual clarity increases at MAN3 relative to upstream sites, while visual clarity decreases at MAN2. Although no specific explanation can be offered for this spatial trend, a few options exist to explain this trend:

- Input of storm water and water discharged from Pahiatua township via the stormwater system
- Increase in slime observed at MAN4 (which might be related to the input of DRP in the treated wastewater discharge):
  - once established, these periphyton growths slough material into the river on an ongoing basis
  - the decrease in visual clarity will be proportional to the amount of particulate material input to the river.
  - for these two factors to explain the data, the particulate material would need to have more impact at the MAN4 site (immediately downstream from the discharge), and some of this

material would need to be lost from the water column in the 2.7 km reach to site MAN3. Available data do not indicate a significant increase in sludge relative to the site upstream of the discharge.

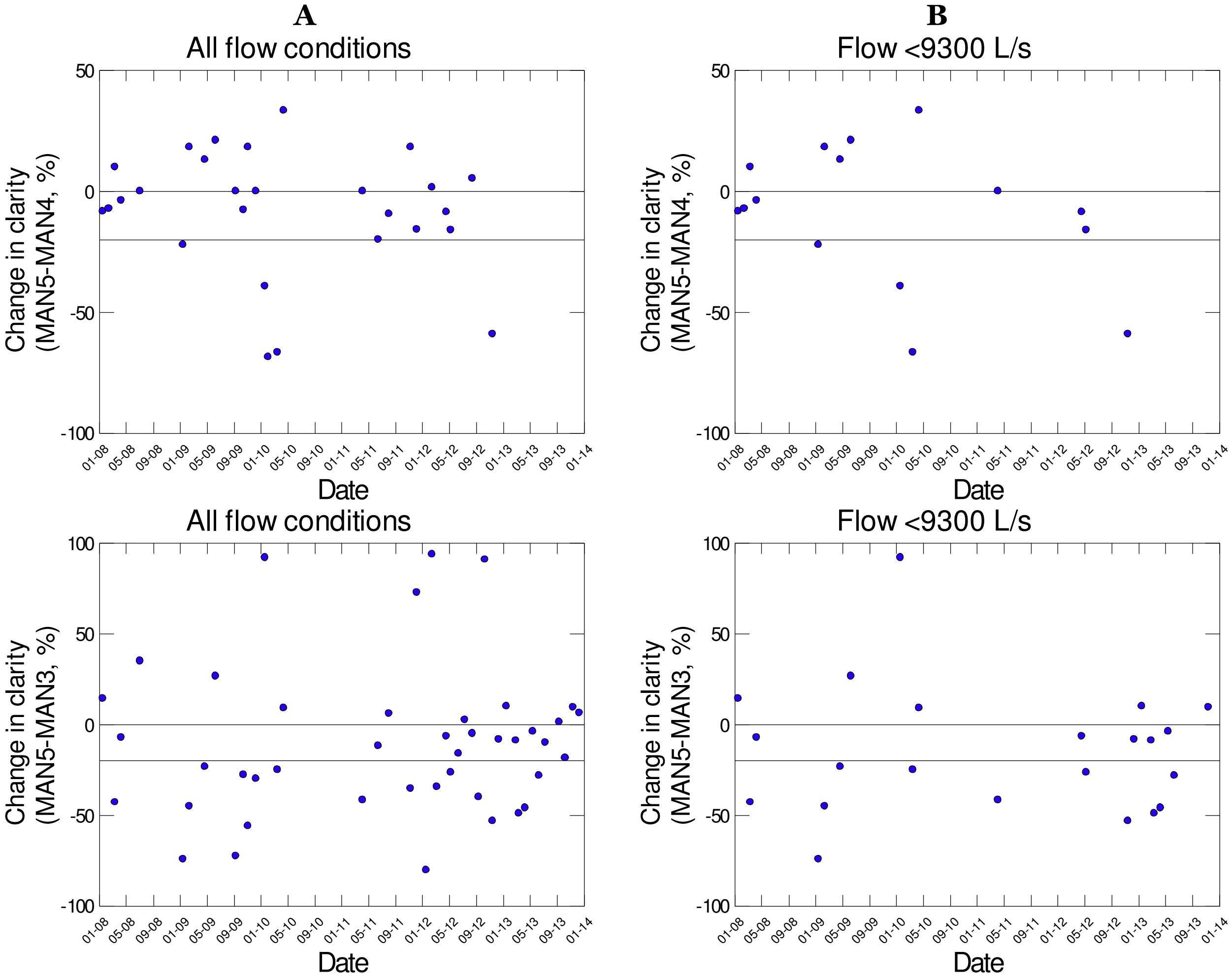


Figure 12. Impact of Pahiatua WWTP discharge on visual clarity in the Mangatainoka River (A) all flow conditions and (B) when flows are less than median (9,300 L/s), 2008-2013. The lower horizontal line indicates a decrease of 20%.

Summary for Visual Clarity

Under all flow conditions, visual clarity in the lower Mangatainoka River catchment is generally likely to be lower than 3 m.

25% of visual clarity measurements made at site MAN3 are likely to exceed this target (the highest for all sites between the Town Bridge site and the confluence with the Tiraumea River).

For flows less than the median, more than 75% of all measurements of visual clarity are likely to be lower than 3 m with the exception of the MAN3 site (downstream of the wastewater discharge), where 50% of measurements are likely to be lower than 3 m.

It is possible that the increased clarity apparent for this site is a consequence of the greater number of clarity measurements, rather than water quality improvement. Pairwise comparison (of measurements made on the same day) indicates that visual clarity is more likely to decrease downstream of the wastewater discharge than increase.

3.2.4 *E. coli* Concentrations

Two targets have been established for the lower Mangatainoka River catchment in terms of *E. coli* concentrations:

- The instantaneous maximum *E. coli* concentrations should not exceed 260 cfu/100 mL for flow conditions equal to or less than median, and
- The instantaneous maximum *E. coli* concentrations should not exceed 550 cfu/100 mL for flow conditions equal to or less than the 20%ile exceedance value.

Figure 13 indicates that the wastewater discharge has the highest median concentration and the largest range in concentrations. This is not surprising because it reflects undiluted sewage after treatment, but prior to dilution and further die-off along the lower river. Median *E. coli* concentrations are greatest in the Makakahi River catchment; highest median concentrations in the Mangatainoka River occur at site MAN2 (SH2 site).

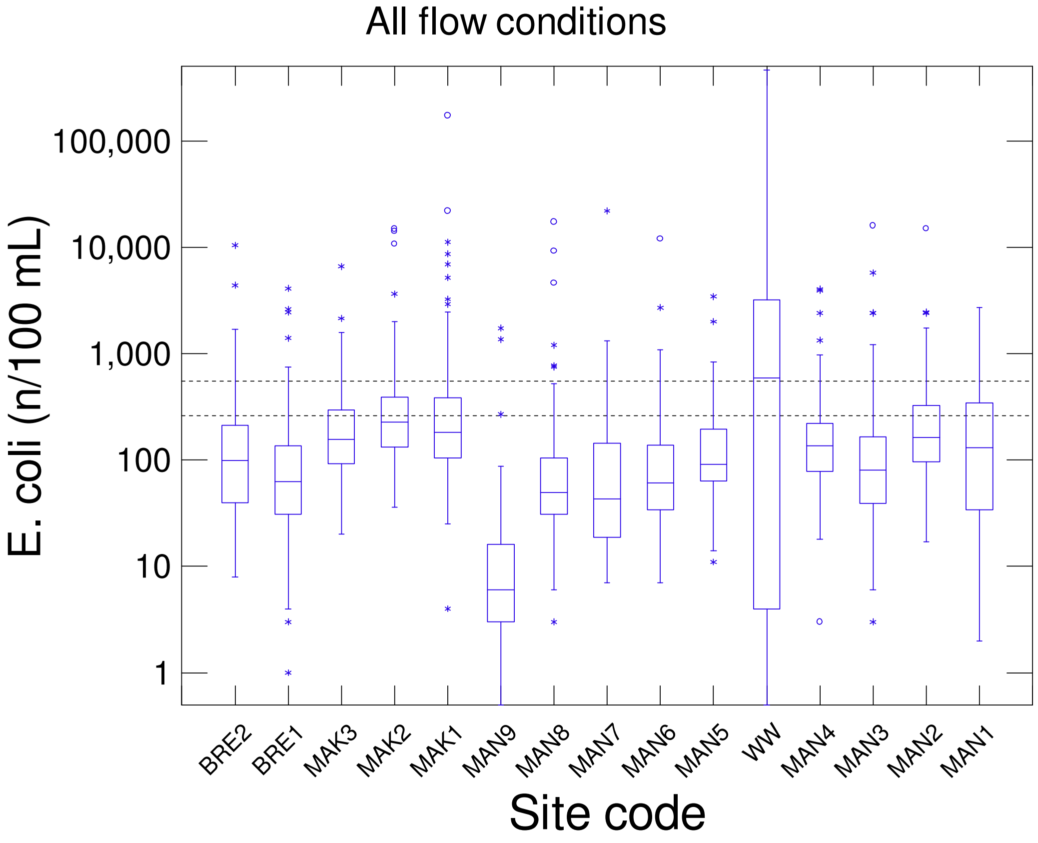


Figure 13. *E. coli* concentrations in the Mangatainoka River catchment (2008-2013) under all flow conditions. Note y axis has $\log_{10}$ scale. The upper and lower horizontal lines are the 550 cfu/100 mL and the 260 cfu/100 mL targets respectively

The relationship between *E. coli* concentrations and sample points is reasonably consistent at median and 20%ile exceedance flows (Figure 14).

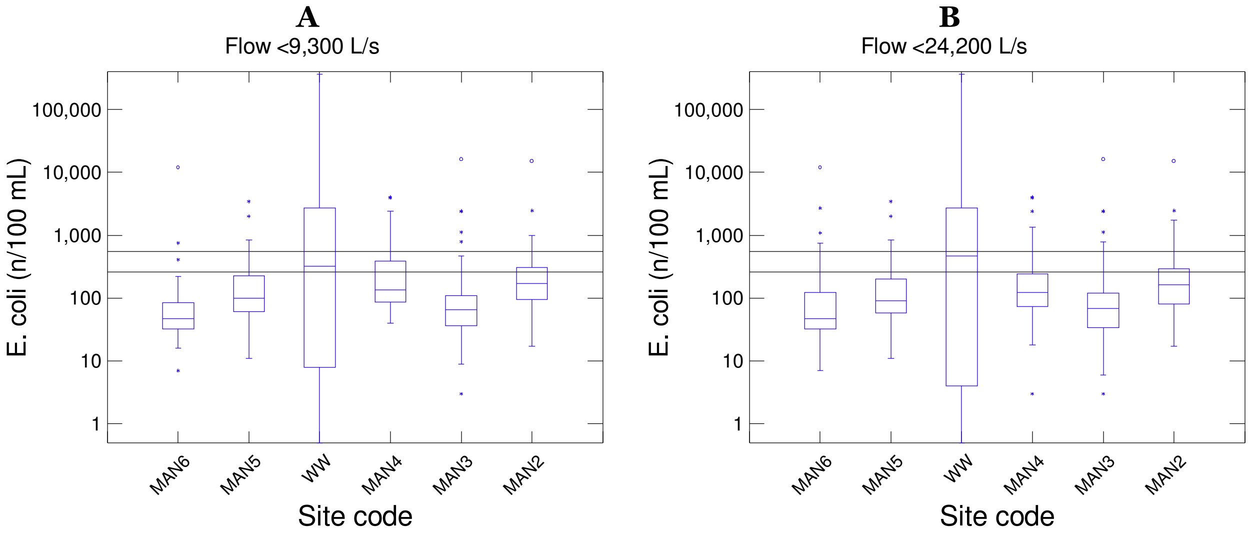


Figure 14. *E. coli* concentrations in the lower Mangatainoka River catchment (2008-2013) aggregated according to defined flow conditions. Note y axis has $\log_{10}$ scale

In Figure 16, median and discrete sample *E. coli* concentration results are compared with the HRC water quality targets for sites in the lower Mangatainoka River on an annual basis:

- Graphs in the left-hand column compare measured concentrations with the water quality target for flows less than the annual median, while
- Graphs in the right-hand column compare measured concentrations with the target for flows less than the 20th percentile exceedance value.

For both flow conditions, the median concentration in the Pahiatua WWTP exceeded the 550 cfu/100 mL target during 2008 and 2009, and the 260 cfu/100 mL target during these years as well as during 2010.

After 2010, however, the median wastewater discharge concentration was generally less than the target for the river and the number of exceedances by discrete samples decreased proportionately.

These results reflect what was described in Section 2.6, where an approximately log-4 reduction in *E. coli* concentration was noted over the period 2008 to 2013. Trend in proportion of samples non-compliant with the surface water targets established by HRC is summarised for all sites on an annual basis in Figure 15. In this figure it must be remembered that the target values apply to surface waters after mixing, not the discharges themselves.

Although the concentration of *E. coli* in the discharge from the Pahiatua WWTP has decreased over time, and the number of exceedances of the HRC water quality targets by the wastewater discharge has decreased steadily, the number exceedances of the HRC water quality standard in the river downstream of the discharge has not decreased to the same extent. This indicates that the microbiological quality of the river is influenced less by the wastewater discharge than input from other sources of contaminants. It is actually possible that the wastewater discharge may improve the quality of the receiving river on occasions through slight dilution of the bacterial load already in the river.

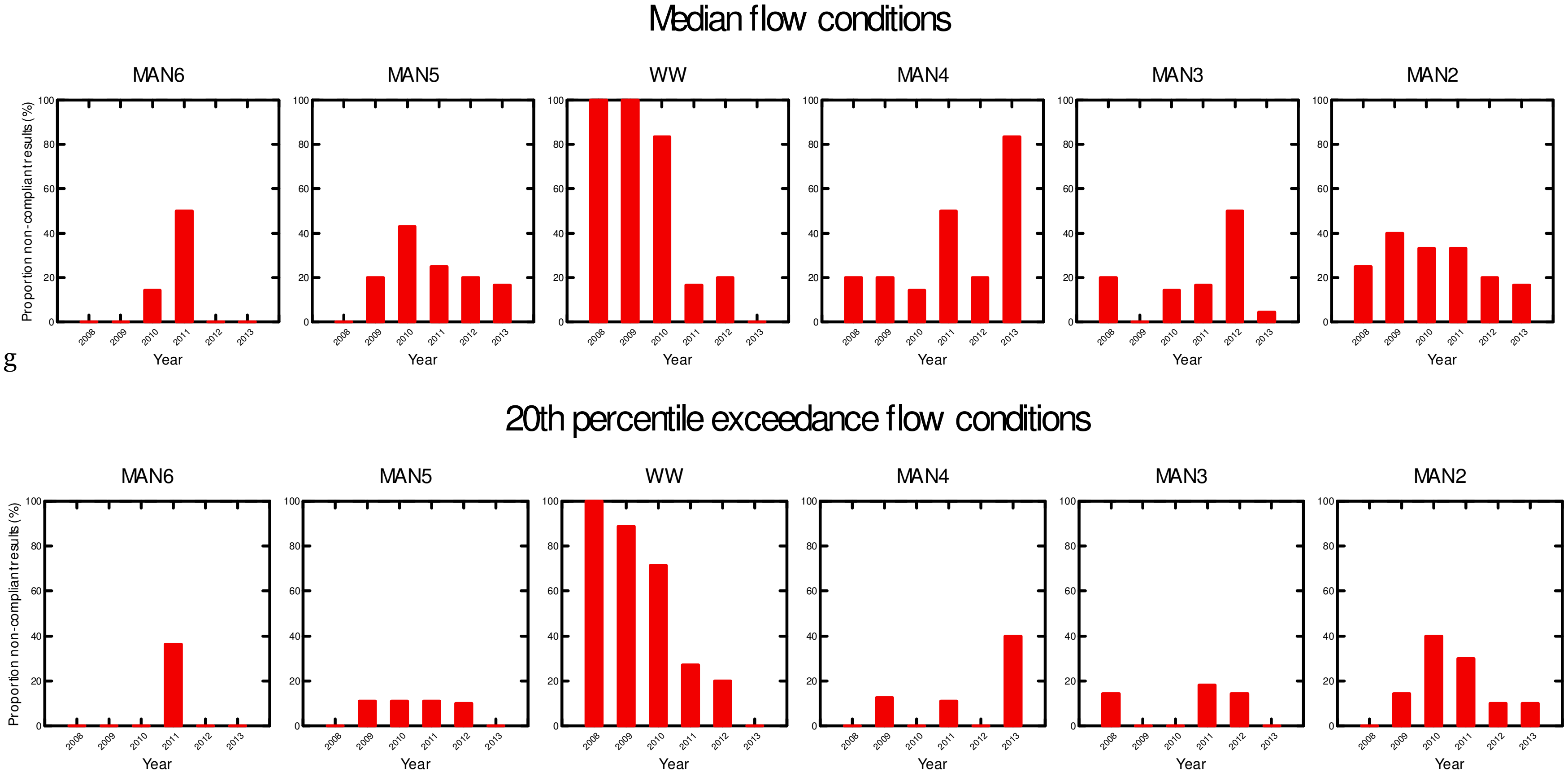


Figure 15. Trend in proportion of samples compliant with HRC water quality target for *E. coli* at sampling points in the lower Mangatainoka River by site and year

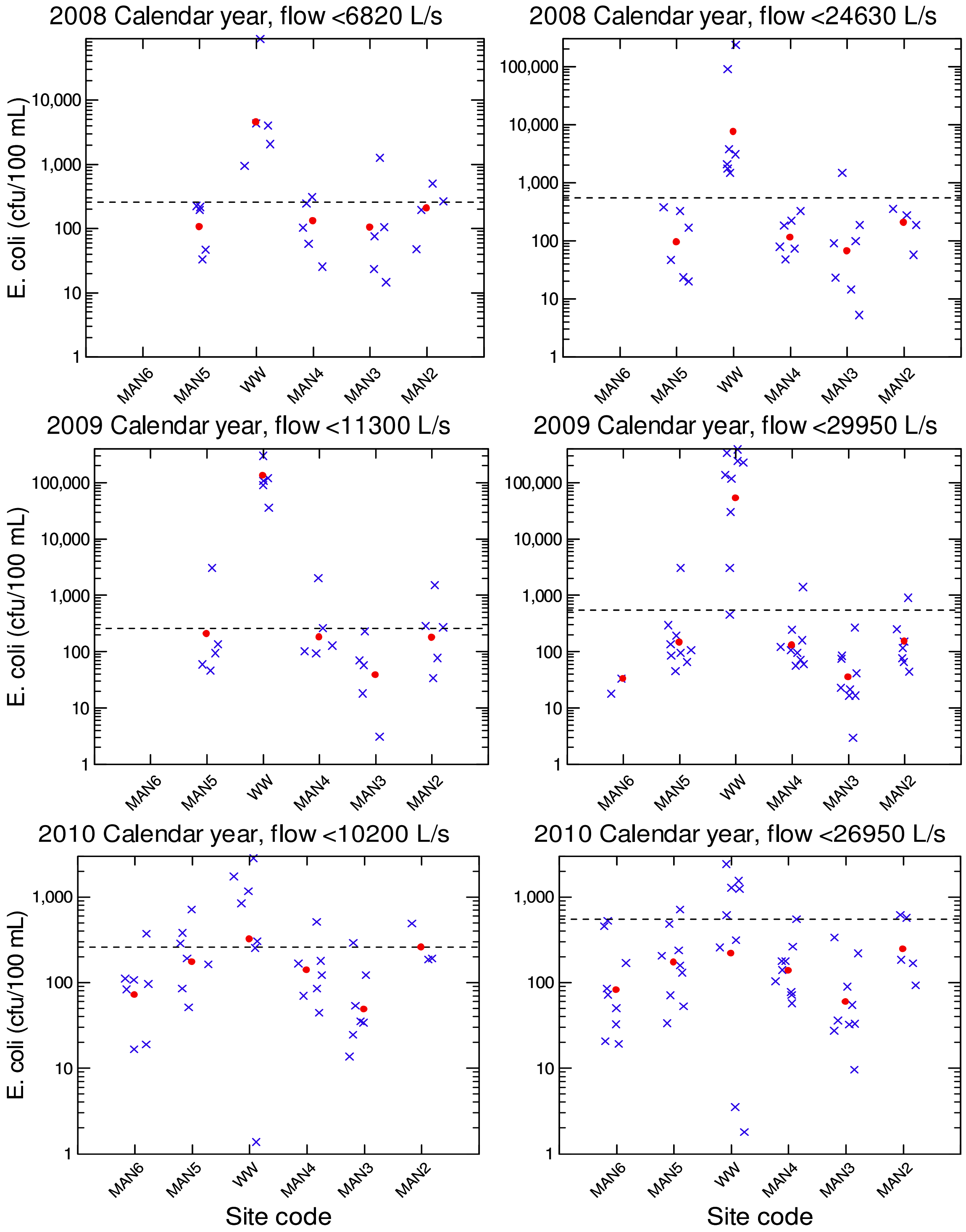


Figure 16 – full caption on next page

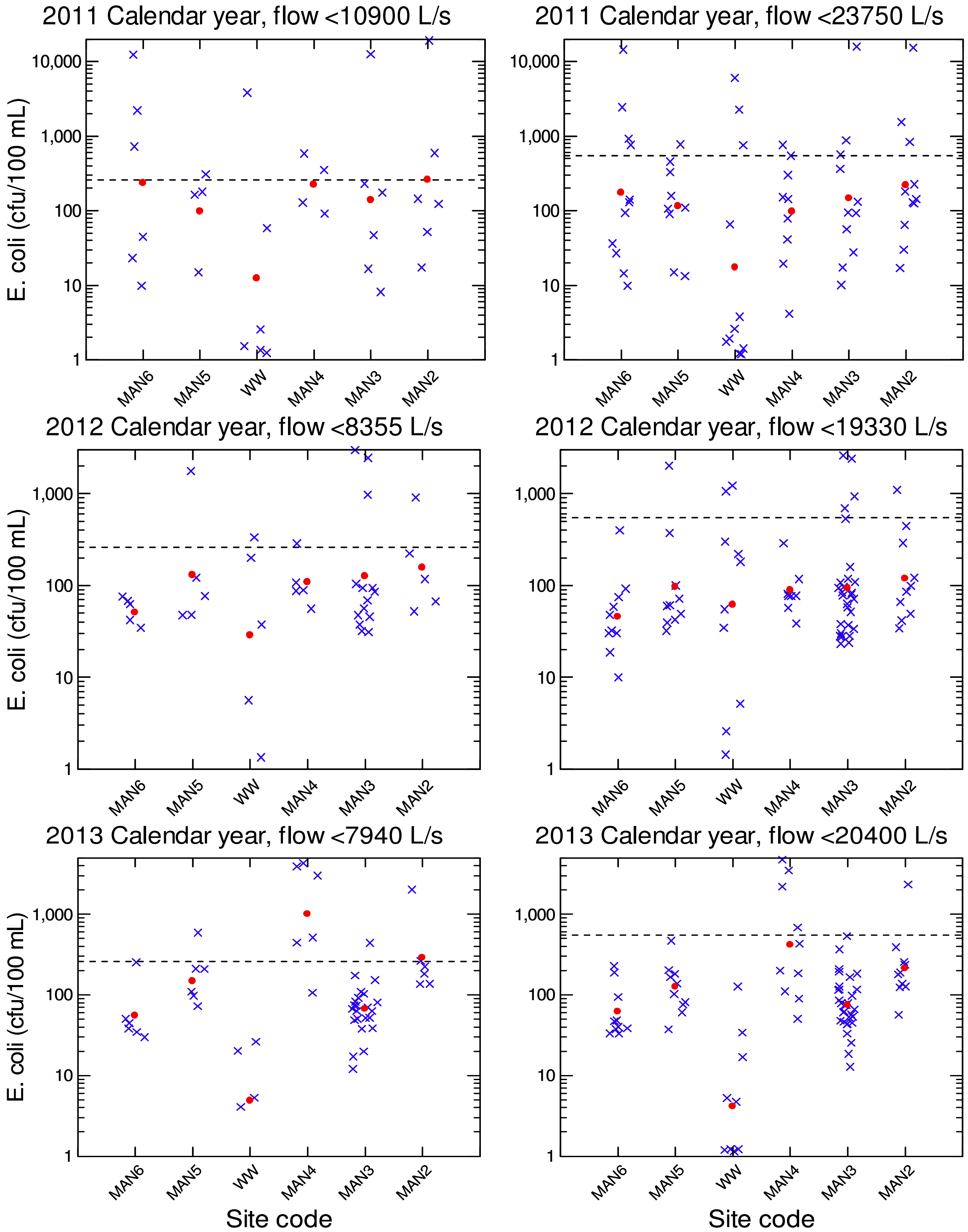


Figure 16. Annual median (red dot) and individual sample *E. coli* concentrations (blue crosses) at sampling points in the lower Mangatainoka River catchment (2008-2013), at flows less than median (left) and flows less than 20th percentile exceedance value (right). The horizontal lines are the 260 cfu/100 mL and 550 cfu/100 mL target defined by HRC for these flow conditions. Note y axis has $\log_{10}$ scale.

Summary for *E. coli* Concentrations

The load of faecal indicator organisms (*E. coli*) discharged from the WWTP to the Mangatainoka River is likely to have decreased measurably since 2008 (no flow data are available to make this assessment).

The concentration of faecal indicator organisms (*E. coli*) discharged from the WWTP to the Mangatainoka River has decreased measurably by approximately 4-log units since 2008.

Under median flow conditions, less than 20% of samples have exceeded the HRC target for river water quality since 2011. In 2013, less than 5% of samples exceeded the HRC target.

Since about 2012, the wastewater discharge may actually improve the microbiological quality of the receiving environment by slightly diluting upstream water and associated faecal indicator organism contaminant load.

3.2.5 Soluble Carbonaceous BOD$_5$

Relatively few data are available for soluble cBOD5 for most sites in the lower Mangatainoka River (Figure 17, A-D). The data are generally at or below the analytical detection limit for this variable. Although the single exceedance of the target value at flows less than 20%ile exceedance flow occurs downstream of the Pahiatua WWTP (site MAN4 in 2013), there is insufficient evidence to conclude that the discharge causes non-compliance. Figure 5 (N) indicates that the concentration of cBOD5 has approximately halved over the assessment period. This is likely to translate to halving of the load of cBOD5 discharged to the river, but this is a speculative assumption based on the behaviour of other variables.

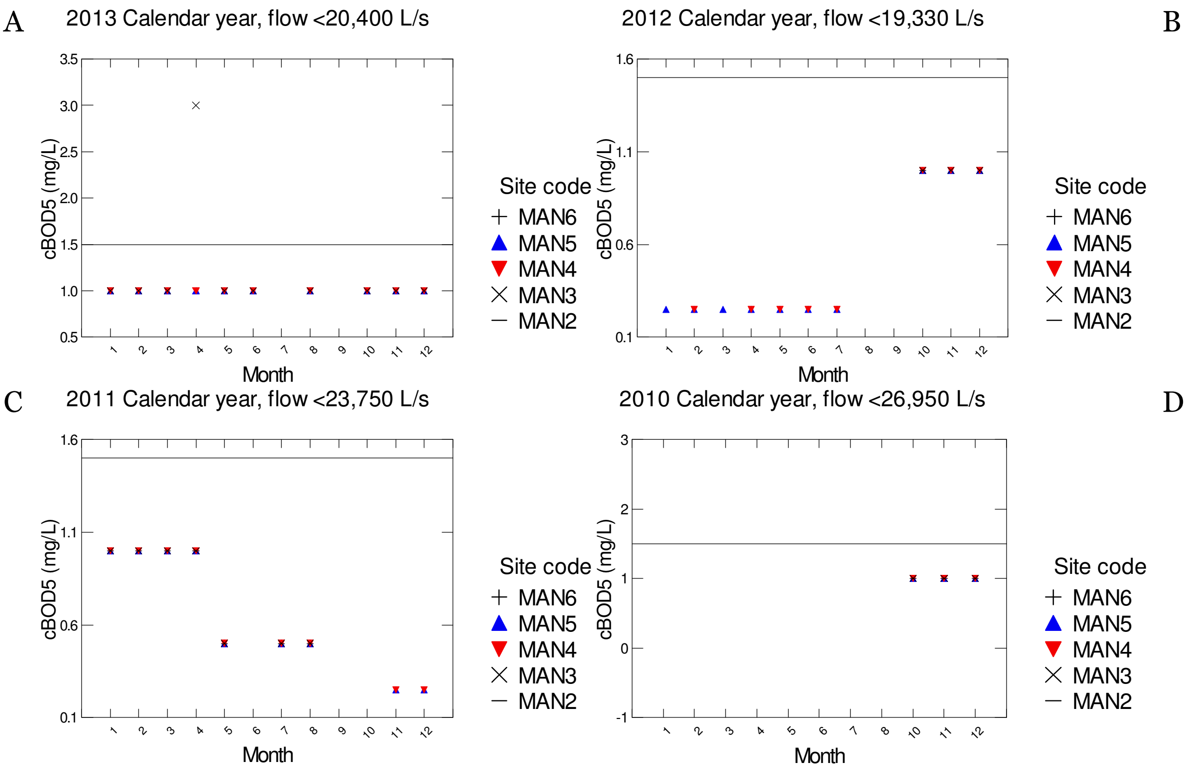


Figure 17. Trend in soluble cBOD5 over time. The stippled horizontal line indicates the water quality target value of 1.5 mg/L

3.2.6 Particulate Organic Matter

Particulate organic matter (POM) is a fraction of total suspended solids (TSS). It is the difference in mass between the result for TSS and the same sample residues after ignition at 500 °C – 600 °C, expressed as a concentration. It is also known as the volatile solids concentration. It is a measure of the amount of organic material in a water sample. This organic material may be derived from point or non-point source inputs to a river, or may be endogenous – produced by biological processes within the river. Elevated POM concentrations is an indication of high productivity - extensive periphyton or algal growth.

Average POM concentrations at flows lower than 50%ile exceedance are summarised on an annual basis for sites along the lower Mangatainoka River in Figure 18 (A-E). No exceedances occurred. When these data are considered as discrete values (shown in Figure 19 A-D for calendar years 2010-2013), there is little evidence of trend over time. Although highest concentrations of VM tend to occur downstream of site MAN4 (Mangatainoka River downstream of WWTP), they may not always occur immediately downstream of the wastewater discharge. For example, during 2010 and 2011, highest POM was observed at the SH2 site, approximately 3400 m downstream from the confluence of Town Creek and the Mangatainoka River. Over this distance it is likely that biomass may be produced in the river channel, some of which will be sloughed off and sampled downstream. Relatively few data exist to assess POM. These results should be considered together with those for other metrics, such as chlorophyll *a* concentrations and visual assessment of bed cover by periphyton and cyanobacteria.

In Section 2.6 trends in concentration of particulate organic matter were considered in terms of Total suspended solids, turbidity and volatile matter. Concentrations of these metrics have decreased appreciably since 2008:

- Median turbidity has decreased from approximately 30 NTU in 2008 to approximately 5 NTU in 2013;
- Median total suspended solids and volatile matter concentrations decreased from approximately 80 mg/L to less than 10 mg/L over this period.

From these data we can conclude that increasing concentrations of soluble and particulate organic matter in the lower Mangatainoka River are not directly attributable to the load of these substances in the discharge. Increases in organic material in the river are most likely related to increases in primary production (i.e. periphyton growth) in the river itself. What needs to be determined however is whether the nutrient input to the river in the wastewater discharge is responsible for increases in periphyton growth in the lower river. This is discussed in Section 3.2.9 and 3.2.10.

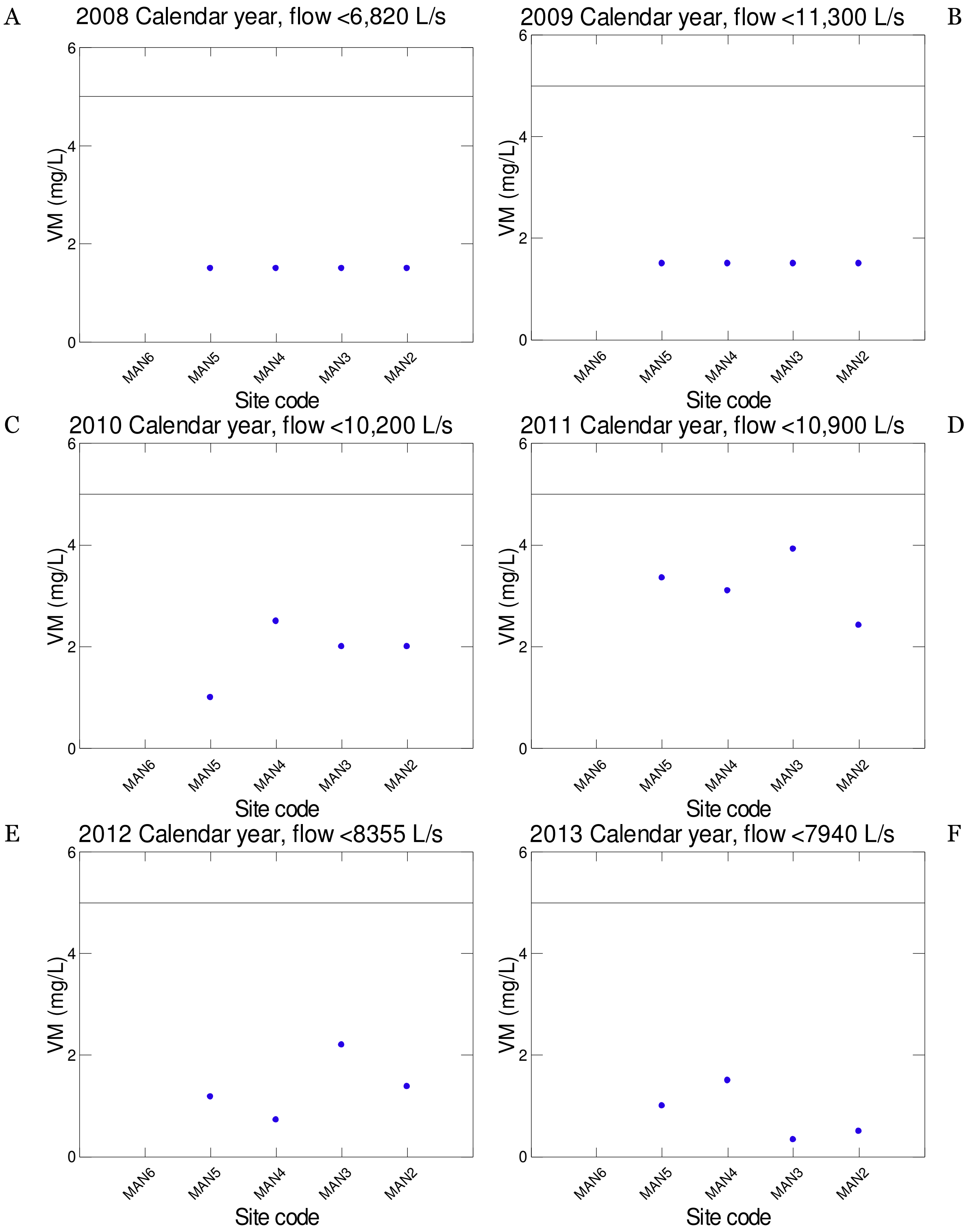


Figure 18. Spatial trend in particulate organic matter over time. POM expressed as average value for flows less than median

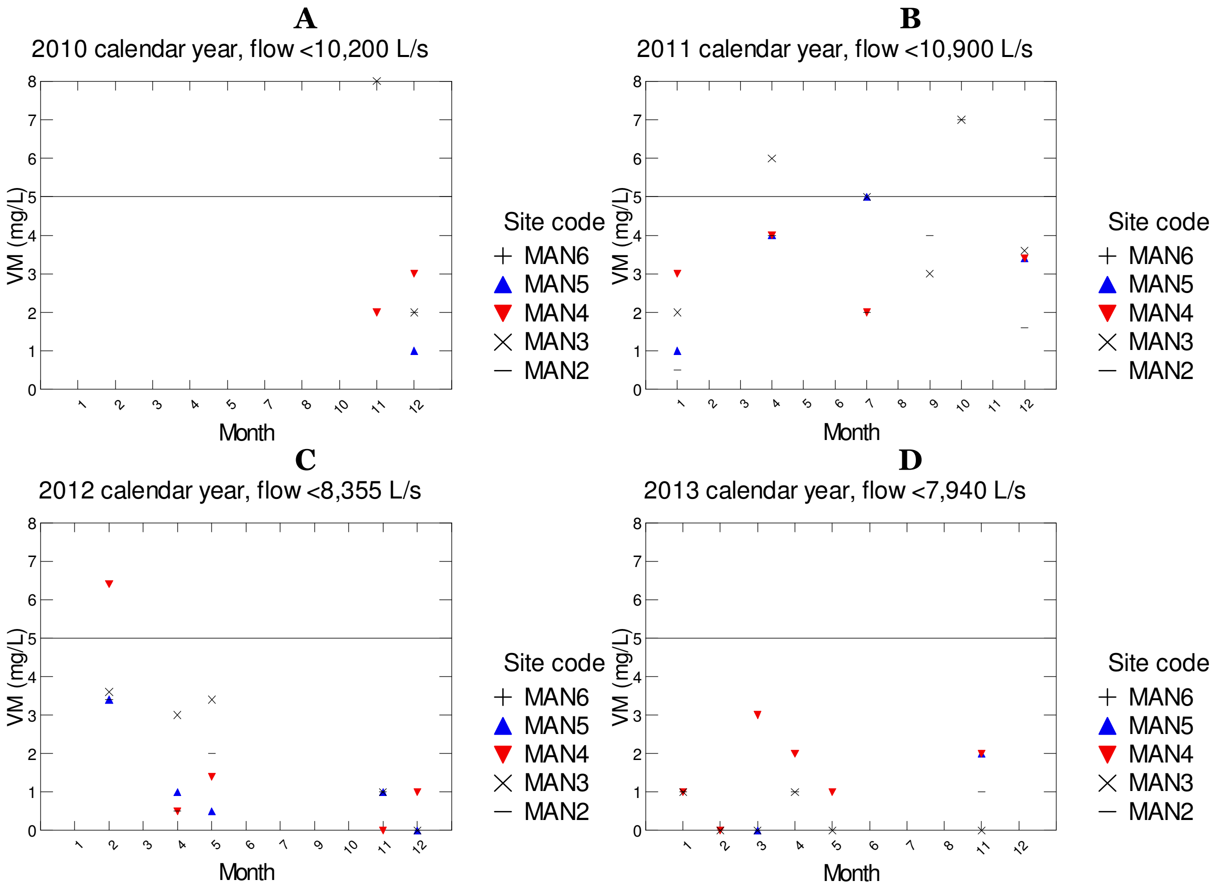


Figure 19. Temporal trend in particulate organic matter by month. Discrete POM concentrations for samples collected when river flows were less than median

3.2.7 Periphyton

3.2.7.1 Periphyton Cover Assessed as Chlorophyll *a* concentration

Chlorophyll *a* is a photosynthetic pigment produced by all plants, including algae. The density of chlorophyll *a* on the river substrate provides a measure of the density of periphyton biomass. Although the proportion of chlorophyll *a* as photosynthetic pigment varies across algal species, measurement of chlorophyll *a* provides insights regarding the relative density of algal biomass on an areal basis. In general, for sites having a similar assemblage of algal species, the density of chlorophyll *a* recovered from the substrate will provide a reasonable estimate of the relative densities of periphyton.

The Horizons OnePlan sets a target for chlorophyll *a* density of 120 mg/m^2. Figure 20 indicates that most chlorophyll *a* densities are lower than 120 mg/m^2. Figure 21 indicates that median and average concentrations were generally below 50 mg/m^2, with exceptions occurring at MAN4 and MAN5 in 2011 and 2013. Median and average concentrations increased at all sites over time, with notable increases in median concentrations at MAN5 and MAN3 in 2013. Median concentrations are highest at MAN4. The range of concentrations measured at MAN4 and MAN3 is larger than at MAN5. Similar concentrations were observed at site MAK1, in the Makakahi River upstream of the confluence with the Mangatainoka River, as at MAN5. The close distance between MAN5 and MAN4 and similar habitat at the two sites suggests that the discharge from the WWTP is exerting a mild stimulatory effect on periphyton growth. Figure 21 indicates similar trends in density of chlorophyll *a* up- and downstream of the discharge, indicating that catchment hydrology and catchment nutrient inputs establish a baseline or potential for periphyton growth, which additional nutrient inputs (including the Pahiatua WWTP discharge) increases.

Chlorophyll *a* densities decrease downstream of site MAN4, suggesting that the wastewater outflow provides a transient increase in nutrients – as periphyton grows, it utilises the additional nutrient input to the lower river and incorporates it as biomass. This nutrient is thereafter relatively unavailable and the chlorophyll *a* density declines in response to lower nutrient availability. Reducing the mass of nutrient input from the discharge may reduce periphyton growth in the immediate vicinity of the discharge, and possibly further downstream as well.

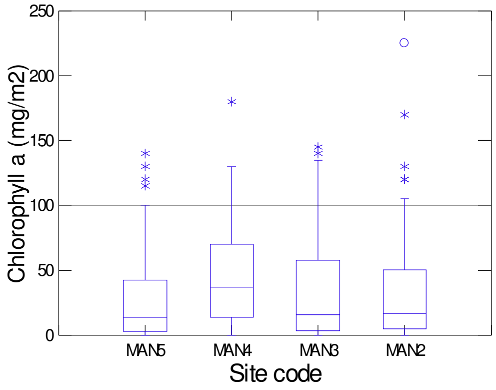


Figure 20. Spatial trend in chlorophyll *a* density (data 2008 – 2013)

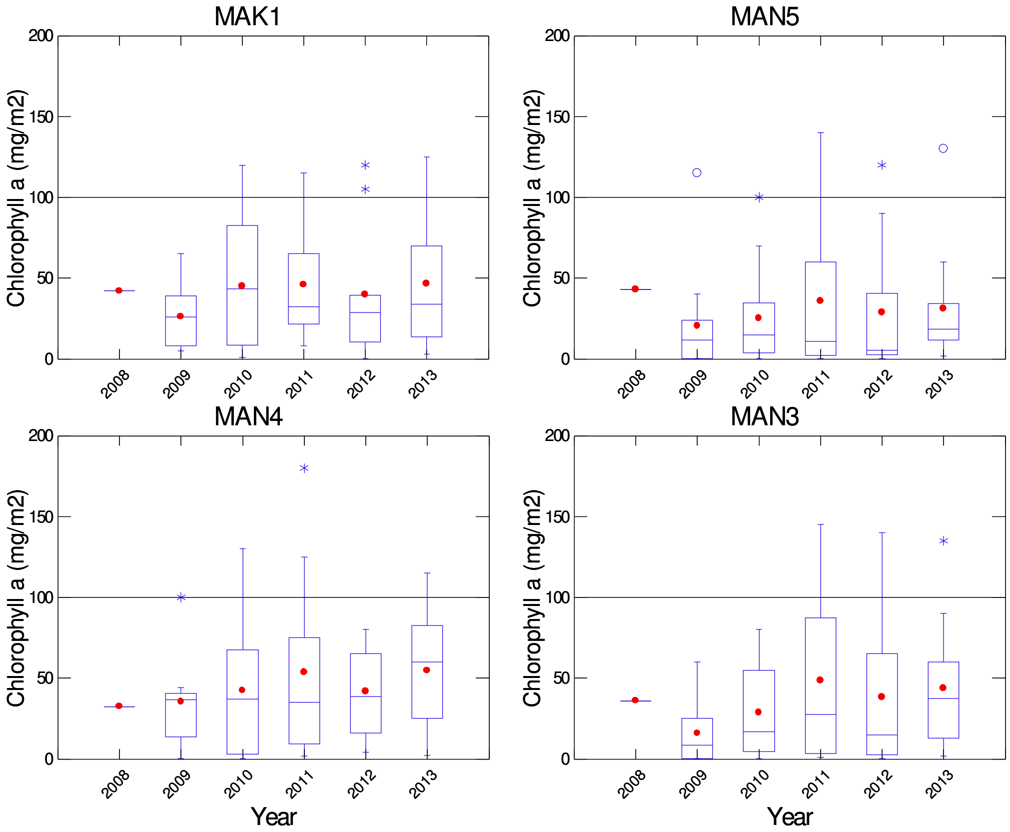


Figure 21. Temporal trend in chlorophyll *a* density. Red dots indicate annual average concentration.

3.2.7.2 Visible Periphyton Cover

Two metrics identified in the OnePlan related to periphyton cover – visible periphyton cover, and proportion of cover by cyanobacteria or diatoms. The latter is a subset of the former.

Visible periphyton cover

The target for the lower Mangatainoka River is less than 30% visible cover by periphyton. HRC measure a series of related metrics:

- Percent clean stones
- Percent filmy
- Percent filamentous (slimy)
- Percent mats
- Percent sludge
- Percent filamentous (coarse).

The extent of cover at each site can be estimated from the "Percent clean stones" measure, with ">70% clean stones" being an appropriate alternate expression of the target. Results are summarised for sites in the lower Mangatainoka River in Figure 22 (A-E). HRC make the comment that results recorded prior to 2010 were derived using different assessment techniques to record results under high flow conditions. Previously high flows were assumed to create "100% clean conditions", on the assumption that significantly elevated flows would strip attached periphyton.
Two measures are particularly informative:

- the change in the proportion of clean substrate at each site over time Figure 22 (A), and
- the proportion of film observed at each site over time Figure 22 (B).

There is an inverse relationship between these values – as the proportion of clean substrate has decreased generally across all sites since 2010, there has been an increase in the proportion of film cover at all sites. The rate of increase in film cover has however been far greater than the decrease in the proportion of clean stone substrate. Although these metrics are based on visual assessment according to a formalised protocol, the results will have an element of uncertainty related to the individuals undertaking the surveys. They do however indicate a general trend of decline in river condition across all sites in the lower Mangatainoka River catchment. This general decline cannot be attributed to the Pahiatua WWTP alone, although the input of nutrient from the wastewater discharge will contribute to the nutrient load in the lower catchment.

Considering periphyton cover on a wider context, Figure 44 (Appendix 1) indicates that

- The upper catchment (Site MAN9) has a greater proportion of clean substrate and a lower proportion of slime cover than the lower catchment sites.
- The proportion of clean substrate is lower in the Makakahi River than the Mangatainoka River at the town bridge site (MAN6), and the proportion of film cover is at least as large as that downstream of the Pahiatua WWTP discharge.
- The proportion of filamentous mats in the Makakahi River is at least as great as that observed in the lower Mangatainoka River.

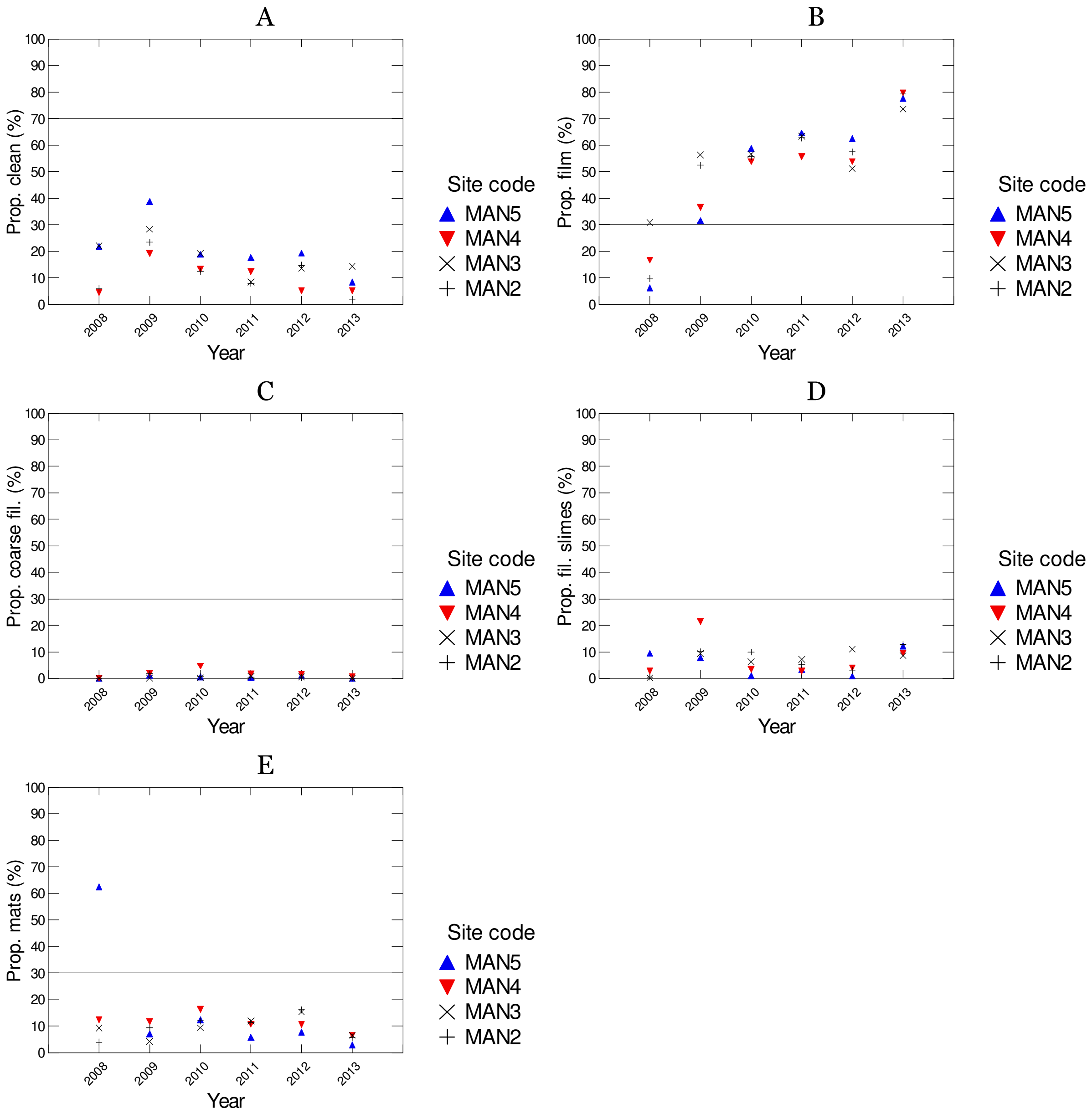


Figure 22. Temporal trend in periphyton density

Earlier it was noted that visible periphyton cover indicates a general increase in the proportion of film metric at all sites in the lower Mangatainoka River over the period 2008 to 2013. The trend is less clear in the Makakahi River. This trend is equally strong at MAN5 and MAN4, indicating that it cannot be related exclusively to the WWTP discharge.

Although the close distance between MAN5 and MAN4, similar habitat at the two sites and relative increase in chlorophyll *a* concentration suggests that the discharge from the WWTP may exert a mild stimulatory effect on periphyton growth, it does not account for the general increase in proportion of film at all sites in the lower catchment. These trends are probably best explained by the flow conditions that prevailed over this period.

In Figure 23 the proportion of film at key sites is plotted together with annual median flow. At all sites the high proportion of film may be explained by the generally low flow conditions that prevailed. It appears likely that once a median flow threshold of about 8000 L/s is reached, periphyton is able to accumulate (increasing the chlorophyll *a* concentration) and the proportion of films increase.

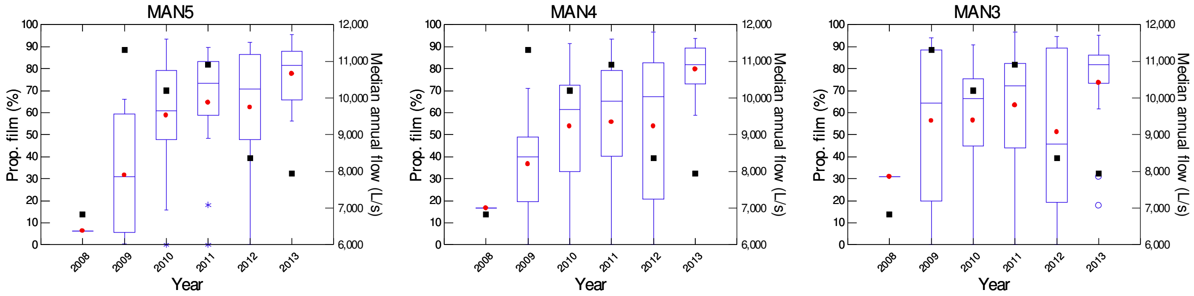


Figure 23. Relationship between temporal trend in periphyton density and median annual flow (black square and right-hand scale).

Proportion of Cover by Cyanobacteria or Diatoms

Fewer data exist for cyanobacteria or diatom assessments. Results are reported for two methods of assessment:

- From the bank, as an assessment of the appearance of river substrate at the observation location
- From within the water column, using an underwater viewer to make a set number of observations along a specific number of defined transects.

Although these assessments are conducted according to a formalised protocol, the results will have an element of uncertainty related to the individuals undertaking the surveys, the nature of the assessment and the growth habit of cyanobacteria. Results are summarised in Appendix 1 in Figure 45, Figure 46 and Figure 47. These results indicate:

- The incidence of cyanobacteria is very low in the upper reaches of the Mangatainoka River (Figure 45) – generally <5% cover.
- The incidence of cyanobacteria at all sites in the lower Mangatainoka River is generally higher, but very variable.
- There is little indication of trend over time from the data assessed, although generally higher cover occurred in early 2012.
- There is a generally higher proportion of cyanobacteria cover downstream of the Pahiatua WWTP discharge.
- There is a generally higher incidence of cyanobacteria at all sites during the summer period (January – June annually).
- Although the incidence of cyanobacteria is generally higher in the lower Mangatainoka River catchment, the target value of 30% cover was exceeded only once during the period assessed.

When considered together with the results for visible periphyton cover, these results indicate that cyanobacteria are probably a minor component of periphyton cover, and are not responsible for the general decrease in the proportion of clean substrate or increase in the proportion of slimes observed in the lower river.

The results of periphyton and cyanobacteria analysis are consistent with those for chlorophyll *a*:

- Generally declining water quality along the Mangatainoka River catchment (evident as an increase in periphyton cover, as film)

- Possible increase in cyanobacteria cover downstream of the Pahiatua WWTP discharge
- Failure to achieve the HRC water quality target of <30% periphyton cover on one occasion.

Reducing the input of nutrients from the wastewater works will probably not in itself allow the water quality target to be achieved – water is generally degraded in the lower Mangatainoka River as a consequence of other point and non-point source discharges.

Periphyton Growth and Nutrient Ratios

Nutrient concentrations and mass loading rates are considered in detail in Sections 3.2.10 and 3.3.2. In the current section nutrient ratios are considered because of their role in determining periphyton growth. From pioneering work undertaken by Redfield in 1934, and extended by Redfield and others (Loladze & Elser, 2011; A Redfield, 1958; AC Redfield, 1934), it has been possible to predict the likelihood of algal species from the relative amounts of nitrogen and phosphorus present in a water body. Redfield identified that when nutrients are not limiting, the molar elemental ratio of C:N:P in most phytoplankton is 106:16:1. As the ratio of N:P moves away from about 16:1, one or other of these nutrients becomes limiting. As the N:P ratio becomes smaller, the likelihood of shifting the algal population toward cyanobacteria increases; these algae are able to capture nitrogen directly from the atmosphere, providing them with a competitive advantage over green species. The N:P ratio is calculated from the concentrations of TN and TP after conversion to molar concentrations.

N:P ratios for sites along the lower Mangatainoka River are summarised on an annual median basis in Figure 24. These data indicate that surface waters in the lower Mangatainoka River are generally enriched with regard to N relative to P. This ratio is generally consistent with the low incidence of cyanobacteria. It is also a situation where small inputs of soluble phosphorus are likely to favour the growth of green algae. There has also been little change in the ratio over the assessment period – in-stream ratios have generally fallen in a range from about 40:1 to 110:1.

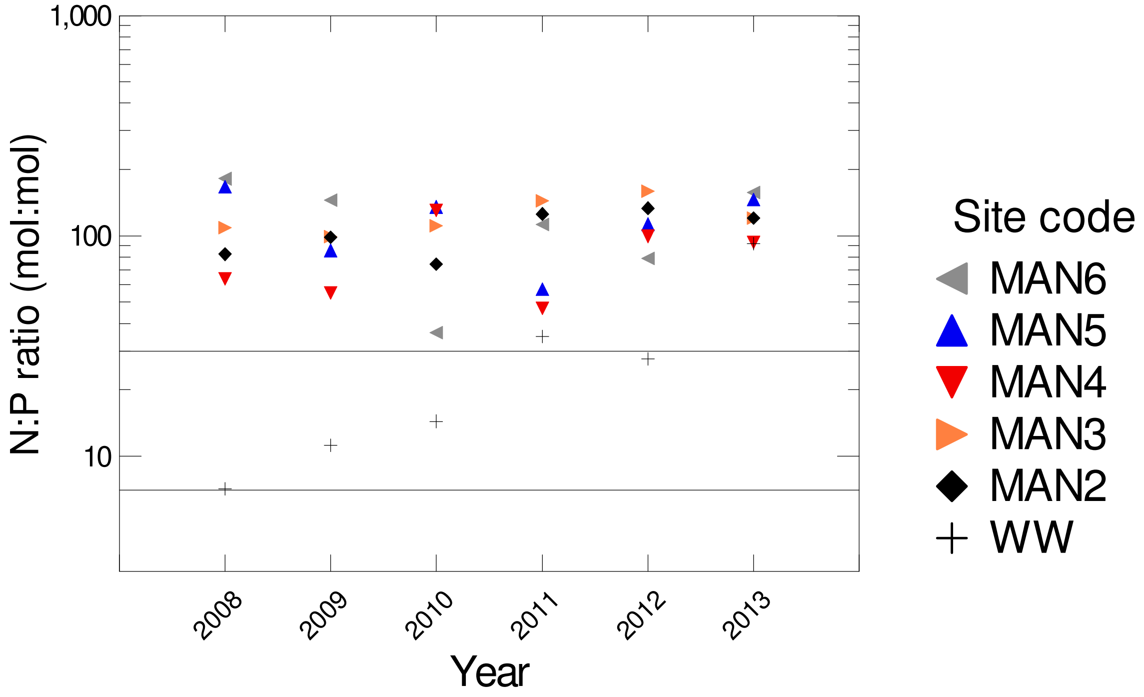


Figure 24. Trend in median N:P ratio in sites in the lower Mangatainoka River. The horizontal lines indicate the 7:1 and 30:1 ratio lines

3.2.8 Macroinvertebrate Species Composition and Numbers

One target has been established for the lower Mangatainoka River catchment in terms of macroinvertebrate numbers and species composition – change in the Quantitative Macroinvertebrate Community Index (QMCI) downstream of a discharge should be less than 20%. The QMCI is an aggregated score derived from the number and types of macroinvertebrates present at the sample location. It was developed specifically to provide a quantitative measure of the impact of point source discharges, particularly in stony-bottomed waters.

Macroinvertebrate data exist for a number of sampling points in the Mangatainoka River catchment, but few recent data exist for sites in the lower catchment. MCI and QMCI scores derived from SoE monitoring undertaken in 2013 are summarised in Figure 25. Highest MCI and QMCI scores are measured in the upper reaches of the catchment. Lowest MCI scores were measured in the Makakahi River upstream of the confluence with the Mangatainoka River and the Mangatainoka River upstream of the Pahiatua WWTP discharge. Lowest QMCI scores were recorded in the Mangatainoka River immediately upstream and downstream of the Pahiatua WWTP discharge. Both MCI and QMCI scores increase in the reach between MAN4 and MAN3.

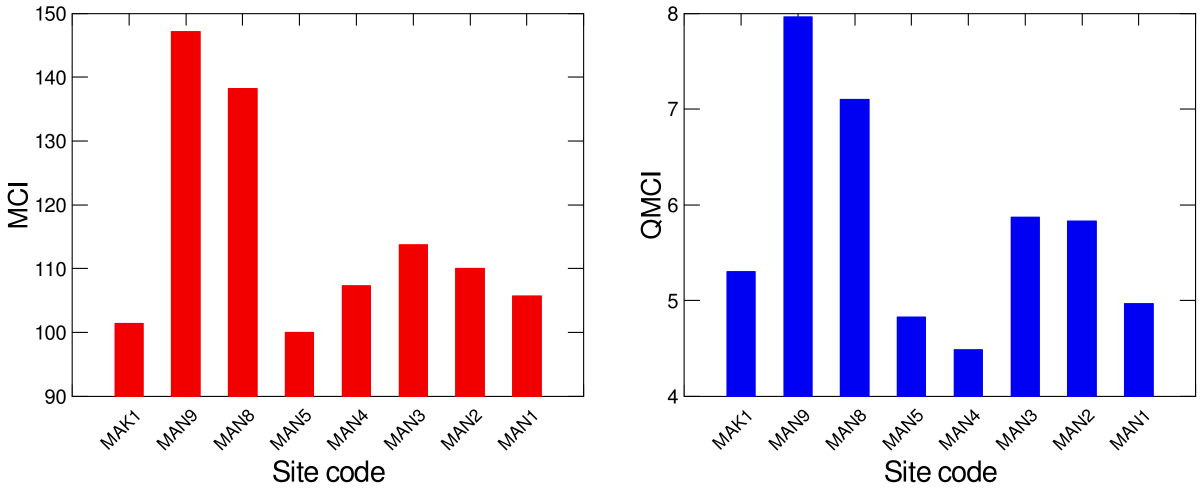


Figure 25: Macroinvertebrate community index scores for the Mangatainoka River catchment, 2013

Changes in the QMCI score between successive sampling points along the course of the Mangatainoka River in 2013 are summarised in Figure 26. None of the decreases in QMCI exceed 20%, and the single increase occurred downstream of the wastewater discharge.

Earlier, chlorophyll *a* and periphyton cover was discussed in terms of increasing primary productivity in response to nutrient inputs from the wastewater discharge. Assessment of the wastewater indicated that relatively little DRP is currently discharged as a consequence of changes to the wastewater treatment process. It is possible however that the limited input of DRP and soluble carbon subtly alters nutrient ratios and stimulates primary productivity immediately downstream of the discharge under summer low flow conditions. This increase in primary productivity causes a slight depletion of available nutrients (particularly P) further downstream (MAN3 and MAN2). It is possible that:

- the decline in QMCI immediately downstream of the discharge is caused by the transient increase in primary productivity, and

- the subsequent increase in QMCI results from a decrease in primary productivity arising from a slight nutrient limitation.

This explanation is speculative and is based on relatively few data – the results of ongoing monitoring should allow this proposal to be confirmed, or provide alternate explanations.

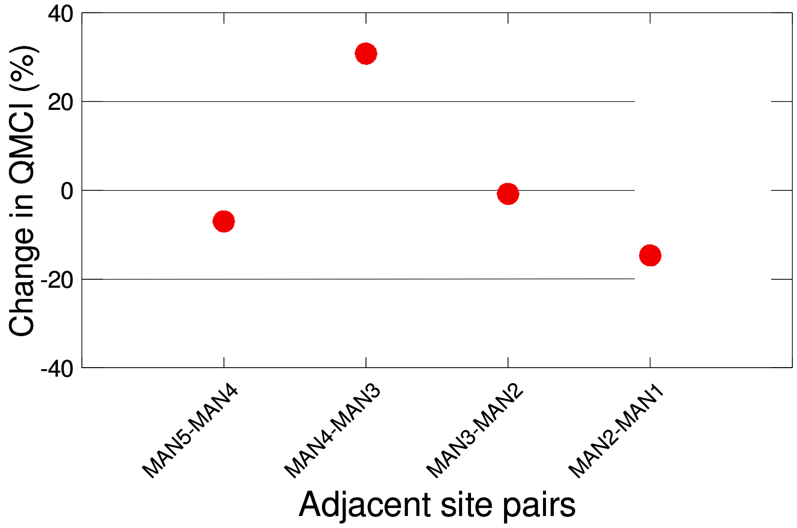


Figure 26: Proportional change in QMCI score between adjacent sites in the lower Mangatainoka River catchment, 2013

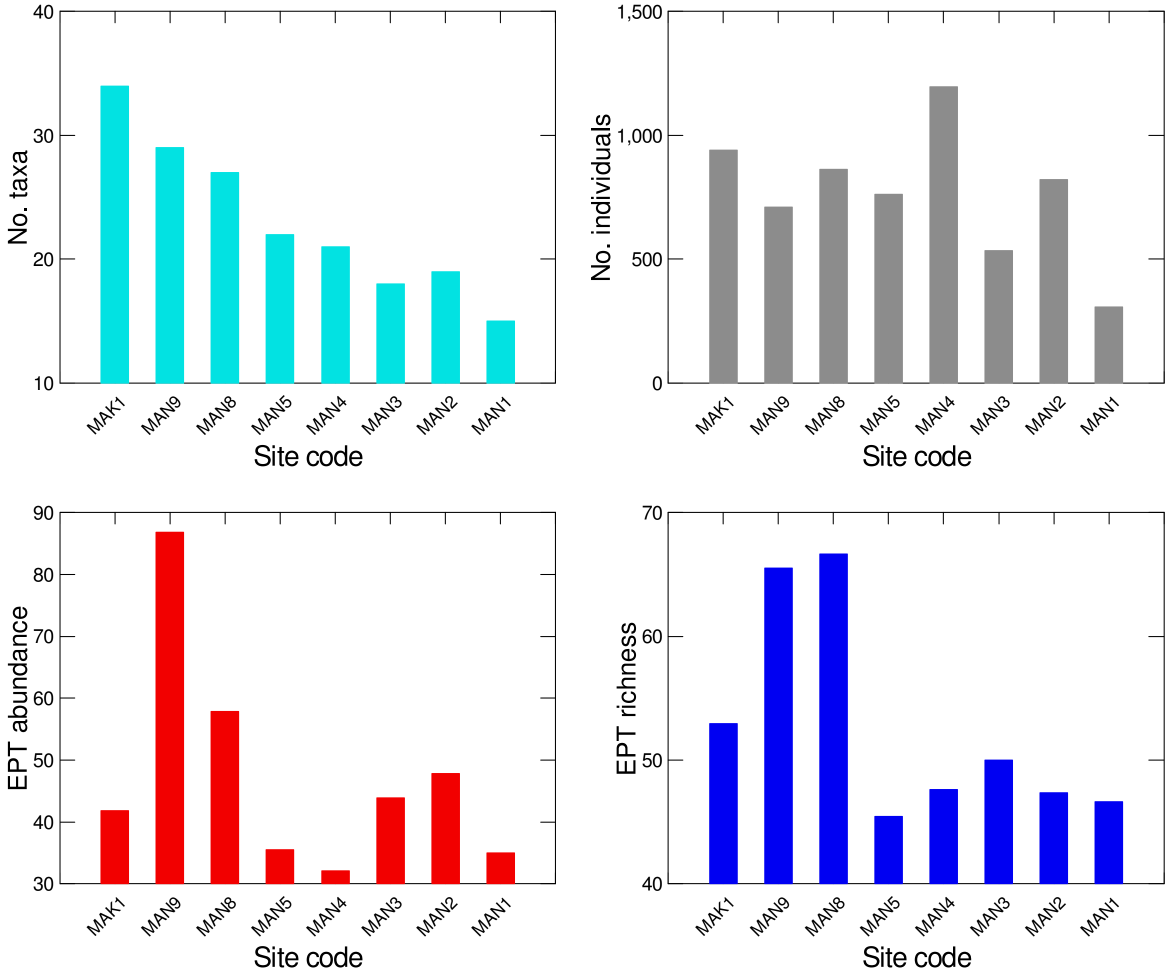


Figure 27: Scores for specific macroinvertebrate metrics in the lower Mangatainoka River catchment, 2013

3.2.9 Dissolved Reactive Phosphate (DRP) Concentrations

Dissolved reactive phosphate (DRP) is one of the key nutrients that controls or regulates plant growth, including algae and periphyton. Excessive concentration of DRP is likely to promote excessive or nuisance plant and algae growth. The sensitivity of plant growth to DRP concentrations is reflected in the low guideline or target thresholds generally proposed – for example, the ANZECC guidelines indicated a value of 0.01 mg/L (ANZECC & ARMCANZ, 2000), the New Zealand Periphyton Guidelines (Ministry for the Environment (MfE), 2000) recommended values less than approximately 0.02 mg/L to achieve chlorophyll *a* concentrations lower than 120 mg/m^2 (with consideration of accrual period). In-stream plant and nutrient guidelines for New Zealand were recently reviewed (Matheson, 2012). The water quality target proposed for DRP in the Horizons region reflects the desire to minimise nuisance growth and achieve or maintain various values (e.g. nuisance growth of periphyton or chlorophyll *a* densities maintained below threshold values). The target for the Mangatainoka River is an annual average of 0.01 mg/L for conditions when river flows are less than the 20%ile exceedance value.

DRP concentrations in the Mangatainoka River catchment under all flow conditions for the period 2008-2013 are summarised in Figure 28; equivalent data for the sites in the lower catchment are summarised in Figure 29(A), while in Figure 29(B) data are shown for conditions where flows are less than the 20%ile exceedance value (24,200 L/s). Considering all flow conditions, these figures indicate:

- Average and median concentrations for all sites but two (the Pahiatua WWTP and the site immediately downstream, MAN4) are less than the target value,
- The 75%ile value of all sites except five are less than the target concentration value,
- Average and median concentrations exceed the target value downstream of the Pahiatua WWTP discharge (at site MAN4).

Generally similar trends exist when flow conditions are less than the 20%ile value (Figure 29(B)):

- With the exception of the site immediately downstream of Pahiatua WWTP (MAN4), average and median concentrations are less than the target value,
- The 75%ile value of the site upstream of the WWTP discharge and at site MAN2 (SH2) exceed the target concentration value.

Trends in concentration under flow conditions less than the 20%ile exceedance value (24,200 L/s) are summarised at annual time-step in Figure 30. This figure indicates:

- DRP concentrations at site MAN6 appear to have increased over the period 2008-2013 (although the number of data are limited and this apparent trend is speculative).
- Elevated concentrations observed downstream of the Pahiatua WWTP discharge site (MAN4) are matched by similar concentrations at the upstream site (MAN5) – these elevated concentrations are associated with inputs from the upper catchment.
- Elevated concentrations observed in 2009 and 2011 are associated with above average flow conditions (median flows 11,300 L/s and 10,900 L/s respectively relative to the longer term median value of 9,300 L/s).

The change in DRP upstream and downstream of the Pahiatua WWTP discharge is indicated in Figure 30 (A) and (B) in terms of change in concentration under all flow conditions and Figure 30 (C) and (D) in terms of proportional change (expressed in per cent), MAN4 vs. MAN5.

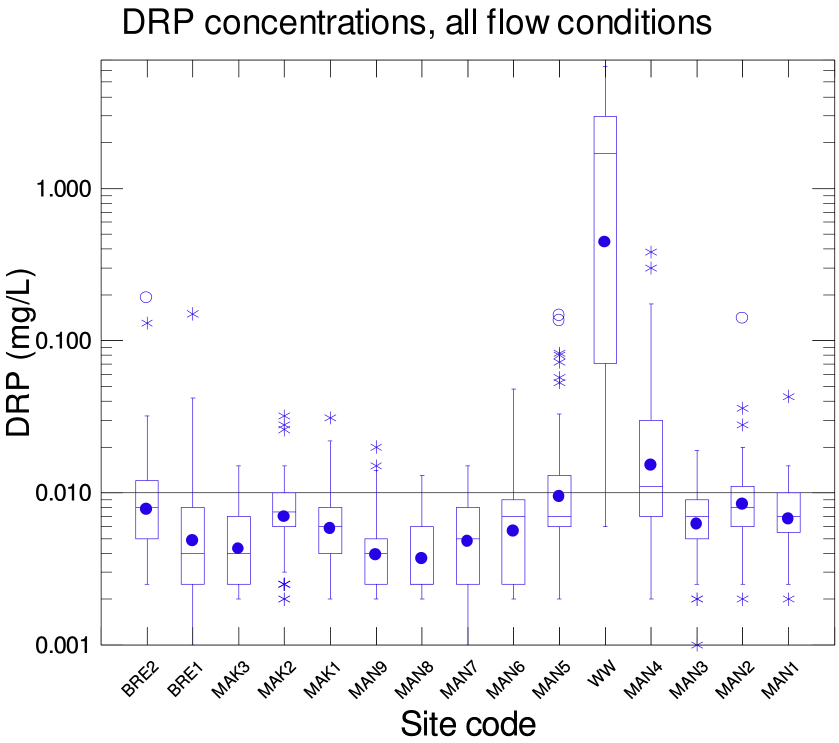


Figure 28. Comparison of DRP concentrations in the Mangatainoka River under all flow conditions, 2008-2013. Solid dot represents average value, dashed line is HRC target

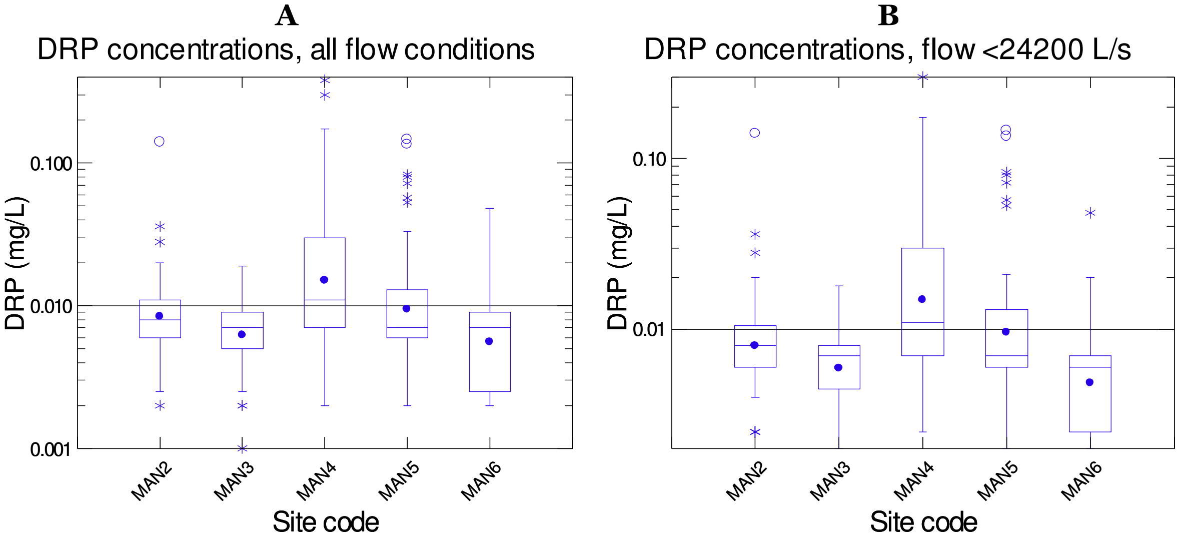


Figure 29. Spatial trend in DRP concentrations under all flow conditions (A) and under flow conditions less than the average 20%exceedance value – 24,200 L/s (B). Solid dot represents average value, dashed line is HRC target

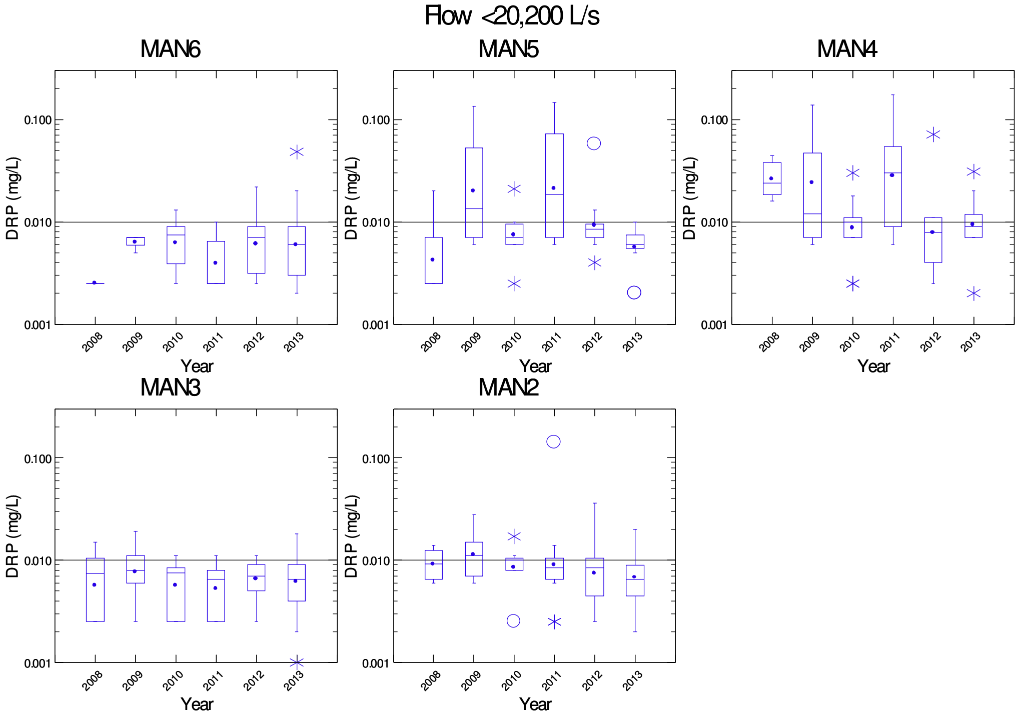


Figure 30. Comparison of DRP concentrations in the Mangatainoka River under all flow conditions, 2008-2013. Solid dot represents annual average value, dashed line is HRC target

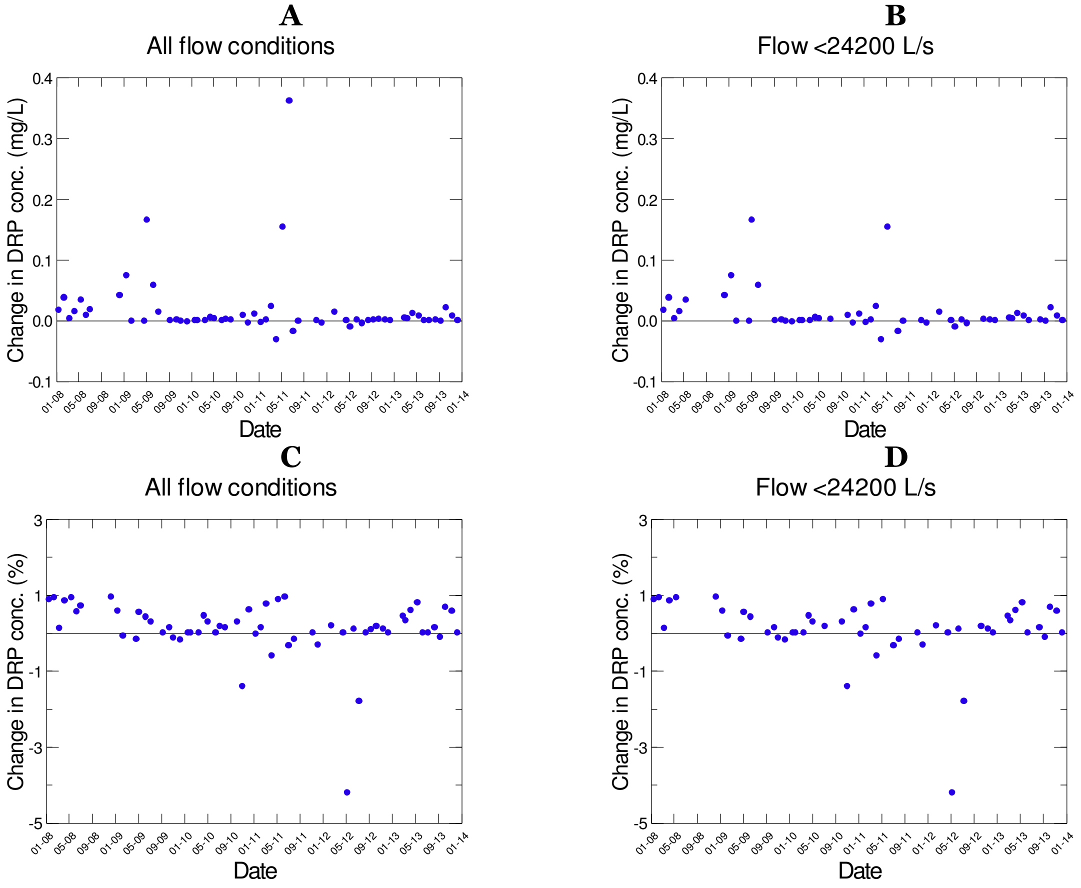


Figure 31. Change in DRP concentrations in the Mangatainoka River up and downstream of the Pahiatua WWTP discharge; (A) and (B) change in concentration under all flow and less than 20 % flow exceedance values, and (C) and (D) as proportional change in concentration under all flow and less than 20 % flow exceedance values, 2008-2013

For flows less than the 20%ile exceedance value, the number of occasions when the concentrations decreased, did not change or increased downstream of the discharge relative to the upstream site are summarised in Figure 32. This figure indicates that the number of increases in concentration at the downstream site relative to the upstream site always exceeded the number of decreases in concentration. In 2009 the number of occasions when the concentration was unchanged equalled the number of occasions when it increased, and in 2011 the number of occasions when it was unchanged exceeded the number of occasions when it increased.

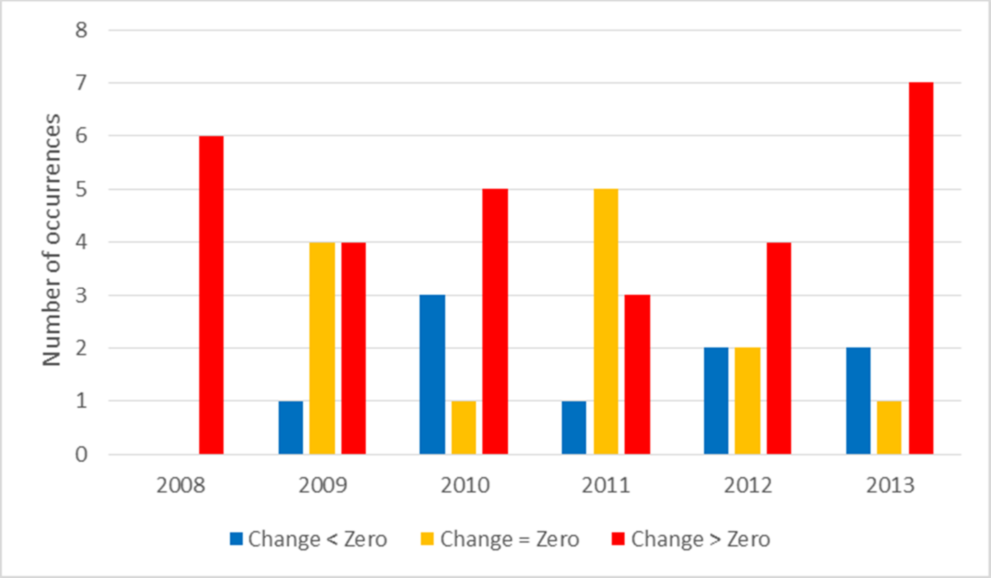


Figure 32. Change in DRP concentrations in the Mangatainoka River up and downstream of the Pahiatua WWTP discharge. "Change < Zero" = decrease in concentration at downstream site relative to upstream site

Formal equivalence testing indicates that concentrations are greater at MAN4 than MAN5 (i.e. greater downstream of the wastewater discharge), but the difference is not practically important at a significance level of 5% and limits of +10% to -10% change.

Formal trend testing failed to demonstrate a significant trend in deseasonalised data after adjusting for the effects of river flow at MAN5, upstream of the wastewater discharge. A change of –9% per annum was detected at site MAN4, downstream of the wastewater discharge. Although this result indicates that concentrations in the lower Mangatainoka River have decreased over the relatively short assessment period (six years), the reliability of this trend may be questioned until it has been demonstrated over a longer period. The results of statistical testing are included as section 6.6.

In Section 2.6 changes in the concentration of key water quality variables in the wastewater discharge were discussed. Median concentrations of DRP have decreased from approximately 3 mg/L in 2008/2009 to less than 0.1 mg/L since 2011. Under dry conditions, the mass of DRP discharged from the WWTP is currently less than 2 kg/month. As will be discussed in Section 3.3.2.1, loads of this magnitude will have an undetectable impact on DRP concentrations in the Mangatainoka River given the magnitude of the DRP load at site MAN5 (hundreds to thousands of kg/month), upstream of the wastewater discharge.

Summary for DRP

DRP concentrations in the lower Mangatainoka River are subject to catchment-wide influences, as well as the wastewater discharge. In Section 2.6 it was demonstrated that average and median DRP concentrations in the wastewater discharge have decreased from approximately 3 mg/L in 2009 to less than 0.5 mg/L in 2013.

Although mean DRP concentration is greater downstream of the wastewater discharge than upstream, it is not possible to demonstrate a statistically meaningful increase in DRP concentrations downstream of the wastewater discharge, and any difference may be trivial relative to the +10% to -10% limit used for the assessment.

Trend testing indicates that DRP concentrations in the Mangatainoka River appear to be decreasing over time – this is consistent with the decrease in DRP concentration in the discharge. A more extensive record is required to improve the certainty of this apparent trend.

These trends need to be considered together with trends observed for chlorophyll *a* and periphyton cover – both metrics are increasing downstream of the wastewater discharge. It is possible that the moderate increase in periphyton growth downstream of the wastewater discharge is evidence of rapid incorporation of the additional DRP as biomass, i.e. this additional nutrient is not transported downstream as un-utilised, bioavailable material.

The limited information available for cyanobacteria indicates that the incidence of these species may be increasing downstream of the discharge. Further increases in DRP concentrations may promote the growth of cyanobacteria.

Consideration of the measured concentration and estimates of the probable load of DRP in the wastewater discharge demonstrates that has decreased substantially since 2009. Currently the concentration of DRP in wastewater is less than 0.1 mg/L. Although this is 10 times larger than the target for the Mangatainoka River, the small volume of the discharge is unlikely to lead to measurable increases in river concentrations.

If there is a requirement to further reduce in-stream DRP concentrations, this will be achieved most cost-effectively by introducing mitigation measures at catchment scale.

3.2.10 Soluble Inorganic Nitrogen (SIN) Concentration

SIN is defined as the sum of oxidised forms of nitrogen plus ammoniacal-N. A target SIN concentration for the Mangatainoka River has been set at 0.444 mg/L for river flows less than the 20%ile exceedance value (24 200 L/s).

SIN concentrations in the Mangatainoka River catchment under all flow conditions for the period 2008-2013 are summarised in Figure 33; equivalent data for the sites in the lower catchment are summarised in Figure 34(A), while in Figure 34(B) data are shown for conditions where flows are less than the 20%ile exceedance value (24,200 L/s). Considering all flow conditions, these figures indicate:

- Median SIN concentrations exceed 0.444 mg/L under all flow conditions at all sites except three sites representing the headwaters of the Mangatainoka River and the Makakahi River (upstream of significant agricultural intensification or wastewater discharge)

- 25%ile SIN concentrations exceed 0.444 mg/L under all flow conditions at all sites in the Mangatainoka River downstream of Scarborough/Konini Road
- Median SIN concentrations are almost uniform in the lower Mangatainoka River catchment, with little evidence of increase as a consequence of the Pahiatua WWTP discharge.

Formal equivalence testing did not indicate a practically important difference in concentration between sites MAN4 and MAN5 (downstream and upstream of the Pahiatua WWTP discharge) using test thresholds ranging from ±1% to ±30% difference from the upstream reference site (MAN5).

Formal trend testing indicated an increasing trend at both the MAN5 and MAN4 sites, but these trends were not statistically significant at either site (*P* > 0.05). LOWESS smoothing (accounting for flow effects on concentration) accounted for 21% and 12% of the variation in the relationship between flow and concentration at site MAN5 and MAN4 respectively, but did not alter the outcomes of the trend assessment. The results of statistical testing are included as section 6.7.

In Section 2.6 trends in measured concentration and estimated loads in the wastewater discharge were discussed. It was demonstrated that the concentrations of nitrate-N have increased since 2008 – these were approximately 2 mg/L and 36 kg/month under dry flow conditions in 2013. Although the concentration of SIN exceeds the target value, achieving the target of 0.444 mg/L in the wastewater will not have a measurable impact on SIN concentrations in the lower Mangatainoka River because of the magnitude of the SIN load upstream of the wastewater discharge.

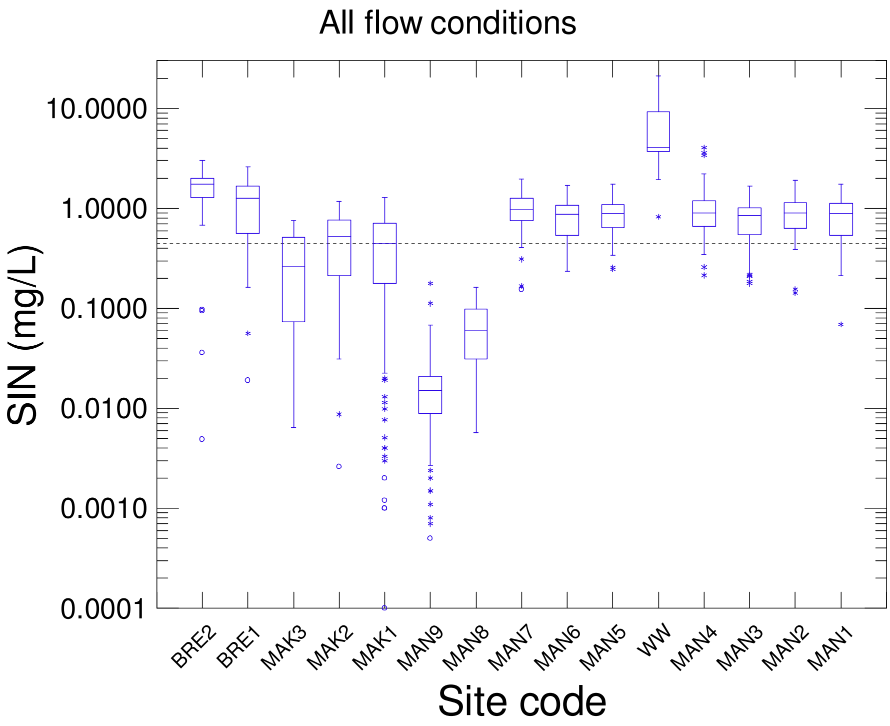


Figure 33. Comparison of SIN concentrations in the Mangatainoka River under all flow conditions, 2008-2013

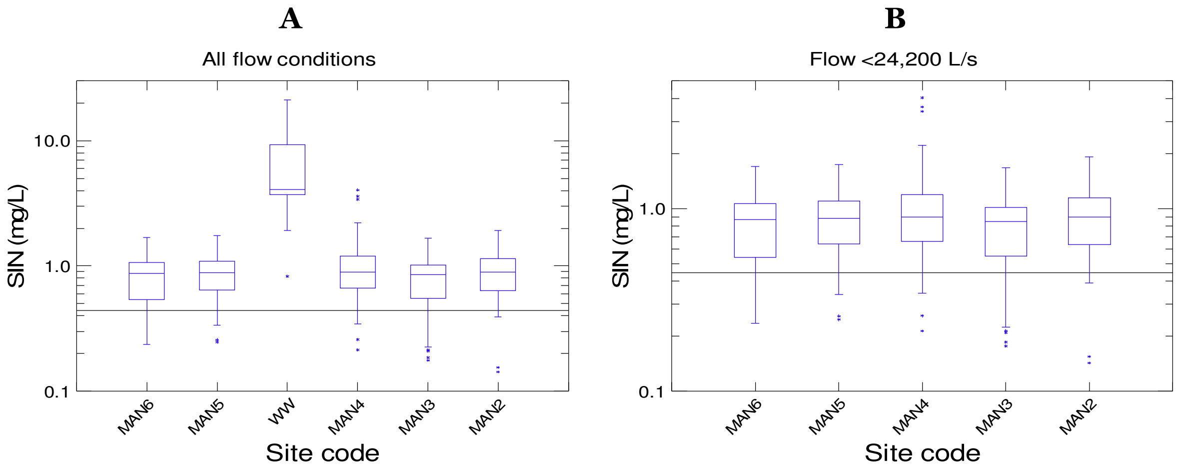


Figure 34. Spatial trend in SIN concentrations under all flow conditions (A) and under flow conditions less than the average 20%exceedance value – 24,200 L/s (B)

Summary for SIN

Although the median concentration of SIN in the discharge exceeds the target concentration by a factor of ten and the 1%ile SIN concentration is approximately twice the target threshold, reducing the concentration of SIN in the discharge is unlikely to have measurable effect on the concentrations of SIN downstream of the Pahiatua WWTP because of the persistently high load of SIN entering the Mangatainoka River upstream of Pahiatua.

3.2.11 Ammoniacal-N Concentration

Two targets have been established for the lower Mangatainoka River catchment:

- The annual average ammoniacal-N concentrations should not exceed 0.4 mg/L, and
- Ammoniacal-N concentration should never exceed 2.1 mg/L.

No flow conditions apply to either of these target values. Ammoniacal-N concentration data for the Mangatainoka River catchment are summarised in Figure 35(A), with concentrations in the lower catchment summarised in Figure 35(B).

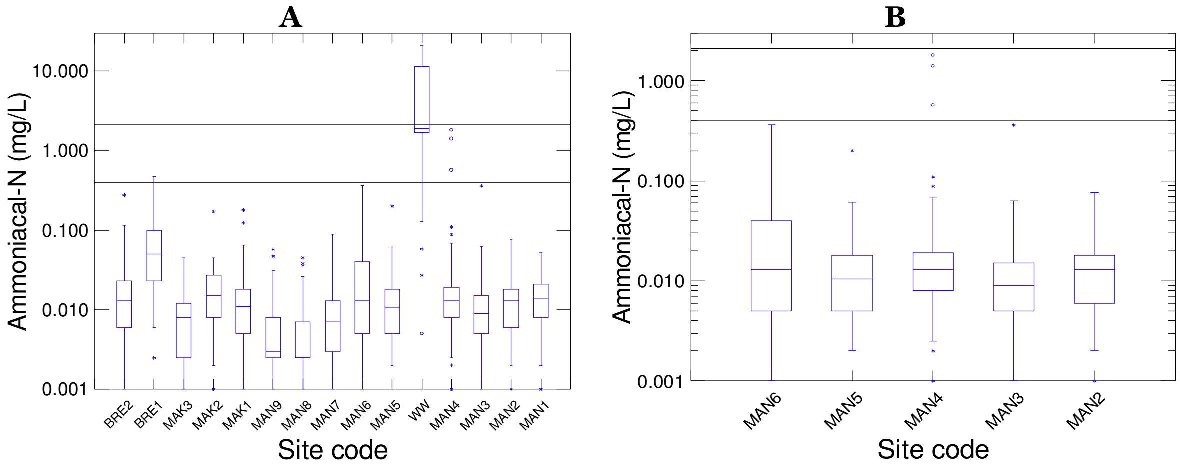


Figure 35. Comparison of ammoniacal-N concentrations in the Mangatainoka River under all flow conditions, 2008-2013

The results summarised in Figure 35 indicate that 75%ile concentration values for all sites except the wastewater discharge are lower than the regional target value. Median and average concentrations at all sites are well below the regional target value.

- Formal statistical testing indicated no practically important difference existed between sites MAN5 and MAN4 (upstream and downstream of the Pahiatua WWTP discharge).
- Statistical testing also indicated absence of trend over the period 2008-2013 for either site MAN5 or MAN4.
- Although the concentration of ammoniacal-N is elevated in the discharge, there is no measurable increase in river ammoniacal-N concentration after mixing.

It is also necessary to consider ammoniacal-N from the perspective of free ammonia concentrations. In aqueous solutions under natural conditions, ammonia exists in two forms –free ammonia (NH_3) and the ammonium ion (NH_4^+). The proportion of these interchangeable forms is determined by the pH and temperature of the water according to the equation:

$$Proportion\ of\ free\ ammonia\ (NH_3) = \frac{100}{1 + 10^{pK_a - pH}}\ (\%)$$

Where:

$$pK_a = \frac{2729.69}{T} + 0.1105 - 0.000071T$$

pK_a is the temperature-compensated dissociation constant for ammonia
T and pH are the measured water temperature and pH respectively.

The proportion of NH_3 (which is toxic in freshwater and marine environments) increases with pH. The ANZECC guidelines identify a high reliability trigger value for free ammonia of 0.9 mg/L at pH 8 that provides 95% species protection. At 20 °C and pH 9 this is equivalent to about 0.035 mg/L NH_3. The median temperature and pH of the Mangatainoka River downstream of the discharge (site MAN3) are 14.1 °C and 7.73 respectively. At these temperature and pH values the relative concentrations of a 0.9 mg/L ammoniacal-N solution will be 0.897 mg /L [NH_4^+] and 0.003 mg/L [NH_3]. This concentration is more than 10 times less than the ANZECC trigger value.

In Figure 36 the concentrations of unionised ammonia upstream and downstream of the wastewater discharge calculated from the ammoniacal-N concentration, pH and temperature at the time of sampling are summarised. The ANZECC 95% species protection concentration for pH 8 and 20 °C (0.035 mg/L) is also shown as a conservative reference (more than 50% of the samples collected have a pH less than 8, i.e. these will have a lower proportion of free ammonia). Figure 36 indicates:

- Exceedance of the ANZECC guideline in a single sample over the period 2008-2013.
- The trend line fitted to the data for the three sites indicates that there is little difference between free ammonia-N concentrations at these sites.
- Earlier Figure 5 (H) indicated that concentrations of ammoniacal-N in the wastewater discharge had decreased over the assessment period -
  - it is unlikely that the discharge will currently contain sufficient ammoniacal-N to cause exceedance of the free ammonia-N trigger concentrations after mixing.
  - the concentration of free ammonia-N upstream of the discharge are of the same magnitude as those downstream, i.e. there is no measurable increase in concentration associated with the wastewater discharge.

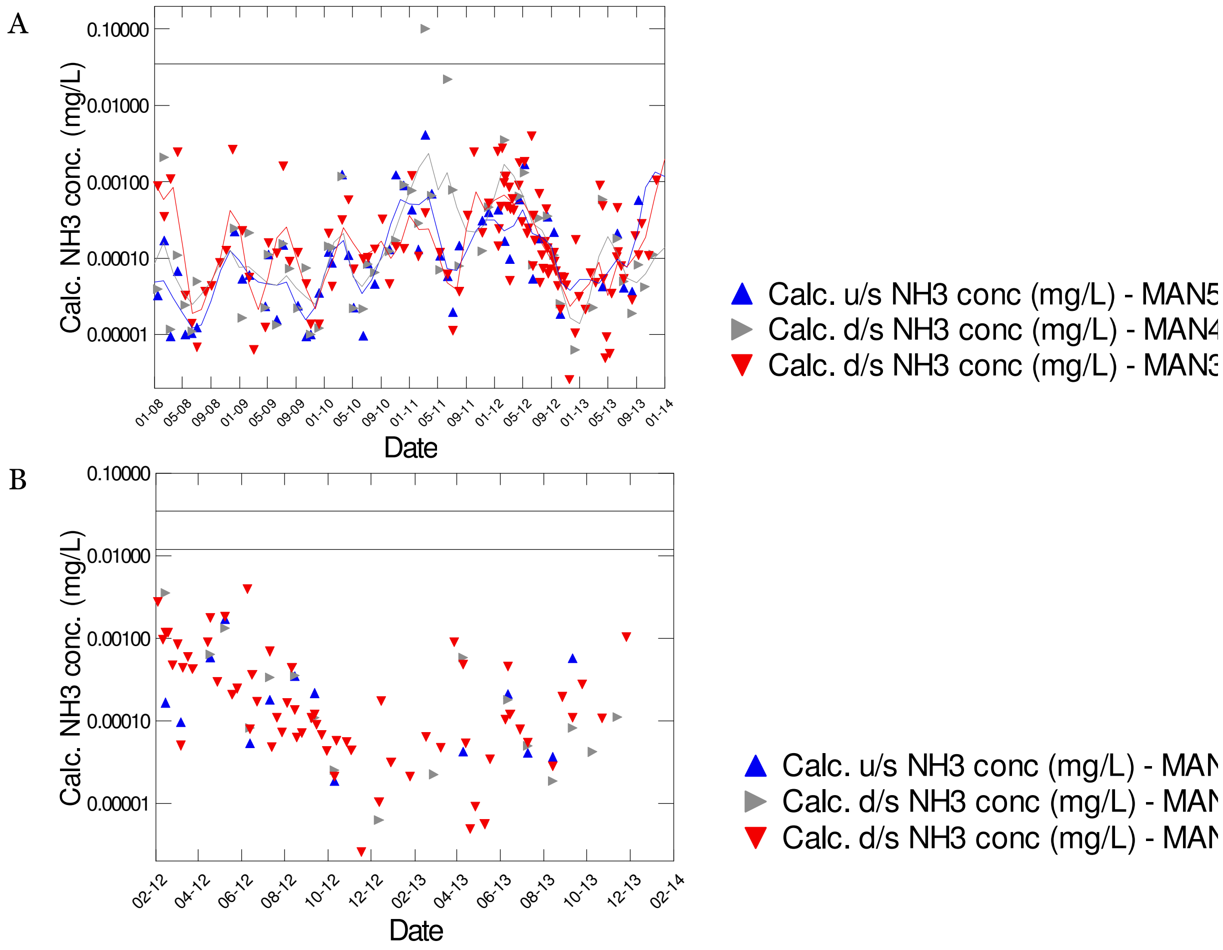


Figure 36. A) Comparison of free ammonia-N concentrations in the Mangatainoka River up- and downstream of the Pahiatua WWTP discharge under all flow conditions, 2008-2013. The horizontal line indicates the 95% species protection level (0.035 mg/L trigger concentration identified in the ANZECC guideline). The red, gray and blue lines indicate a least-squares trend line fitted to each data set. In B), the ANZECC 95% and 99% species protection trigger levels are shown for the period January 2012 – December 2013.

The results of statistical testing are included as section 6.8.

Summary for Ammoniacal-N

75th percentile ammoniacal-N concentrations in the Mangatainoka River are below the target concentrations.

The concentration (and presumably load) of ammoniacal-N in the wastewater discharge has decreased substantially since 2008.

There is no measurable increase in the concentration of ammoniacal-N downstream of the wastewater discharge.

Free ammonia-N concentrations are approximately 10 times and five time lower than the ANZECC 95 % and 99% species protection level respectively, and free ammonia concentrations are similar up- and downstream of the discharge.

3.3 Nutrient Load Modelling

The ability to effectively assess the effect of a discharge or treatment device may be limited by the available data. For river assessments, “continuous” flow data may be available at key locations in the catchment (typically measured every 15 minutes), whereas for most water quality variables (specifically nutrients), concentration data may only be available for relatively few grab samples. The input of materials to the stream and dilution once this material is in the stream channel is strongly dependent on flow conditions. Relating flow and concentration using instantaneous load or flux measurements allows the concentration time series to be extended over the flow time series record. Several techniques are available to undertake this task, including (e.g., (Cohn, 1995)):

- Manually fitting a line through a plot of concentration against time
- Calculating the instantaneous load or flux for the measured samples, and extrapolating these results to the entire flow record
- Developing "rating curve" that describes the relationship between instantaneous load or flux and flow
- Direct estimation methods, such as stratified sampling (where the relationship between concentration and flow is considered on a probability basis) – future sample collection is defined on the basis of current or recent historical flow-concentration data
- Ratio estimators, such as the Beale Estimator, which assumes a constant ratio between concentration and discharge.

Although some techniques are better than others, all are associated with elements of error or uncertainty. For example, the empirical relationship at the heart of the rating curve approach does not have a physical basis - nevertheless, it is commonly used and is adequate for many purposes. Through inclusion of additional terms (such as time, season or discharge), the variability associated with flow variability and time trends may be taken into account. The LOADEST software (Runkel, Crawford, & Cohn, 2004) incorporates three statistical procedures for calibrating models used for load estimation.

Statistical models are by nature limited – they are unable to incorporate terms necessary to account for the complex biogeochemical processes that take place within the river or stream. For example, nutrient uptake within biomass is poorly represented within the LOADEST suite (through flow variability, seasonal and time of day factors), whereas rating table approaches cannot account for flow variability or seasonal factors without significant manual intervention.

Despite these limitations, however, load modelling provides some insights into within-stream processes along a river channel and the impact of nutrient inputs and natural mitigation processes.

Estimating nutrient dynamics in the lower Mangatainoka River was undertaken using three techniques:

- A rating table approach (e.g. (Glysson, 1987)
- Application of a rating table approach that incorporates a series of randomised rating tables developed using a "bootstrap" selection processes (e.g. (Hudson, 2011))
- Application of the LOADEST modelling tool (Runkel et al., 2004).

In some cases, one of the modelling approaches was obviously better than others; for selected variables none of the models performed adequately. Despite these limitations, the model outputs are informative regarding season trends in nutrient concentration.

3.3.1 Modelling Procedures

3.3.1.1 Rating Table Models

- For each variable, the instantaneous flux was calculated for each sample result (i.e. the product of concentration (mg/L) and discharge (L/s) = flux (mg/s)).
- The relationship between flux and stream flow was explored using MS Excel; generally a log-linear relationship provided an acceptable relationship.
- The regression relationship was then applied to the daily mean stream-flow record to provide an estimate of the daily stream load or flux.
- An estimate of average daily stream concentration could be calculated by dividing the daily flux estimate by mean flow for the day.

3.3.1.2 LOADEST Estimates

- Three input files were prepared for the LOADEST modelling suite:

    - A daily stream flow record (in cubic feet per second)
    - A calibration file (flow in cubic feet per second and concentration at the time of sampling in mg/L)
    - An input file that instructed the software in terms of the output, units of measure, output and selection of model.

- Output included daily load estimates (kg/d) and monthly, seasonal and annual aggregates of load estimates.
- A daily stream concentration could be calculated by dividing the daily flux estimate by the mean flow for the day.

3.3.1.3 BOOTSTRAP Modelling Estimates

- A calibration file was pasted into one sheet of a macro-enabled MS Excel workbook
- A daily flow file was pasted into another sheet
- The VBA programme embedded in the workbook was used to randomly select a subset of the total number of pairs of concentration and flow results to create a regression relationship (rating table)
- Typically 100 samples were selected to provide 100 estimates of the river load or flux.
- These estimates were used to provide an estimate of the uncertainty associated with the load estimation.

3.3.1.4 Use of Model Outputs

Generally the BOOTSTRAP estimates were used to check the load estimates derived from the other models, while the time-series concentrations derived from the LOADEST and rating table approaches could be compared.

In all cases, use of the output is limited by model assumptions, including:

- log transformation creates a linear relationship between flux and stream flow,
- a sufficiently large number of samples exist to calibrate the regression model,
- the model is not being used to extrapolate beyond the range of calibration data.

3.3.2 Model Predictions

3.3.2.1 Estimated DRP Concentrations

Estimated DRP concentrations derived from rating table and LOADEST model estimates are summarised in Figure 37 through Figure 41.

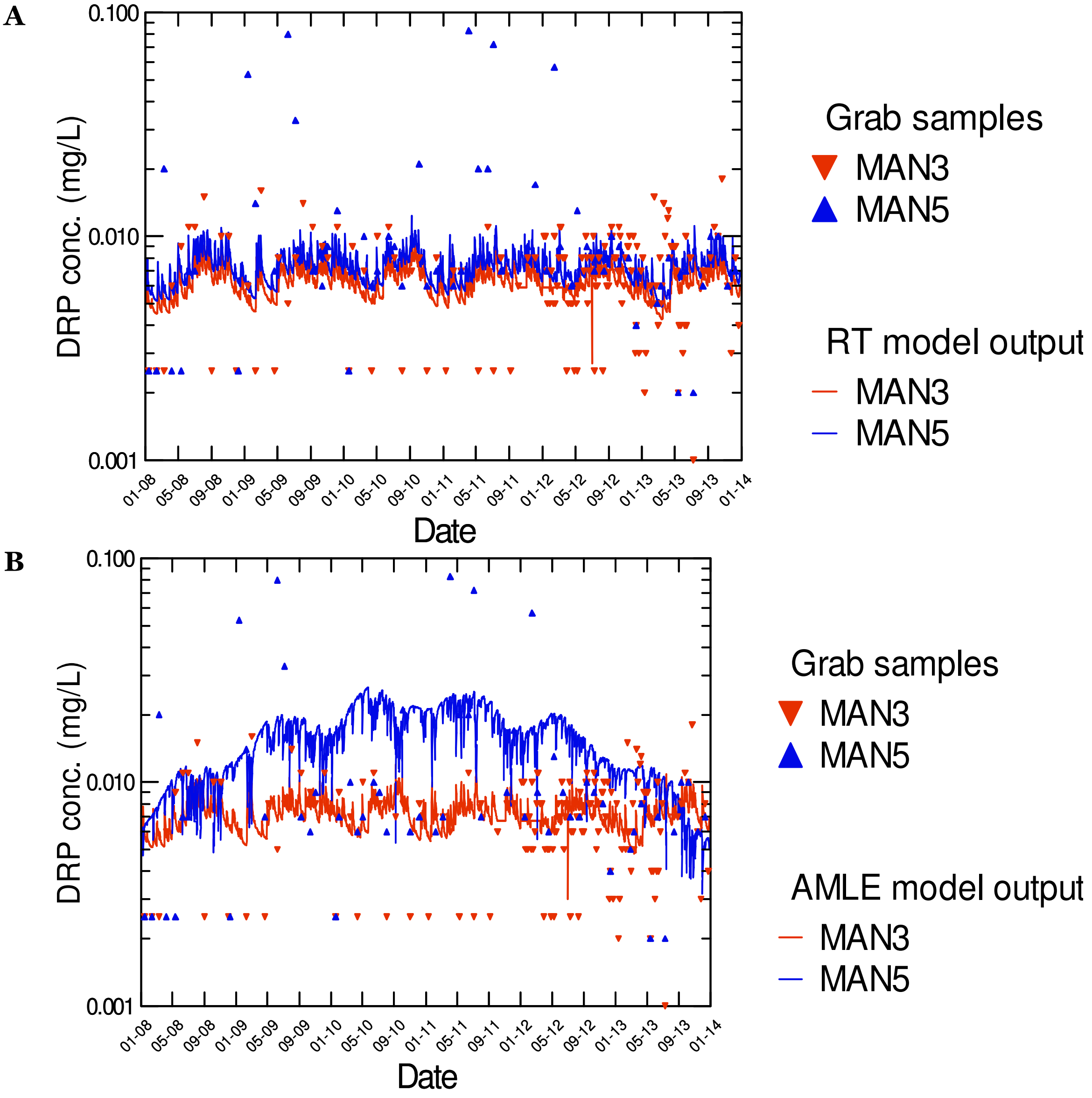


Figure 37. Estimates of DRP concentration derived from rating table (A) and LOADEST (B) model procedures

Estimates of DRP concentration appear subject to model selection. Both rating table and LOADEST model output indicate that upstream DRP concentrations appear slightly larger than those downstream of the wastewater discharge. In Section 3.2.9 it was demonstrated that DRP downstream DRP concentrations were generally within 1% of the upstream value. In Section 3.2.7 it was demonstrated that chlorophyll *a* concentrations increased immediately downstream of the wastewater discharge (MAN4), but decreased further downstream. The modelling results are consistent with these observations, and the following ecological mechanisms are proposed:

- Additional DRP input from the wastewater discharge stimulates periphyton response

- The periphyton growth in turn reduces the concentration of DRP in the river
- A seasonal effect is also evident, with lowest DRP concentrations occurring in the summer-autumn period
- The impact of the drought in summer 2012/13 is also evident, with particularly low DRP concentrations indicated – these conditions are consistent with low flows, clear water, warm water temperatures, resulting in elevated periphyton growth.

3.3.2.2 Estimated TP Concentrations

A time series of estimated TP concentrations derived from modelling is summarised in Figure 38 A and B. None of the models selected appeared to predict TP concentrations reliably. Although the rating table models for the two sites appeared to match each other closely (Figure 38 A), the relationship to grab samples was not good. These models under-predicted during periods of elevated TP concentrations, and over-predicted TP concentrations significantly during periods of low flow and low measured TP concentrations. This was particularly noticeable during the summer of 2011/12.

The LOADEST model outputs for the MLE and AMLE options provided almost invariant TP concentrations for the MAN5 site, with very minor indication of seasonality. The LAD option indicated a seasonal response similar to that of the rating table models, and more consistent with the observed concentrations. The LAD model estimated consistently higher concentrations in the river at the upstream site, whereas much smaller difference between upstream and downstream concentrations were predicted by the rating table models.

Neither model appears able to predict TP concentrations in response to within-river processes. This is exacerbated by three periods of missing flow record for the period January 2012-April 2012. Application of a rating table based on data for the period encompassing intensive data collection (May 2012-April 2013) did not improve rating table estimates appreciably.

Modelling DRP and TP concentrations upstream and downstream of the discharge demonstrates a complex ecological response to nutrient concentrations, likely to include:

- Uptake of dissolved, bioavailable nutrient and incorporation into plant tissue
- Very low concentrations of dissolved or sequestered nutrient in the water column during periods of low flow (available nutrient is effectively fully utilised by the plant community)
- Sloughing off of nutrient incorporated in algal detritus during periods of high flow
- Modelling indicates slightly higher concentration of dissolved and particulate phosphorus upstream of the wastewater discharge – this probably reflects the continual input of phosphorus into the lower Mangatainoka River from the wastewater discharge. This material is able to:
    - » sustain a population of periphyton that is able to more rapidly respond to increases in nutrient input from other sources (i.e. further upstream),
    - » incorporate this nutrient as biomass, and
    - » effectively deplete phosphorus from the water column.

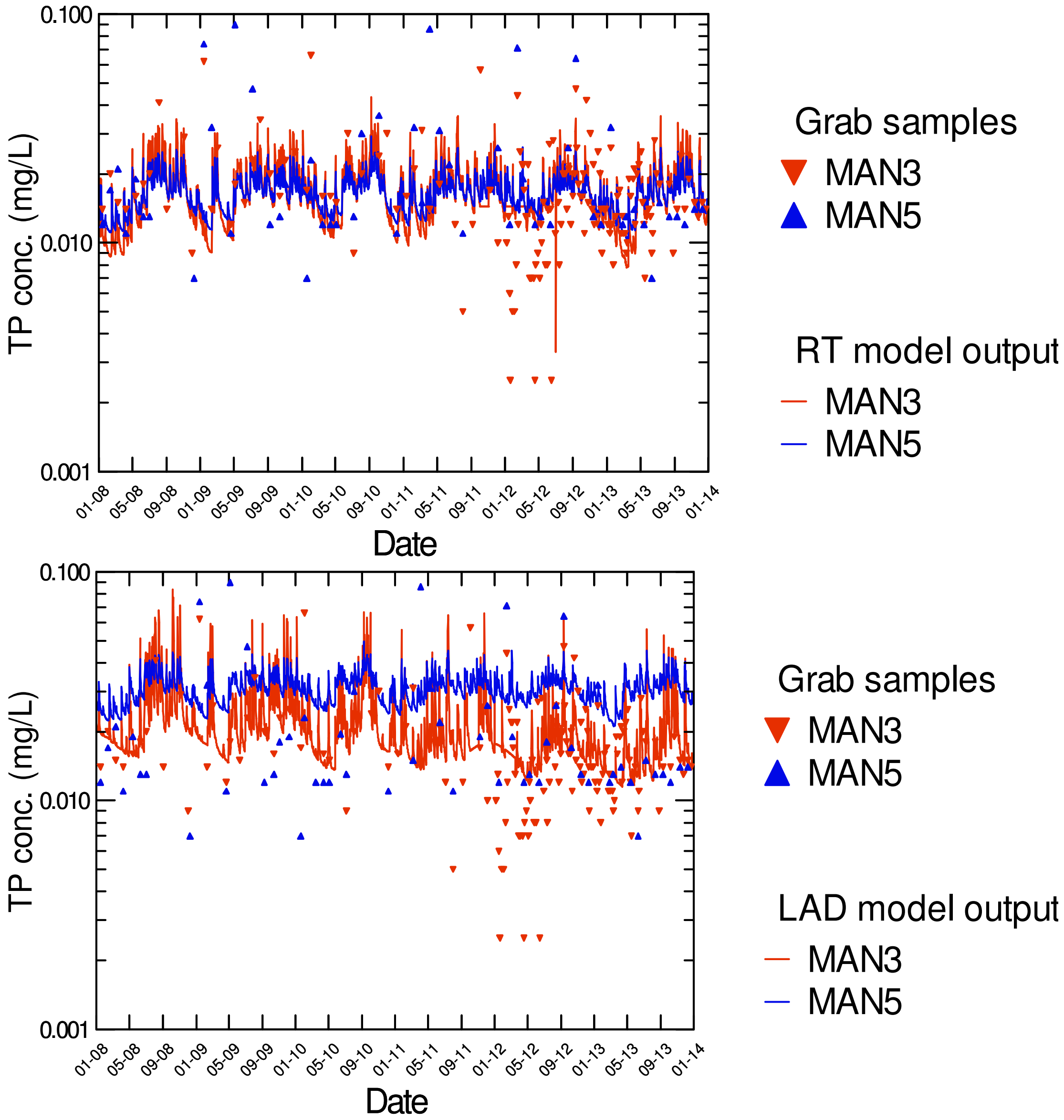


Figure 38. Estimates of TP concentration derived from rating table (A) and LOADEST (B) model procedures

3.3.2.3 DRP and TP Load Estimates

From the modelling it is possible to estimate the magnitude and timing of the likely load of nutrients in the lower Mangatainoka River (Figure 39 A-D). From the earlier discussion, the values derived from the LOADEST modelling are considered to better represent the actual magnitude of the DRP and TP loads. Either model adequately represents the dynamics of phosphorus loads over time. Both models indicate seasonal minima in DRP and TP load during the summer low-flow periods, and seasonal maxima in winter.

If this hypothesis is true, the reach downstream of the wastewater discharge is most likely to experience nuisance growths under summer low-flow conditions. Additional input of phosphorus is likely to be utilised rapidly by the existing periphyton or allow additional periphyton to establish.

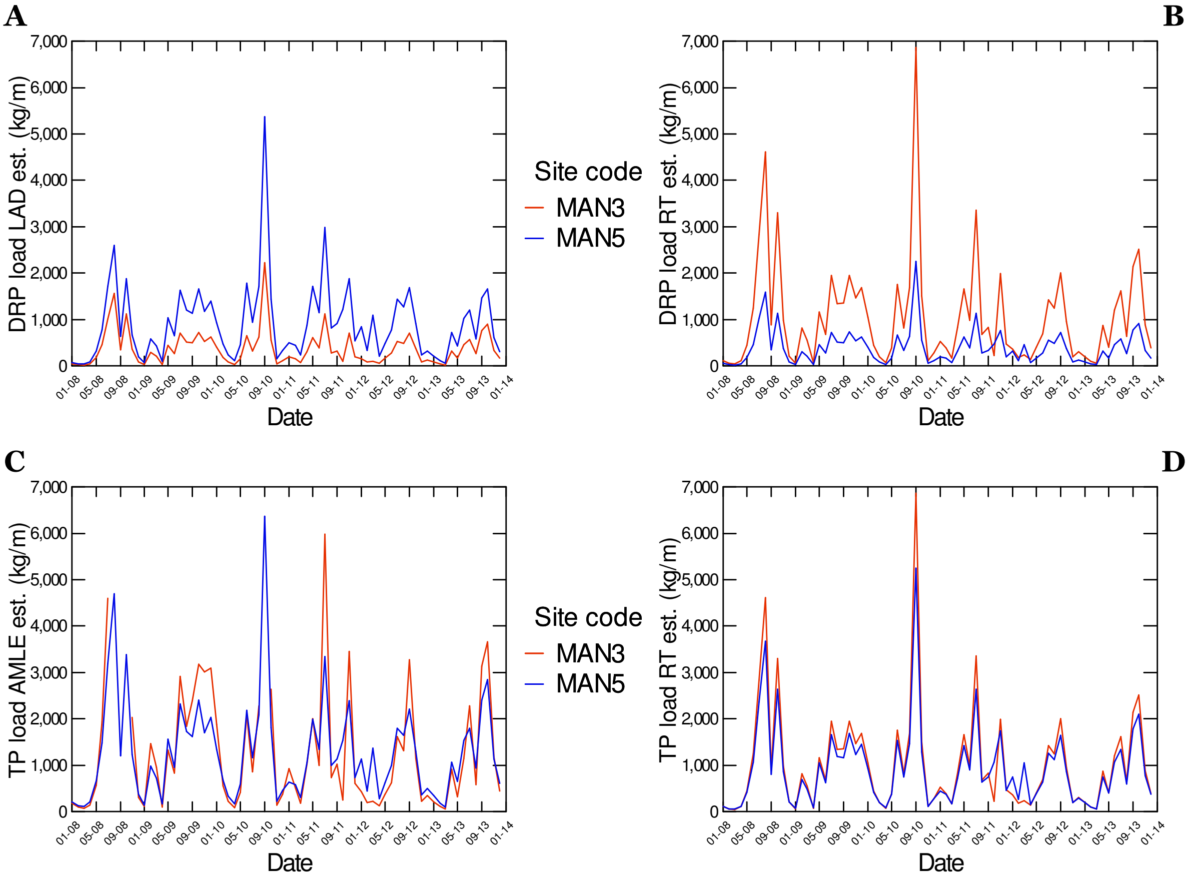


Figure 39. Estimates of DRP and TP load derived from LOADEST (A, C) and rating table (B, D) modelling procedures

Although limiting phosphorus input to the river from the wastewater discharge is appropriate, this action should be accompanied by a catchment-wide strategy aimed at reducing phosphorus inputs to the river from all sources. The modelling exercise indicates that the increase in P load from the wastewater discharge is relatively minor in comparison to the load arising from the upper catchment. This assessment would greatly benefit from having wastewater flow data, allowing the accurate estimation of phosphorus loads in the wastewater – currently only concentration data are available. More detailed investigation of productivity in the lower reaches of the river should accompany this assessment, so that the ecological response to nutrient inputs may be better understood.

3.3.2.4 Nitrate-N Concentrations

Estimated nitrate-N concentrations derived from rating table and LOADEST model estimates are summarised in Figure 40 A and B respectively. The rating table model poorly represents the wide variation in concentration evident from the grab samples; although all of the LOADEST model options better represented this variability, all also failed to perfectly capture the seasonal minima evident in grab samples collected during the summer months. The modelling confirms the conclusions reported in Section 3.2.10:

- SIN concentrations (of which nitrate-N is the dominant component) were similar upstream and downstream of the Pahiatua WWTP discharge.
- The impact of the discharge is likely to be less than minor because of the magnitude of the load of nitrate-N from the upper catchment.

- The modelling also confirms that with the exception of the summer low-flow period, concentrations of SIN are likely to exceed 0.444 mg/L both up- and downstream of the discharge.

Seasonal minima are related to biological activity in the river, particularly denitrification. This microbiologically-mediated process is influenced by a complex interaction between water temperature, labile carbon (i.e. readily bioavailable carbon) and redox conditions in sediments and biomass as follows:

- Stable, low flows and high solar radiation in summer increase water temperature, which in turn:
  - Increases biological activity (e.g. primary productivity, which increases biomass, in turn increasing labile carbon)
  - Reduces dissolved oxygen concentrations (by reducing oxygen solubility and re-aeration rates)
  - Favours more reducing conditions in sediments.

These processes all favour high rates of denitrification. The model outputs indicate roughly equivalent minimum nitrate-N concentrations both upstream and downstream of the wastewater discharge – this indicates that inputs of labile carbon in the discharge are minor relative to the carbon generated within the river channel. This is consistent with what was concluded regarding inputs of $sCBOD_5$ in Section 3.2.5.

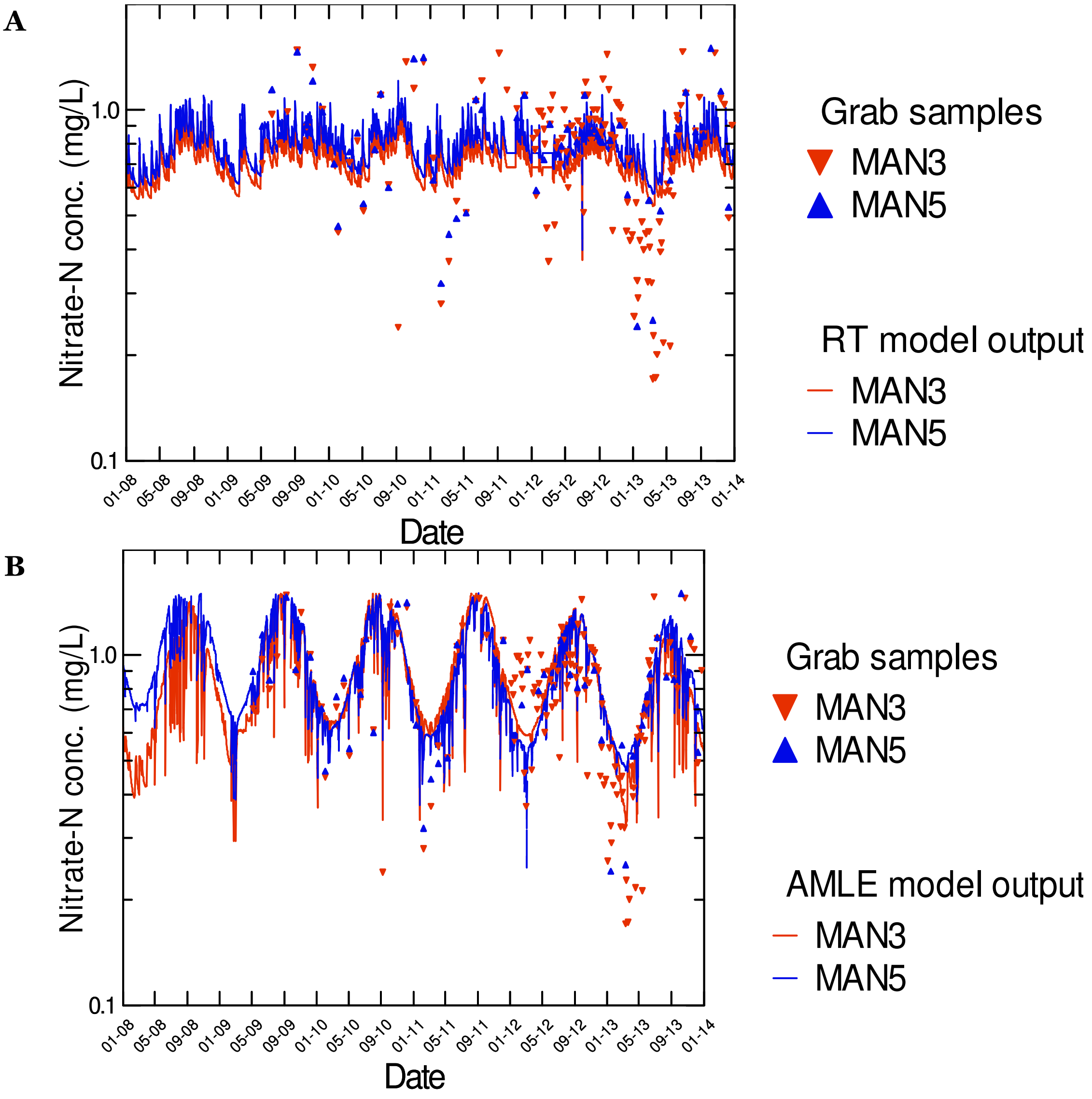


Figure 40. Estimates of nitrate-N concentration derived from rating table (A) and LOADEST (B) modelling procedures

3.3.2.5 Total Nitrogen Concentrations

Figure 41 (A and B) summarises TN concentrations predicted by rating table and LOADEST modelling. They are very similar to those earlier calculated for nitrate-N. This is to be expected, because nitrate-N is the major component of TN in the lower river. For example, nitrate-N accounted for more than 90% of the TN concentration both upstream and downstream of the discharge during 2013.

The earlier discussion regarding the suitability of a rating table model for estimating nitrate-N concentrations apply equally to TN – any of the LOADEST options appear better suited to the purpose.

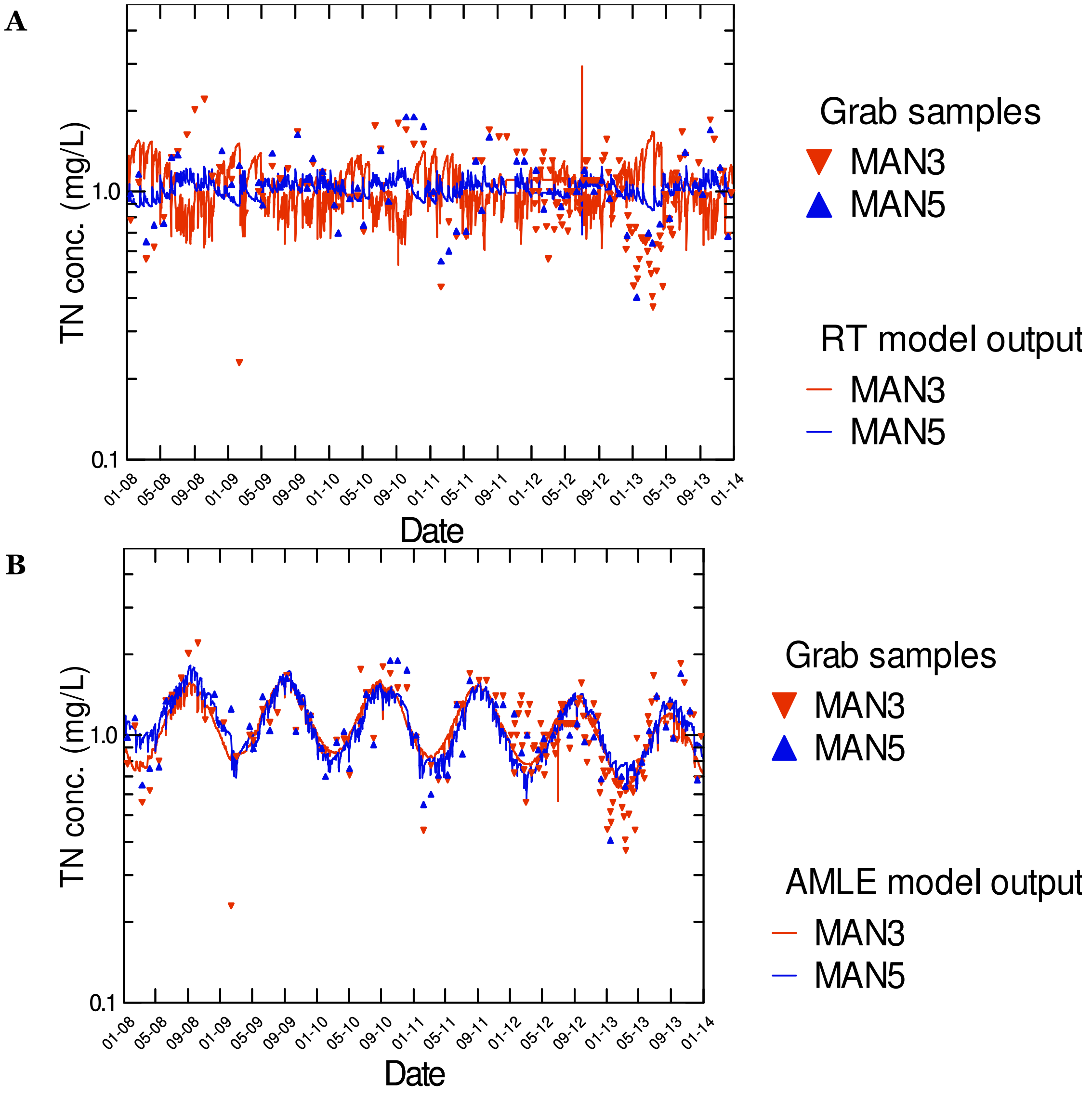


Figure 41. Estimates of TN concentration derived from rating table (A) and LOADEST (B) model procedures

3.3.2.6 Nitrate-N and TN Loads

In the previous section it was noted that nitrate-N accounted for most of the measured TN concentration, so the discussion that follows relates primarily to nitrate-N loads.

Regardless of their abilities to capture the nitrogen concentration minima, both modelling procedures clearly indicate the strong seasonal trend in nitrogen concentration (Figure 42 A-D). Although input of nitrogen to waterways is complex, it is dominated by two routes:

- Input of particulate-bound material as surface runoff during rainfall events, and
- Input of soluble forms of nitrogen through groundwater (shallow and deep).

Figure 42 indicates the response of nitrogen movement through soils in response to rainfall – nitrate is poorly retained in the landscape and emerges in surface waters in annual “pulses” during winter and spring. In the subsequent summer, the input of nitrogen decreases and the biological processes (denitrification and assimilation) reduce the concentration of nitrogen in surface waters and the volume of surface waters decrease as well. This creates the distinctly seasonal variation in concentration and load.

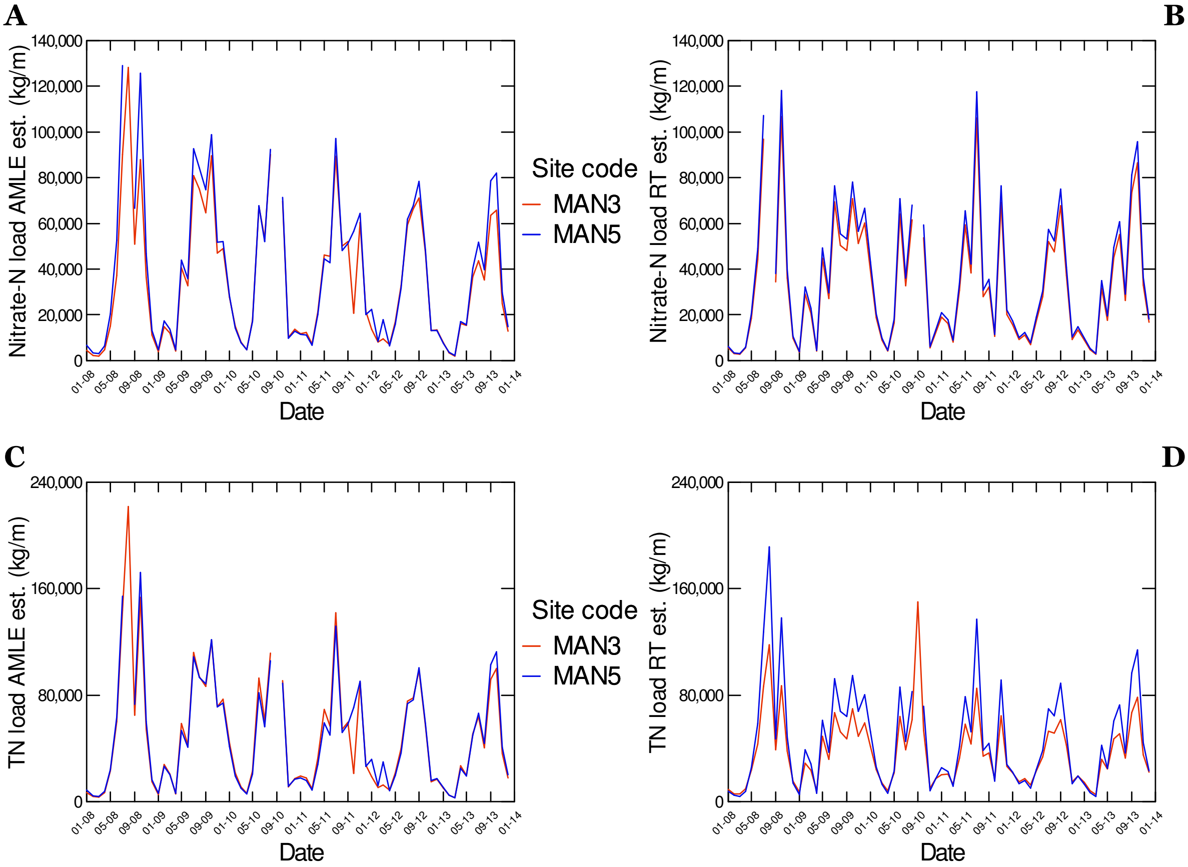


Figure 42. Estimates of nitrate-N and TN load derived from LOADEST (A, C) and rating table (B, D) modelling procedures

3.3.3 Toxic Contaminants

Limited data exist for the assessment of toxic contaminants. For example, no data exists for toxic metals or hazardous organic contaminants in either the wastewater discharge or the Mangatainoka River upstream or downstream of the wastewater discharge. Presumably limited manufacturing occurs in Pahiatua, and trade waste monitoring ensures that discharge of potentially hazardous materials are maintained within acceptable limits.

Toxicity limits have been established by ANZECC for ammoniacal-N (and the associated free ammonia component). These were discussed in Section 3.2.11, where it was identified that the discharge does not pose a toxicity risk to the Mangatainoka River in terms of free ammonia-N.

Recently the nitrate-N toxicity thresholds for New Zealand were revised on behalf of Regional Councils and Central Government (Hickey, 2013). A series of Grading and Surveillance nitrate-N concentration thresholds were established for a range of ecosystems in terms of median and 95th percentile concentrations respectively. It is appropriate to assess nitrate-N concentrations in the lower Mangatainoka River in terms of the chronic exposure concentration guideline proposed for moderately disturbed systems (providing 95% species protection). This ecosystem is described as being “subject to a range of disturbance from human activities, but with minor effects”. The two toxicity guideline values are 2.4 mg/L (annual median concentration) and 3.5 mg/L (95th percentile concentration). In-river and wastewater concentration values are compared with these two toxicity guidelines in Figure 43 (A and B). River and wastewater concentrations are below both toxicity thresholds, indicating that the discharge is not a source of nitrate-N in amounts likely to constitute a toxicity hazard.

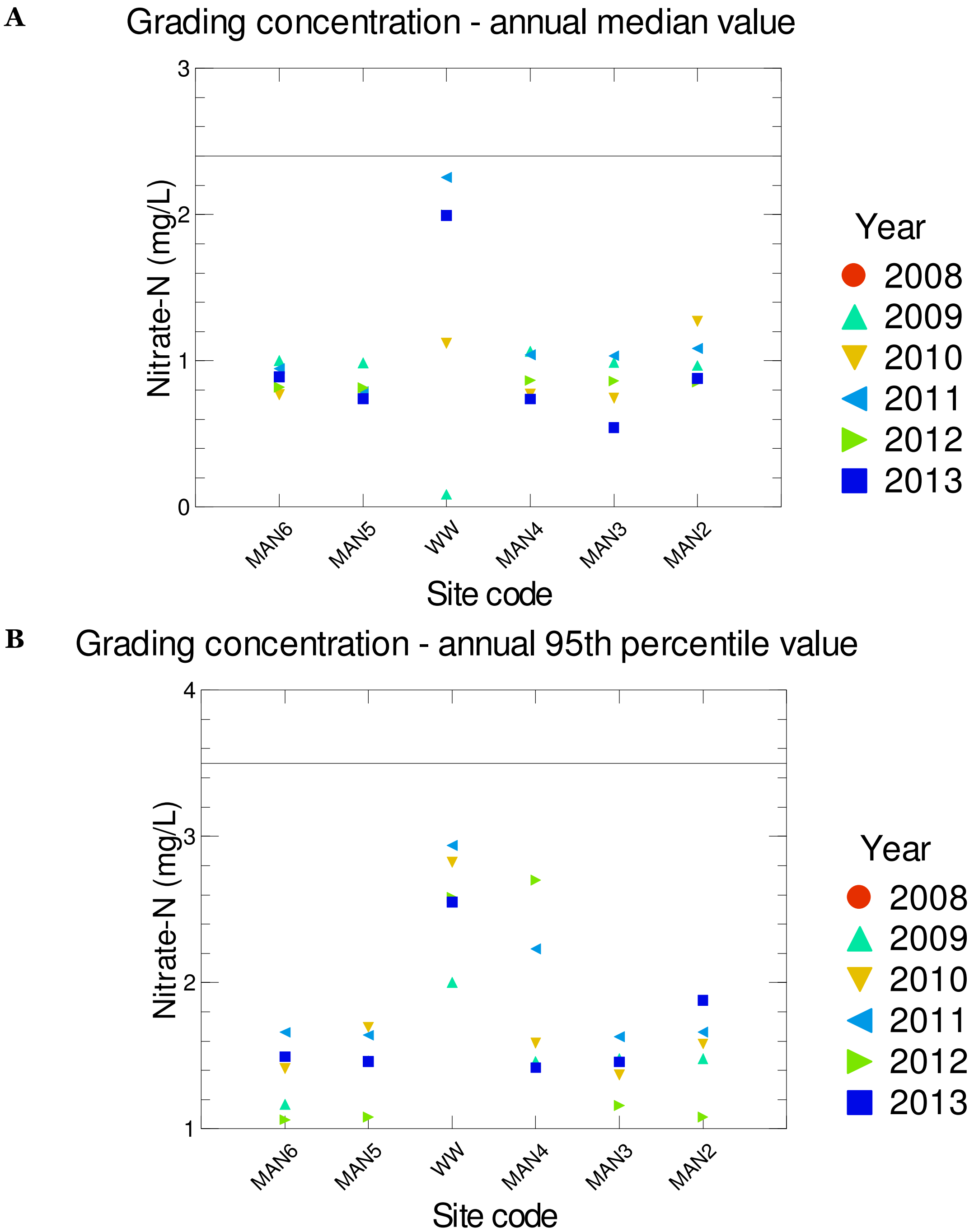


Figure 43: Comparison of A) annual median and B) 95th pecentile nitrate-N concentrations in the lower Mangatainoka River catchment with toxicity guideline values, 2008-2013. In A) the guideline value is 2.4 mg/L and in B) the value is 3.5 mg/L

4 Outcomes of Assessment of Effects

Between 2008 and 2010, Tararua District Council implemented a series of wastewater treatment process upgrades aimed at reducing the concentration particulate materials, phosphorus, and faecal bacteria in the treated wastewater discharge.

Although the absence of flow data makes estimation of the loads of these and other wastewater constituents difficult, the concentration data indicates that the quality of wastewater has improved measurably from 2008 to 2013. Much of the improvement in wastewater quality occurred during the 2010 calendar year. Table 10 summarises the changes in wastewater quality (data obtained from the site “Pahiatua STP at Tertiary oxipond waste” (coded “WW” in this assessment).

Of the 14 water quality variables summarised above, monitoring data indicate that for 12, the changes to wastewater treatment have improved the quality of wastewater measurably (decreased concentrations). For the remaining two variables, the concentrations have increased. This creates the potential for increased impact on receiving waters. If these impacts occur, there is the potential for adverse effect. Ideally the concentrations of specific variables would be combined with flow to estimate the load or flux of material. Although flow data are not available, it is likely that the volumes and rate of discharge of wastewater have not altered appreciably over the assessment period, and changes in the size of loads of all variables are likely to mirror the trends evident from the concentration data.

The Horizons Regional Council (HRC) OnePlan identifies a series of water quality targets and management objectives – these translate to the quality of water (in terms of concentrations of specific variables) that are likely to achieve or support a series of uses. For example, if the concentration of faecal indicator bacteria are below a specific threshold, the water is likely to be suitable for contact recreation or comply with specific cultural requirements. Targets defined in OnePlan Table D.1A and OnePlan Table D5.A were used to assess the impact of the wastewater discharge on surface water quality in the Mangatainoka River in the reach downstream of the Pahiatua WWTP discharge.

Assessment of the relative change in water quality between sites upstream and downstream of the wastewater discharge allows the magnitude of impact (positive or negative) to be assessed. Key assessment sites were “Mangatainoka River at u/s Pahiatua STP” (MAN5), “Mangatainoka River at d/s Pahiatua STP” (MAN4) and “Mangatainoka River at Brewery – SH2 bridge” (MAN3). Flow data were available for the “Mangatainoka at Pahiatua Town Bridge” site (MAN6). Data were assessed over the period 2008-2013 (inclusive).

The impact of the wastewater discharge was assessed specifically for the period 2012-2013 inclusive. Assessment over this period allows:

- the impact of the discharge to be assessed over a sufficient period of time to allow the impact to be determined, and
- allows the impact of the current discharge to be determined.

The results of this comparison of measured concentrations with target concentrations identified in the Horizons OnePlan are summarised in Table 11.

Table 10: Change in the quality of treated wastewater over the period 2009-2013 (unless indicated otherwise)

Water quality variable	Median Concentration		Change in concentration	Proportional change (%)	Likely effect on receiving environment
	2008	2013			
E. coli (cfu/100 mL)	4362.5	0	-4362.5	-100[c]	Improvement in quality, Reduced impact
Enterococci (cfu/100 mL)	8015.5	0	-8015.5	-100[c]	Improvement in quality, Reduced impact
Total suspended solids (mg/L)	71.5	1	-70.5	-98	Improvement in quality, Reduced impact
Suspended solids (mg/L)	3.5[A]	1[A]	-2.5	-71	Improvement in quality, Reduced impact
Turbidity	29.8	5.2	-24.6	-83	Improvement in quality, Reduced impact
Volatile matter (mg/L)	65	0.5	-64.5	-99	Improvement in quality, Reduced impact
Ammoniacal-N (mg/L)	6.07	1.7765	-4.293	-71	Improvement in quality, Reduced impact
Nitrite-N (mg/L)	0.056[B]	0.006[B]	-0.050	-89	Improvement in quality, Reduced impact
Nitrate-N (mg/L)	**0.086[B]**	**1.991[B]**	**1.905**	**2203**	**Increase in concentration, Possible increased impact**
Total organic nitrogen (mg/L)	**0.350**	**2.001**	**1.650**	**471**	**Increase in concentration, Possible increased impact**
Total nitrogen (mg/L)	14.95	3.945	-11.005	-74	Improvement in quality, Reduced impact
Dissolved reactive phosphate (mg/L)	2.517	0.027	-2.489	-99	Improvement in quality, Reduced impact
Total phosphorus (mg/L)	4.225	0.107	-4.117	-97	Improvement in quality, Reduced impact
Carbonaceous BOD$_5$ (mg/L)	2.25	1	-1.25	-55	Improvement in quality, Reduced impact

Notes:

[A] Assessment period 2011-2013

[B] Assessment period 2009-2013

[C] Rounding up; practically >>99%

Table 11: Comparison of measured surface water quality in terms of key water quality variables (2012-2013 inclusive) with Horizons OnePlan target concentrations or values (text in bold). Other results indicate median concentrations, or distribution of measured concentrations (as percentile) relative to target threshold values.

Water quality variable	Statistic or measurement	Value or Range	Units	Flow condition	Measured concentration or value of water quality variable at each site		Proportion noncompliant, 2012-2013 (%)	Comment
					Upstream (MAN5)	Downstream (MAN4)		
pH	**Instantaneous**	**7.0 – 8.5**	**Units**	**All flows**	**7.6 (median)**	**7.6 (median)**	**-**	
				All flows	pH 7 = 5th % ile	pH 7.2< 5th %ile	5 - 10	
				All flows	pH 8.5 = 95th %ile	pH 8.5 > 90th %ile		
pH	**Instantaneous change**	**<0.5**	**Units**	**All flows**	**-**	**-**	**10**	
Water temperature	**Instantaneous**	**<19**	**°C**	**All flows**	**19 ≅ 85th %ile**	**19 ≅ 85th %ile**	**~15**	
				All flows	14.7 (median)	13.9 (median)	-	
Water temperature	**Instantaneous change**	**<3**	**°C**	**All flows**	**-**	**-**	**0**	
Dissolved oxygen	**Instantaneous**	**>80**	**% sat.**	**All flows**	**86.4 = 1st %ile**	**88.4 = 1st %ile**	**<1**	
				All flows	104.1 (median)	100.8 (median)	-	
Soluble cBOD5	**Monthly average, flow condition**	**1.5**	**mg/L**	**Flow <20%ile exceedance**	**0.78 (mean)**	**0.8 (mean)**	**-**	**(Insufficient data to assess - single value/month)**
			mg/L	Flow <20%ile exceedance	1 < 99th %ile	1 < 99th %ile	-	
Particulate Organic Matter	**Average, flow condition**	**<5**	**mg/L**	**Flow <50%ile exceedance**	**1.13 (mean)**	**1.7 (mean)**	**0**	
					3.4 = 99th %ile	5 ≅ 94th %ile	-	
Periphyton as Chlorophyll *a*	**Instantaneous**	**<120**	**mg/m^2**	**All flows**	**96th %ile**	**92nd %ile[A]**	**~4% (u/s) - ~8% (d/s)**	
					13.6 (median)	37 (median)	-	
					13.6 (median)	33.5 (median)[A]	-	
Visible periphyton cover	**Instantaneous**	**<30**	**%**	**All flows**	**92% (median)**	**~96% (median)**	**~85% (u/s) – 95% (d/s)**	
Visible periphyton cover as diatoms or cyanobacteria	**Instantaneous**	**<60**	**%**	**All flows**	**3.5 % (median)**	**~ 2% (median)**	**4% (u/s) - ~1% (d/s)**	

Water quality variable	Statistic or measurement	Value or Range	Units	Flow condition	Measured concentration or value of water quality variable at each site		Proportion noncompliant, 2012-2013 (%)	Comment
					Upstream (MAN5)	**Downstream (MAN4)**		
Dissolved reactive phosphate	**Annual average, flow condition**	**<0.010**	**mg/L**	**Flow <20%ile exceedance**	**0.009 (mean)**	**0.013 (mean)**	**~30**	
					0.010 ≅ 84th %ile	0.010 = 70th %ile		
Soluble inorganic nitrogen	**Annual average, flow condition**	**<0.444**	**mg/L**	**Flow <20%ile exceedance**	**0.773 (mean)**	**0.920 (mean)**	**0**	
					0.444 ≅ 15th %ile	0.444 ≅ 15th %ile		
Proportion deposited sediment cover	Maximum	<20	%	All flows	-	-	-	SoE reporting only
Macroinvertebrate Community Index (MCI)	Minimum	Not defined	Units	All flows	-	-	-	SoE reporting only
QMCI	**change (reduction)**	**<20%**	**Units**	**All flows**	**4.83**	**4.49**	**-7%**	
Ammoniacal-N	**Annual average**	**0.400**	**mg/L**	**All flows**	**0.012 (mean)**	**0.035 (mean)**	**0**	
					0.1 > 95th %ile	0.4 > 95th %ile		
Ammoniacal-N	**Maximum**	**2.1**	**mg/L**	**All flows**	**0.005 (max)**	**0.57 (max)**	**0**	
Toxic contaminants	Maximum	<99%	mg/L	All flows	-	-	-	Specific data not available
Toxic contaminants – Nitrate-N	Annual median	2.4	mg/L	All flows	**0.81**	**0.85**	**0**	**Uses latest ecotoxicology assessment guideline values**
Toxic contaminants – Nitrate-N	95th percentile	3.5	mg/L	All flows	**1.24**	**1.95**	**0**	**Uses latest ecotoxicology assessment guideline values**
Toxic contaminants – Ammoniacal-N	Maximum	0.32	mg/L	All flows	0.005	0.011	0	ANZECC 99% species protection
Visual clarity	**Minimum according to flow condition**	**>3**	**m**	**River flow < 50%ile exceedance**	**3.05 = 75th %ile**	**3.04 = 40th %ile**	**~70% (u/s) – 80% or 40%[A] (d/s)**	

Water quality variable	Statistic or measurement	Value or Range	Units	Flow condition	Measured concentration or value of water quality variable at each site		Proportion noncompliant, 2012-2013 (%)	Comment
					Upstream (MAN5)	Downstream (MAN4)		
Visual clarity	**Change**	**<20%**		**River flow < 50%ile exceedance**			**45%[A]**	
***E. coli* concentration**	**Instantaneous maximum, flow condition**	**260**	**/100 mL**	**Flow < 50%ile exceedance**	**2000 (max)**	**4045 (max)**	**-**	
					260 ≅ 78th %ile	260 ≅ 45th %ile	12% (u/s) - 55% (d/s)	
	Instantaneous maximum, flow condition	**260**	**/100 mL**	**Flow < 50%ile exceedance**	**2000 (max)**	**2421 (max)[A]**	**-**	
					260 ≅ 78th %ile	260 ≅ 85th %ile[A]	12% (u/s) – 15% (d/s)	
***E. coli* concentration**	**Instantaneous maximum, flow condition**	**550**	**/100 mL**	**Flow < 20%ile exceedance**	**2000 (max)**	**4045 (max)**	**-**	
					550 ≅ 91st %ile	550 ≅ 82nd %ile	9% (u/s) – 18% (d/s)	
	Instantaneous maximum, flow condition	**550**	**/100 mL**	**Flow < 20%ile exceedance**	**2000 (max)**	**2421 (max)[A]**	**-**	
					550 ≅ 91st %ile	550 ≅ 92nd %ile[A]	9% (u/s) – 8% (d/s)	

Notes:

[A] = compliance assessed using MAN3 as impact site because more results were available than for MAN4.

Consideration of the data available indicates that the concentrations (and loads) of many variables of concern are elevated upstream of the wastewater discharge. This reflects the impact of general land use (primarily pastoral farming), as well as point source discharges (domestic and industrial wastewater discharges).The policies, objectives and water quality targets of the OnePlan intend to decrease the impact of all these sources of contaminants to achieve catchment-wide water quality improvement. This approach is consistent with the National Policy Statement for Freshwater Management, associated National Environmental Standards (NES FM), the National Objectives Framework (NOF) process (New Zealand Government, 2011) and associated technical work (e.g. (Davies-Colley, Franklin, Wilcock, Clearwater, & Hickey, 2013; Matheson, 2012; Snelder, Biggs, Kilroy, & Booker, 2013)).

Consideration of river water quality and condition in terms of the HRC OnePlan water quality targets indicates:

4.1 pH change and compliance with absolute target pH values

- 10% of sample pairs indicated change in pH greater than 0.5 units during the assessment period.
- Less than 10% of upstream samples did not fall within the pH range 7 – 9.5, whereas 17% of downstream samples did not fall into this range.
- In general, non-conforming pH happens both upstream and downstream of the discharge, indicating that the pH response is general, rather than the wastewater discharge.

The pH changes observed are not extreme and are within the range likely to be caused by primary productivity and respiration in nutrient enriched streams. As such they are symptoms of general nutrient enrichment of the Mangatainoka River, rather than impact by the Pahiatua WWTP specifically. This is supported by a decrease in the number of non-conformances downstream of the discharge since 2008.

4.2 Change in water temperature

The discharge does not alter the temperature of the Mangatainoka River measurably.

4.3 Changes in visual clarity

- Under all flow conditions, visual clarity in the lower Mangatainoka River catchment is generally likely to be less than 3 m.
- 25% of visual clarity measurements made at site MAN3 are likely to exceed this target (the highest for all sites between the Town Bridge site and the confluence with the Tiraumea River).
- For flows less than the median, more than 75% of all measurements of visual clarity are likely to be lower than 3 m with the exception of the MAN3 site (downstream of the wastewater discharge), where 50% of measurements are likely to be lower than 3 m.
- It is possible that the increased clarity at this site is a consequence of the greater number of clarity measurements, rather than water quality improvement. Pairwise comparison (of measurements made on the same day) indicates that visual clarity is more likely to decrease downstream of the wastewater discharge than increase.

The discharge does not alter the visual clarity of the Mangatainoka River measurably (sites MAN5 vs. MAN4). Highest visual clarity in the lower Mangatainoka River occurs at site MAN3, downstream of the WWTP discharge.

4.4 Faecal indicator organism concentrations (*E. coli*)

- The concentration of faecal indicator organisms (*E. coli*) discharged from the WWTP to the Mangatainoka River has decreased by approximately 4-log units since 2008.
- Under median flow conditions, less than 20% of samples have exceeded the HRC target for river water quality since 2011. In 2013, less than 5% of samples exceeded the HRC target.

Since about 2012, the wastewater discharge may actually improve the microbiological quality of the receiving environment by slightly diluting upstream water and associated faecal indicator organism contaminant load.

4.5 Soluble carbonaceous BOD_5 concentrations

Insufficient data exists to determine the impact of the discharge in terms of this variable. When other variables are considered as well, however, it is unlikely that the wastewater has an adverse effect on the concentrations of soluble BOD_5 in the lower Mangatainoka River.

4.6 Particulate Organic Matter (POM)

No exceedance of the water quality target for POM occurred along the lower Mangatainoka River catchment, and there is no evidence of an increase in POM downstream of the WWTP discharge.

4.7 Periphyton (as chlorophyll *a*, extent of cover and proportion of cyanobacteria)

The OnePlan establishes a water quality target of 120 mg chlorophyll *a*/m^2, on a sample by sample basis.

Median chlorophyll *a* concentrations are greatest at MAN4, downstream the WWTP discharge. Trends in chlorophyll *a* concentration over time indicate catchment-wide influences as well as a possibly stimulatory effects from the Pahiatua WWTP discharge

Visible periphyton cover indicates a general increase in the proportion of film metric at all sites in the lower Mangatainoka River over the period 2008 to 2013. This trend is equally strong at MAN5 and MAN4, indicating that it cannot be related exclusively to the WWTP discharge.

These trends in both chlorophyll *a* concentration and periphyton cover indicate that low river flow conditions exert a strong influence over the periphyton response in the lower Mangatainoka River. Periphyton growth is likely to be strongly nitrogen limited – input of bioavailable phosphorus is likely to exert a transient stimulatory effect, which is what is observed.

Under normal flow conditions, the reduced concentrations and load of phosphorus discharged from the WWTP are likely to have a positive effect in terms of periphyton growth and chlorophyll *a* concentrations.

Further reduction in nutrient discharged from the WWTP is unlikely to reduce the incidence of periphyton, chlorophyll *a* concentrations or proportion of cover by slimes or cyanobacteria – water is generally degraded in the lower Mangatainoka River and inputs will need to be reduced from other point sources and non-point sources.

4.8 Macroinvertebrate species change by less than 20% change in QMCI

Macroinvertebrate numbers changed by less than 20% at all sites in the lower Mangatainoka River with the exception of the reach between MAN4 and MAN3, where the QMCI increased by 30%.

4.9 Dissolved reactive phosphate (DRP) concentrations

It is not possible to demonstrate a statistically meaningful increase in DRP concentrations downstream of the wastewater discharge, and any difference may be trivial relative to the +10% to -10% limit used for the assessment.

Trend testing indicates that DRP concentrations in the Mangatainoka River appear to be decreasing over time, i.e. the discharge is having less effect on phosphorus concentrations.

The concentration of DRP in the wastewater discharge has decreased substantially since 2009. Currently the concentration of DRP in wastewater is less than 0.1 mg/L. Although this is 10 times larger than the target for the Mangatainoka River, the small volume of the discharge is unlikely to lead to measurable increases in river concentrations.

If there is a requirement to further reduce in-stream DRP concentrations, this will be achieve most cost-effectively by introducing catchment scale mitigation measures.

4.10 Soluble Inorganic Nitrogen (SIN) concentrations

SIN concentrations exceed the water quality target at all sites in the lower Mangatainoka River.

No practically important difference in SIN could be determined between sites MAN5 and MAN4 (upstream and downstream of the wastewater discharge).

Although the current wastewater discharge concentration exceeds the water quality target by a factor of ten, the small volume of the discharge and the persistently elevated load of SIN in the river upstream of the discharge will make it difficult to detect complete removal of the wastewater input.

4.11 Toxic contaminants

The discharge principally treats domestic wastewater – there is little potential for the input of significant amounts of toxic contaminants. In terms of the wastewater itself, free ammonia and nitrate-N constitute potentially toxic contaminants.

For ammoniacal-N:

- 75th percentile ammoniacal-N concentrations in the Mangatainoka River are below the target concentrations.

- The concentration (and presumably load) of ammoniacal-N in the wastewater discharge has decreased substantially since 2008.
- There is no measurable increase in the concentration of ammoniacal-N downstream of the wastewater discharge.
- Free ammonia-N concentrations are approximately 10 times lower than the ANZECC 95 % species protection level, and free ammonia concentrations similar up- and downstream of the discharge.

For nitrate-N:

- River and wastewater nitrate-N concentrations were assessed against recently revised toxicity guideline values
- Wastewater nitrate-N concentrations are well below both toxicity thresholds, indicating that the discharge is not a source of nitrate-N in amounts likely to constitute a toxicity hazard.
- River nitrate-N concentrations are well below both toxicity thresholds.

4.12 Implications for values identified in OnePlan Schedule AB

4.12.1 Life Supporting Capacity, Trout Fishery and Trout Spawning values and Site of Significance (Dotterel)

Although the wastewater discharge does not alter the measured concentrations or values of most of the water quality variables, general river water quality indicates a potential that life-supporting capacity may be impaired at times:

The **pH of surface waters** influences the concentration, speciation and solubility of a range of other water quality variables, including metals, free ammonia and selected organic contaminants. The limited number of exceedances of the OnePlan target range indicate that the potential to impair life supporting capacity exists. These exceedances cannot be related directly to the wastewater discharge, indicating that catchment-wide measures will be required to minimise excessive pH variation.

Recent work undertaken for the Ministry for the Environment (MfE) (Davies-Colley et al., 2013) identifies slightly different pH thresholds to those in the OnePlan. Generally, however, the pH values measured in the Mangatainoka River indicate that water quality is likely to comply with Grading B: “Occasional minor stress caused by pH on particularly sensitive freshwater organisms (viz. fish and insects)”. To ensure that this grading is correctly applied, however, measured pH should be compared with suitable near-pristine reference sites. The work undertaken for MfE was to provide a discussion document – application of these values should be undertaken on a region-specific basis. The methodology does indicate however that care is required to ensure that the data used for assessment of life-supporting capacity are appropriate.

Natural conditions may lead to **exceedance of the temperature target**. This is evident and MAN3, where the maximum temperature in 2012-2014 was 26°C, and the 90th percentile was 19.3 °C. The combination of low flow conditions, clear skies and broad shallow river channel may cause the water temperature to exceed the temperature target. From the work done by Davies-Colley et al., (2013) we may conclude that “Minor thermal stress on occasion (clear days in summer) on particularly sensitive organisms such as certain insects and fish” is possible. To ensure that this grading is correctly applied, however, measured temperatures compliant with the Cox-Rutherford Index (averaged summer period measurements over the five hottest days derived from inspection of a continuous temperature record) should be compared with those obtained for suitable near-pristine reference sites. For the current assessment, a relatively small number of intermittent, discrete values were used. These are unlikely to have described the diel temperature range, or the seasonal minima or maxima.

Dissolved oxygen concentrations generally exceed 8.5 mg/L (86% saturation), and increase downstream of the wastewater discharge. Assessment of the life-supporting capacity should have regard for the work done by Davies-Colley et al., (2013). They identified that three specific metrics should be determined: 7-day mean, 7-day mean minimum and one-day minimum dissolved oxygen concentration. These values should be obtained for discrete specified periods during summer. All three metrics should be met for each band. For the current assessment, a relatively small number of intermittent, discrete values were used. These are unlikely to inform us adequately regarding conditions during critical summer low periods, particularly daily minima.

The **MCI and QMCI** provide a direct measure of life-supporting capacity. MCI values greater than 120 indicate high quality habitat – in the Mangatainoka River catchment, these are only observed in the upstream reaches. Lower MCI scores occur in the lower catchment, particularly in the downstream reaches of the Makakahi River and the Mangatainoka River upstream of the wastewater discharge. MCI and QMCI values increased downstream of the WWTP. The Mangatainoka River clearly supports life, but a range of catchment-wide factors determine the quality of life supported. The quality of the wastewater discharge has improved measurably since 2008; currently, there is little indication that the discharge exerts a deleterious impact on life supporting capacity. Improvement in life supporting capacity will need to consider catchment-wide factors, including the impact of land use and other wastewater discharges.

A Dotterel nesting and foraging area is a specific Site of Significance identified in the Mangatainoka River catchment. Key requirements include the gravel and sand resources in this area. Provided periphyton cover does not increase to nuisance proportions, increasing the likelihood of scouring and subsequent deposition of detritus on these resources, impact on dotterel habitat is unlikely. Assessment of the nutrient discharge from the wastewater works indicates that the discharge is having an increasingly small impact on the nutrient status in the lower Mangatainoka River.

4.12.2 Aesthetics and Contact Recreation

Visual clarity, extent and nature of periphyton growth and concentrations of *E. coli* are useful metrics for these management values.

Visual clarity generally does not achieve the OnePlan target value for the catchment. The concentration of suspended solids and volatile matter in the wastewater discharge has decreased steadily since 2009. Non-compliance with OnePlan targets is not related to the wastewater discharge. Greatest visual clarity occurs downstream of the wastewater discharge at MAN3. A range of catchment-wide factors limit clarity, rather than the wastewater discharge. The generally shallow depth of the river and the braided nature of the channel suggest that decreased clarity will not be manifest except in deeper pools. Low clarity at these sites may increase the requirement for caution by swimmers, but should not impair contact recreation.

The extent and nature of periphyton cover do not generally cause non-compliance with OnePlan targets, or impair these values. Assessment of nutrient concentrations indicates that catchment-wide inputs of nitrogen and phosphorus dominate the inputs from the WWTP. Improvement in water quality to more consistently fulfil the aesthetic and contact recreation values and reverse the trend of increasing chlorophyll *a* concentration will require a series of catchment-wide actions, rather than further reduction in nutrient loads in the wastewater discharge.

Although the proportion of samples compliant with the OnePlan *E. coli* target for contact recreation is relatively low at site MAN4 (downstream of the wastewater discharge), it is unlikely to be related to the wastewater discharge. The microbiological quality of the wastewater has increased considerably since 2010 – a range of other factors, including stormwater and runoff from agricultural lands will also need to be considered if recreational water quality is to be improved in the lower Mangatainoka River.

4.12.3 Mauri

Water quality likely to fulfil the requirements for Mauri are closely related to those for life-supporting capacity and recreation. The cumulative impact of a range of catchment-wide activities will need to be considered to improve the Mauri of the lower Mangatainoka River. Implementing measures that reduce the concentration of nutrients and faecally-contaminated water will generally improve the condition of the river and increase the Mauri measurably. Specific cultural assessment of water quality is recommended to ensure that management actions will achieve the benefits required to enhance or improve the Mauri of the river.

4.12.4 Capacity to assimilate pollution

The lower Mangatainoka River is subject to inputs of pollutants from agricultural activities as well as point source discharges. This assessment has demonstrated that the Pahiatua WWTP is exerting a smaller impact on the river than was the case prior to about 2010. Currently it is not possible to attribute deterioration in water quality in the Mangatainoka River to the wastewater discharge for variables other than DRP (minor) and periphyton density (minor). It is possible that the minor input of DRP from the discharge is stimulating periphyton growth. This indicates limited capacity to assimilate pollution without undesirable consequences.

This assessment has demonstrated that surface waters in the lower Mangatainoka River catchment generally contain elevated concentrations of nitrogen and phosphorus. Limited data exist for organic pollutants (such as $cBOD_5$). It appears likely that the assimilative capacity of the river is generally constrained, and input of nutrients and organic matter should be reduced generally. It would be inappropriate to focus these actions on discrete discharges only – catchment-wide action will be required.

4.12.5 Other values identified for the lower Mangatainoka River

Other values identified for the lower Mangatainoka River include **Industrial abstraction**, **Irrigation abstraction**, **Stock water**, **Existing infrastructure** and **Flood control**.

This assessment has demonstrated that the discharge from the wastewater works is having an increasingly small impact on the quality and condition of the lower Mangatainoka River. As a consequence it is possible to conclude that the wastewater discharge will continue to have minimal impact on these values, particularly those associated with abstraction for industrial, irrigation and stock watering purposes. Should improvement in water quality be required to meet these objectives, it will be necessary to take action at catchment scale, and not by focusing on point-source discharges alone.

4.13 Water quality modelling

Estimates of key nutrients loads upstream and downstream of the wastewater discharge demonstrate that there is little difference, and that it is impossible to measure the impact of the wastewater discharge using simple models. The modelling exercise does however demonstrate the magnitude and seasonality of the loads of nitrogen and phosphorus in the Mangatainoka River upstream of the wastewater discharge. These results indicate that measures to improve water quality will have to be implemented catchment-wide, and not be focused exclusively on wastewater discharges such as the Pahiatua WWTP.

4.14 Overall conclusion

Improvements made to the wastewater treatment process have delivered measurable benefits to the quality of wastewater currently being discharged in terms of 12 of 14 variables. For the two variables where concentrations have increased, the consequences will be less than minor.

Water quality in the lower Mangatainoka River is subject to upstream point source and land use impacts – currently these are the principal determinants of surface water quality in the Mangatainoka River both upstream and downstream of the discharge.

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6 Appendices

6.1 Summary Statistics for Flow by Year, 2008-2013.

Statistic	Flow metric by year					
	2008	**2009**	**2010**	**2011**	**2012**	**2013**
N of Cases	366	365	365	365	366	365
Arithmetic Mean	18904.8	18461.1	19601.7	18174.2	14435.1	15466.9
Pct1	742.1	893.9	1373	1287.5	2214.8	490.7
Pct5	846	1395	1785	1765	2720	742
Pct10	1104	1760	2230	2480	3161	1070
Pct20	1687	3070	2870	4250	4196	2525
Pct25	2370	4950	3575	5350	4710	3502.5
Pct30	2839	6030	4250	6530	5333	4400
Pct40	4147	8625	6870	8555	6539	6360
Pct50 (median)	6820	11300	10200	10900	8355	7940
Pct60	10800	14850	13650	13200	11300	10500
Pct70	15810	20300	18200	17000	14770	14500
Pct75	20900	24125	22100	19525	16800	16825
Pct80	24630	29950	26950	23750	19330	20400
Pct90	50170	41200	44100	39900	29480	38900
Pct95	97360	58550	67275	56200	39360	53475
Pct99	144880	113250	155850	152400	112128	118850
Maximum	190000	160000	471000	218000	226000	218000
Minimum	729	862	1310	1140	2080	458
Std dev.	30623.6	21950	34606.7	25833.8	20611.5	23226.2
Std err. Mean	1600.7	1148.9	1811.4	1352.2	1077.4	1215.7

6.2 Summary Statistics for Water Quality Monitoring Sites in the Mangatainoka River Catchment

BRE1												
Statistic	**E. coli**	**Entero.**	**Tot. coli**	**Clarity**	**Temp.**	**DO sat.**	**DO**	**EC**	**pH**	**Tot. SS**	**Turb.**	**VM**
Average	260.776		16927.739	2.152	21.476	83.098	7.748	128.472	6.965	5.986	1.715	3.121
Max.	4100		240000	6.5	46.37	147.5	13.74	419.6	9.7	110	35.4	15
Median	63		2420	1.98	21.02	82.85	8.08	100.1	6.79	2	0.875	2
Min.	1		450	0.5	9.93	31.2	2.41	4.7	5.98	0	0.25	0
N	67		23	45	66	48	66	57	67	66	66	52
Pct1	1.34		450	0.5	10.037	31.2	2.628	4.707	5.982	0	0.263	0
Pct10	12.4		862.8	1	11.22	60.04	4.606	36.64	6.36	0.5	0.472	0.35
Pct20	26.8		1224.1	1.2	12.94	64.92	5.23	58.99	6.543	1	0.595	1
Pct25	31		1435.5	1.5	13.89	66.3	5.41	68	6.59	1	0.65	1.45
Pct30	33.6		1540	1.6	15.16	68.87	6.316	70.44	6.6	2	0.68	1.5
Pct40	46.6		1910.1	1.8	18.599	77.82	7.119	87.18	6.713	2	0.749	1.5
Pct5	4		710	0.925	10.688	52.96	4.064	9.31	6.158	0	0.38	0
Pct50	63		2420	1.98	21.02	82.85	8.08	100.1	6.79	2	0.875	2
Pct60	86		2474	2	22.19	87.27	8.578	114.42	6.968	3	1.042	2
Pct70	117.6		3764	2.2	25.17	93.84	9.094	133.68	7.164	4	1.315	4
Pct75	137.25		4410	2.5	26.9	95.65	9.22	169.25	7.303	5	1.39	4
Pct80	182.9		8208	2.95	27.43	97.36	9.713	181.6	7.413	5.3	1.572	5
Pct90	535.8		33400	3.6	33.04	106.87	10.528	278.28	7.878	9.9	1.886	7.44
Pct95	1557.8		119750	4.45	41.284	123.14	11.856	387.73	8.049	23.2	3.68	9.9
Pct99	3847.21		240000	6.5	46.087	147.5	13.628	418.998	9.464	99.92	31.102	15
SE ave	81.24		10467.88	0.177	1.078	3.064	0.301	13.255	0.077	1.817	0.538	0.459
Std. dev.	664.975		50202.191	1.185	8.758	21.225	2.442	100.072	0.634	14.758	4.37	3.313

BRE1										
STATISTICS	**SS**	**NH4-N**	**TN**	**TON**	**Nitrate-N**	**Nitrite-N**	**DRP**	**TDP**	**TP**	**CBOD5**
Average	4.55	0.073	1.59	1.137	1.103	0.006	0.009	0.01	0.041	2.121
Max.	60	0.469	4.4	3.968	2.54	0.08	0.15	0.023	0.385	14
Median	2	0.05	1.465	1.05	1.155	0.004	0.004	0.01	0.022	1
Min.	0	0	0.25	0.006	0.006	0.001	0	0	0.005	0.25
N	34	66	66	66	52	52	66	16	66	38
Pct1	0	0	0.263	0.007	0.006	0.001	0	0	0.005	0.25
Pct10	1	0.006	0.54	0.037	0.147	0.001	0.003	0.004	0.012	0.5
Pct20	1	0.011	0.858	0.285	0.368	0.002	0.003	0.006	0.015	0.78
Pct25	1	0.02	0.94	0.377	0.505	0.003	0.003	0.007	0.016	1
Pct30	1	0.028	1.1	0.577	0.636	0.003	0.003	0.007	0.016	1
Pct40	1.19	0.044	1.198	0.783	0.797	0.003	0.003	0.009	0.019	1
Pct5	0.2	0.003	0.478	0.013	0.023	0.001	0.001	0.001	0.01	0.25
Pct50	2	0.05	1.465	1.05	1.155	0.004	0.004	0.01	0.022	1
Pct60	2.9	0.065	1.82	1.359	1.386	0.005	0.006	0.01	0.025	1
Pct70	3.41	0.09	1.997	1.529	1.497	0.006	0.007	0.011	0.03	1.37
Pct75	4	0.1	2.083	1.654	1.621	0.007	0.008	0.013	0.032	2
Pct80	4.56	0.12	2.163	1.886	1.824	0.008	0.009	0.014	0.035	2
Pct90	6.76	0.152	2.69	2.129	2	0.01	0.017	0.017	0.057	5.59
Pct95	14	0.199	3.176	2.598	2.122	0.017	0.025	0.021	0.172	9.26
Pct99	60	0.446	4.24	3.785	2.54	0.079	0.133	0.023	0.379	14
SE ave	1.756	0.01	0.105	0.105	0.097	0.002	0.002	0.001	0.008	0.47
Std. dev.	10.237	0.08	0.849	0.855	0.699	0.011	0.019	0.005	0.069	2.896

BRE2												
Statistic	**E. coli**	**Entero.**	**Tot. coli**	**Clarity**	**Temp.**	**DO sat.**	**DO**	**EC**	**pH**	**Tot. SS**	**Turb.**	**VM**
Average	409.761		19328.435	2.269	14.491	91.59	9.033	135.639	7.179	14.281	4.724	4.73
Max.	10462		240000	6.5	22.9	180	17.63	232	9.31	220	81.6	54
Median	99		2420	2	14.15	89.15	9.04	137.5	7.04	3	0.87	2
Min.	8		501	0.1	6.41	24.2	1.76	69.1	6.29	0	0.2	0
N	67		23	39	66	48	66	57	67	67	67	53
Pct1	8.34		501	0.1	7.08	24.2	1.869	69.135	6.314	0	0.215	0
Pct10	21.4		866.6	1	10.823	59.53	5.742	93.24	6.574	0.5	0.368	0
Pct20	32.7		1557.7	1.1	11.7	77.24	6.896	111.8	6.68	1	0.47	1
Pct25	39.25		1675	1.225	12.3	79.1	7.8	119.65	6.733	1	0.518	1.15
Pct30	53.2		2020	1.5	12.93	80.78	8.214	124.96	6.85	1	0.576	1.5
Pct40	81.5		2414	1.81	13.7	84.78	8.509	131.74	6.943	2	0.643	1.5
Pct5	15.1		597.2	0.39	10.626	47.4	4.418	75.25	6.501	0	0.307	0
Pct50	99		2420	2	14.15	89.15	9.04	137.5	7.04	3	0.87	2
Pct60	120.7		2890	2.375	15.04	92.93	9.43	140.82	7.231	4.82	1.377	3
Pct70	187.6		5132	2.942	16.1	98.22	10.099	144.94	7.358	6	2.066	4
Pct75	217		12257.5	3	16.3	100.4	10.36	147.325	7.433	7	3.298	4.55
Pct80	242		16721	3.1	16.68	108.51	10.557	150.8	7.658	9.38	4.136	5
Pct90	646.6		36000	3.96	17.79	128.98	12.504	181.6	7.828	32	9.898	9.96
Pct95	1283.5		143800	4.87	19.478	141.13	14.01	189.3	8.178	67.95	24.03	17.7
Pct99	9431.46		240000	6.5	22.598	180	17.235	230.39	9.242	212.52	75.905	53.19
SE ave	168.488		10799.975	0.216	0.362	3.94	0.347	4.293	0.07	4.597	1.505	1.165
Std. dev.	1379.136		51794.861	1.352	2.94	27.299	2.82	32.408	0.577	37.626	12.318	8.478

BRE2										
STATISTICS	**SS**	**NH4-N**	**TN**	**TON**	**Nitrate-N**	**Nitrite-N**	**DRP**	**TDP**	**TP**	**CBOD5**
Average	5.101	0.022	2.051	1.582	1.572	0.007	0.013	0.013	0.062	0.895
Max.	46	0.275	4.71	4.513	3.02	0.074	0.191	0.024	1.008	6.6
Median	1.1	0.011	2.038	1.603	1.705	0.004	0.008	0.012	0.019	1
Min.	0	-0.002	0.29	0.004	0	0.001	0	0	0.005	0.25
N	34	67	67	67	53	53	67	16	67	39
Pct1	0	-0.002	0.297	0.004	0.001	0.001	0	0	0.005	0.25
Pct10	0	0.001	0.86	0.126	0.749	0.001	0.003	0.006	0.01	0.25
Pct20	0.195	0.003	1.3	1.03	1.057	0.003	0.003	0.01	0.012	0.25
Pct25	0.7	0.005	1.483	1.173	1.26	0.003	0.004	0.01	0.014	0.313
Pct30	1	0.005	1.704	1.264	1.355	0.003	0.006	0.011	0.015	0.5
Pct40	1	0.008	1.815	1.477	1.518	0.003	0.006	0.012	0.017	1
Pct5	0	0	0.486	0.022	0.057	0.001	0.003	0.002	0.008	0.25
Pct50	1.1	0.011	2.038	1.603	1.705	0.004	0.008	0.012	0.019	1
Pct60	2	0.017	2.173	1.824	1.836	0.005	0.009	0.014	0.02	1
Pct70	3.44	0.02	2.298	1.92	1.91	0.006	0.011	0.015	0.032	1
Pct75	4.1	0.022	2.448	1.995	1.956	0.008	0.012	0.015	0.038	1
Pct80	5.02	0.027	2.601	2.101	1.999	0.009	0.013	0.016	0.066	1
Pct90	11	0.05	3.28	2.493	2.12	0.013	0.019	0.018	0.122	1
Pct95	35.2	0.079	4.038	2.83	2.329	0.019	0.026	0.022	0.24	1
Pct99	46	0.248	4.691	4.292	3.013	0.073	0.18	0.024	0.919	6.6
SE ave	1.77	0.005	0.114	0.101	0.088	0.001	0.003	0.001	0.017	0.159
Std. dev.	10.319	0.039	0.937	0.829	0.637	0.011	0.027	0.005	0.143	0.995

MAK1												
Statistic	**E. coli**	**Entero.**	**Tot. coli**	**Clarity**	**Temp.**	**DO sat.**	**DO**	**EC**	**pH**	**Tot. SS**	**Turb.**	**VM**
Average	2197.303		4504.241	1.916	13.046	98.988	10.279	107.024	7.42	44.926	29.518	3.778
Max.	173289		61000	8	21.5	113.5	13.71	191.5	8.6	1500	1260	22
Median	182.5		1733	1.75	12.8	99.45	10.185	107.6	7.45	3	1.955	1.5
Min.	4		373	0.05	5.57	78.5	6.69	43	6.48	0	0.72	1.5
N	122		29	67	158	58	80	145	143	68	76	9
Pct1	19.12		373	0.059	6.808	79.332	6.927	60.1	6.499	0.09	0.746	1.5
Pct10	52.8		619.8	0.734	8	91.3	8.605	84.3	6.778	1	1.041	1.5
Pct20	86.9		913	0.98	8.705	94.94	9.18	95.9	7.037	1	1.356	1.5
Pct25	105		920.75	1.03	9.6	95.9	9.305	99.975	7.163	1.7	1.465	1.5
Pct30	115.9		1024	1.23	9.99	96.77	9.41	102	7.254	2	1.54	1.5
Pct40	138.6		1600	1.5	11.4	98.42	9.875	104.55	7.397	2	1.688	1.5
Pct5	34		512.65	0.3	7.34	90.18	8.27	68.25	6.646	0.5	0.983	1.5
Pct50	182.5		1733	1.75	12.8	99.45	10.185	107.6	7.45	3	1.955	1.5
Pct60	242.3		1998.6	1.9	13.8	100.56	10.59	110.1	7.563	3.86	2.462	1.5
Pct70	298.2		2416	2	15.902	101.23	11.105	114	7.616	4	2.963	1.5
Pct75	384		2560	2.175	16.4	102.5	11.315	115.7	7.67	5	3.255	1.5
Pct80	507.4		3876	2.51	16.9	103.27	11.525	118	7.7	6	4.057	1.5
Pct90	1430		7656	3.16	18.6	106.31	12	128	7.92	19.7	7.908	13.8
Pct95	4030		13785	5.038	19.76	107.52	12.495	140.175	8.2	170.5	64.45	22
Pct99	64360.92		61000	7.827	21.013	113.044	13.563	169.175	8.507	1375.8	1077.74	22
SE ave	1431.458		2070.244	0.171	0.321	0.746	0.151	1.676	0.037	24.988	18.021	2.278
Std. dev.	15810.968		11148.607	1.403	4.032	5.682	1.348	20.176	0.443	206.06	157.104	6.833

MAK1										
STATISTICS	**SS**	**NH4-N**	**TN**	**TON**	**Nitrate-N**	**Nitrite-N**	**DRP**	**TDP**	**TP**	**CBOD5**
Average	62.31	0.014	0.71	0.494	0.454	0.004	0.007	0.013	0.025	
Max.	1500	0.18	1.887	1.431	1.261	0.035	0.031	0.053	0.143	
Median	2	0.009	0.666	0.48	0.44	0.003	0.006	0.012	0.021	
Min.	0	-0.002	0.21	0	0	0	0	0.001	0.006	
N	41	160	160	107	143	143	160	115	160	
Pct1	0	0	0.211	0.002	0	0	0.002	0.002	0.006	
Pct10	0.3	0	0.274	0.023	0.01	0.001	0.003	0.008	0.012	
Pct20	1	0.002	0.36	0.158	0.12	0.001	0.003	0.009	0.015	
Pct25	1	0.003	0.41	0.19	0.165	0.001	0.004	0.01	0.016	
Pct30	1	0.003	0.454	0.208	0.191	0.001	0.005	0.01	0.017	
Pct40	1	0.006	0.544	0.29	0.269	0.002	0.006	0.011	0.019	
Pct5	0	0	0.25	0.01	0	0	0.003	0.007	0.01	
Pct50	2	0.009	0.666	0.48	0.44	0.003	0.006	0.012	0.021	
Pct60	2.05	0.012	0.755	0.62	0.573	0.003	0.007	0.014	0.023	
Pct70	3	0.014	0.927	0.68	0.669	0.004	0.008	0.015	0.025	
Pct75	4.425	0.016	0.976	0.779	0.708	0.005	0.008	0.016	0.026	
Pct80	5.02	0.02	1	0.811	0.789	0.006	0.009	0.017	0.028	
Pct90	33.6	0.03	1.19	0.975	0.918	0.007	0.01	0.02	0.036	
Pct95	414.7	0.042	1.4	1.094	1.051	0.008	0.014	0.023	0.05	
Pct99	1500	0.118	1.697	1.421	1.251	0.017	0.022	0.038	0.137	
SE ave	40.597	0.002	0.029	0.035	0.029	0	0	0.001	0.002	
Std. dev.	259.949	0.02	0.365	0.36	0.342	0.004	0.004	0.006	0.019	

MAK2												
Statistic	**E. coli**	**Entero.**	**Tot. coli**	**Clarity**	**Temp.**	**DO sat.**	**DO**	**EC**	**pH**	**Tot. SS**	**Turb.**	**VM**
Average	890.097	88.882	3471.391	2.117	12.666	99.162	10.507	112.978	7.565	8.376	5.035	2.307
Max.	14900	1733	28000	6.05	20.5	129.8	15	296	9.48	260	116	35
Median	228	19	1900	2.025	12.505	99.6	10.39	102	7.53	2.4	1.715	1.5
Min.	36	1	360	0.4	5.4	72.8	6.69	40.7	6.18	0	0.63	0
N	72	51	23	56	72	52	72	59	73	72	72	55
Pct1	36.66	1.01	360	0.424	5.664	73.016	6.763	41.627	6.29	0	0.656	0
Pct10	84.5	3.6	600	1.01	7.4	91.94	8.774	86.14	7.038	0.5	1.007	0
Pct20	113.6	5.7	1097.5	1.3	8.587	94.39	9.41	92	7.244	1	1.168	1
Pct25	131.5	6.75	1140	1.4	9.16	94.95	9.63	96	7.358	1	1.29	1
Pct30	140.2	9.8	1201.2	1.751	9.5	96.01	9.716	97.44	7.404	1	1.32	1
Pct40	172.7	12	1600	1.9	11.16	98.5	10.075	100.11	7.46	2	1.439	1.2
Pct5	49.8	2.05	482.2	0.8	7.11	89.8	8.416	70.135	6.905	0.05	0.9	0
Pct50	228	19	1900	2.025	12.505	99.6	10.39	102	7.53	2.4	1.715	1.5
Pct60	278.1	32	2211	2.1	13.51	100.95	10.853	104.57	7.61	3	1.897	1.5
Pct70	343.1	53	2504	2.355	14.69	102.4	11.128	112.6	7.708	4	2.277	2
Pct75	391	71	3400	2.53	16.22	103.35	11.39	115.3	7.77	4	2.595	2
Pct80	487.1	76.9	4148	2.71	16.83	103.65	11.623	119.58	7.83	4.46	2.978	2.8
Pct90	1013	136.6	5672	3.1	18.972	105.59	12.115	160.78	8.046	8.8	4.422	3.8
Pct95	3485	427.75	15520	4.05	19.46	107.83	13.057	205.4	8.44	16.8	22.99	4
Pct99	14731.92	1720.71	28000	5.963	20.39	129.38	14.971	288.35	9.312	224.8	102.624	33.65
SE ave	314.899	35.653	1183.121	0.133	0.486	1.058	0.177	5.302	0.055	3.83	1.794	0.634
Std. dev.	2672.005	254.616	5674.049	0.994	4.125	7.63	1.498	40.726	0.473	32.499	15.223	4.7

MAK2										
STATISTICS	**SS**	**NH4-N**	**TN**	**TON**	**Nitrate-N**	**Nitrite-N**	**DRP**	**TDP**	**TP**	**CBOD5**
Average	4.135	0.018	0.714	0.469	0.47	0.003	0.008	0.017	0.026	0.718
Max.	27	0.171	1.52	1.36	1.168	0.013	0.032	0.038	0.164	1
Median	2.05	0.014	0.7	0.447	0.505	0.003	0.008	0.015	0.021	1
Min.	0	-0.001	0.17	0.003	0	0.001	0.002	0.007	0.005	0.25
N	34	72	72	72	56	56	72	16	72	39
Pct1	0	-0.001	0.17	0.004	0	0.001	0.002	0.007	0.005	0.25
Pct10	0	0.001	0.31	0.034	0.03	0.001	0.003	0.009	0.011	0.25
Pct20	1	0.003	0.354	0.127	0.166	0.001	0.005	0.011	0.014	0.25
Pct25	1	0.006	0.367	0.175	0.191	0.002	0.006	0.012	0.015	0.25
Pct30	1	0.008	0.391	0.195	0.195	0.002	0.006	0.012	0.016	0.3
Pct40	1.1	0.01	0.523	0.252	0.301	0.002	0.007	0.014	0.019	0.55
Pct5	0	0	0.228	0.029	0.011	0.001	0.003	0.008	0.009	0.25
Pct50	2.05	0.014	0.7	0.447	0.505	0.003	0.008	0.015	0.021	1
Pct60	3.03	0.018	0.798	0.598	0.625	0.003	0.008	0.016	0.022	1
Pct70	5	0.022	0.93	0.718	0.719	0.003	0.009	0.017	0.024	1
Pct75	5.3	0.026	1.004	0.734	0.726	0.004	0.01	0.02	0.028	1
Pct80	5.94	0.028	1.077	0.8	0.784	0.005	0.011	0.022	0.03	1
Pct90	11.2	0.035	1.204	0.945	0.858	0.008	0.013	0.028	0.042	1
Pct95	14.6	0.042	1.346	1.067	0.97	0.009	0.015	0.035	0.052	1
Pct99	27	0.143	1.516	1.358	1.158	0.013	0.031	0.038	0.161	1
SE ave	0.947	0.003	0.043	0.042	0.043	0	0.001	0.002	0.003	0.056
Std. dev.	5.523	0.022	0.362	0.359	0.32	0.003	0.005	0.008	0.025	0.35

MAK3												
Statistic	**E. coli**	**Entero.**	**Tot. coli**	**Clarity**	**Temp.**	**DO sat.**	**DO**	**EC**	**pH**	**Tot. SS**	**Turb.**	**VM**
Average	353.25	63.451	2416.696	2.144	12.568	97.823	10.462	102.119	7.537	9.974	5.446	2.5
Max.	6600	613	14000	7.01	20.82	126.2	16.13	240	9.39	250	159	33
Median	156	16	1900	2	12.41	97.2	10.625	95.1	7.49	2	1.475	1.5
Min.	20	0.5	240	0.2	5.38	76.2	7.24	43	5.84	0	0.68	0
N	72	51	23	62	72	52	72	59	73	72	72	55
Pct1	20.22	0.5	240	0.224	5.604	76.224	7.262	44.71	5.854	0	0.722	0
Pct10	43.1	2.6	364.2	1.07	7.37	86.01	8.258	72.36	7.038	0	1.035	0
Pct20	87.8	4	630.7	1.354	8.486	92.16	9.013	83.23	7.31	1	1.109	0.5
Pct25	92.5	4.25	837.5	1.5	9.3	92.8	9.45	84.8	7.338	1	1.17	1
Pct30	99	5.8	1069.2	1.555	9.807	94.45	9.665	87.32	7.384	1	1.193	1
Pct40	128.1	8	1300	1.912	11.124	95.7	9.912	90.75	7.447	2	1.343	1.5
Pct5	27.3	1.05	318.65	0.828	6.94	78.17	8.047	67	6.683	0	0.912	0
Pct50	156	16	1900	2	12.41	97.2	10.625	95.1	7.49	2	1.475	1.5
Pct60	215.7	32.4	2406	2.121	13.57	99.32	10.959	98.57	7.646	3	1.779	1.5
Pct70	247.8	44.4	2528	2.5	14.69	103.75	11.24	101.92	7.72	4.94	2.237	2
Pct75	297.5	57.75	2600	2.5	15.95	104.45	11.5	113.25	7.753	5	2.625	2.5
Pct80	365.1	65.2	2690	2.81	17.11	105.91	11.673	117.77	7.77	6.1	2.769	3.5
Pct90	559	101.4	4418.4	3.1	18.07	108.09	12.358	134.14	8.122	13	4.869	4.4
Pct95	908.3	430.5	8930	4.02	18.897	109.92	12.742	168.85	8.329	33.6	20.101	7.4
Pct99	5619.46	612.39	14000	6.733	20.552	126.02	15.807	237.57	9.222	223.6	135.812	31.81
SE ave	96.54	18.382	598.542	0.134	0.474	1.335	0.194	4.288	0.06	3.933	2.323	0.62
Std. dev.	819.166	131.276	2870.508	1.059	4.022	9.624	1.649	32.94	0.511	33.374	19.711	4.596

MAK3										
STATISTICS	**SS**	**NH4-N**	**TN**	**TON**	**Nitrate-N**	**Nitrite-N**	**DRP**	**TDP**	**TP**	**CBOD5**
Average	5.335	0.009	0.501	0.296	0.289	0.003	0.005	0.01	0.023	0.769
Max.	49	0.045	1.4	0.998	0.743	0.01	0.015	0.014	0.308	3
Median	1	0.007	0.455	0.25	0.256	0.003	0.004	0.011	0.015	1
Min.	0	-0.003	0.12	0.005	0.001	0	0.002	0	0.005	0.25
N	34	72	72	72	56	56	72	16	72	39
Pct1	0	-0.002	0.122	0.005	0.001	0	0.002	0	0.005	0.25
Pct10	0	0.001	0.197	0.006	0.007	0.001	0.003	0.006	0.008	0.25
Pct20	1	0.003	0.235	0.017	0.026	0.001	0.003	0.007	0.012	0.25
Pct25	1	0.003	0.24	0.027	0.066	0.001	0.003	0.008	0.012	0.25
Pct30	1	0.003	0.261	0.07	0.074	0.001	0.003	0.008	0.013	0.3
Pct40	1	0.005	0.349	0.143	0.169	0.002	0.003	0.01	0.014	0.55
Pct5	0	0	0.155	0.005	0.003	0.001	0.003	0.002	0.007	0.25
Pct50	1	0.007	0.455	0.25	0.256	0.003	0.004	0.011	0.015	1
Pct60	2	0.009	0.554	0.376	0.372	0.003	0.006	0.011	0.016	1
Pct70	3.18	0.01	0.623	0.449	0.449	0.003	0.006	0.011	0.018	1
Pct75	4.1	0.012	0.675	0.51	0.509	0.003	0.007	0.012	0.02	1
Pct80	4.94	0.015	0.76	0.537	0.521	0.004	0.008	0.012	0.02	1
Pct90	14.4	0.018	0.867	0.638	0.602	0.005	0.009	0.013	0.029	1
Pct95	31	0.025	1.075	0.748	0.698	0.006	0.01	0.014	0.046	1
Pct99	49	0.043	1.391	0.989	0.743	0.01	0.015	0.014	0.278	3
SE ave	1.794	0.001	0.035	0.031	0.031	0	0	0.001	0.005	0.081
Std. dev.	10.459	0.009	0.299	0.266	0.234	0.002	0.003	0.003	0.039	0.505

MAN1												
Statistic	**E. coli**	**Entero.**	**Tot. coli**	**Clarity**	**Temp.**	**DO sat.**	**DO**	**EC**	**pH**	**Tot. SS**	**Turb.**	**VM**
Average	343.103		4785.043	2.244	14.613	105.333	10.646	122.192	7.894	3.69	2.808	
Max.	2700		51720	5	20.5	147.8	13.31	251.1	9.29	22	21.4	
Median	131		1700	2.075	14.4	105.1	10.26	113.6	7.865	2	1.18	
Min.	2		272	0.15	8	77.8	7.95	57.6	7.05	0	0.35	
N	39		23	34	39	39	39	39	38	39	39	
Pct1	2		272	0.15	8	77.8	7.95	57.6	7.05	0	0.35	
Pct10	19		347.2	0.95	9.66	91.56	8.968	77.64	7.348	0	0.526	
Pct20	31.2		594.7	1.565	11.56	95.95	9.564	93.27	7.48	0.5	0.643	
Pct25	34		795.25	1.6	11.9	98.225	9.665	97.4	7.52	0.625	0.703	
Pct30	44		1040	1.67	12.06	98.7	9.788	101.54	7.54	1	0.764	
Pct40	89.1		1176	2	14.21	99.64	10.122	107.3	7.726	1.06	0.91	
Pct5	13.25		274.6	0.5	8.79	87.67	8.688	74.71	7.244	0	0.405	
Pct50	131		1700	2.075	14.4	105.1	10.26	113.6	7.865	2	1.18	
Pct60	158.9		1733	2.39	15.98	108	10.939	118.87	7.931	2	1.588	
Pct70	238		2412	2.72	16.6	109.52	11.768	125.4	8.079	3	1.932	
Pct75	380		2420	3	17.05	111.9	12.008	140.975	8.17	3	2.66	
Pct80	450.5		3932	3	17.87	114.19	12.158	151.51	8.219	4	3.509	
Pct90	968.4		11512	3.53	19.16	121.74	12.426	186.38	8.54	12.6	6.292	
Pct95	1818		29152	4.6	20.5	125.285	12.631	212.48	8.764	18.55	14.575	
Pct99	2700		51720	5	20.5	147.8	13.31	251.1	9.29	22	21.4	
SE ave	93.407		2272.842	0.186	0.555	2.031	0.217	6.635	0.078	0.872	0.715	
Std. dev.	583.324		10900.166	1.082	3.465	12.685	1.356	41.437	0.483	5.446	4.463	

MAN1										
STATISTICS	**SS**	**NH4-N**	**TN**	**TON**	**Nitrate-N**	**Nitrite-N**	**DRP**	**TDP**	**TP**	**CBOD5**
Average	5.568	0.012	1.029	0.851	0.847	0.004	0.008	0.014	0.019	
Max.	43	0.052	1.8	1.736	1.73	0.01	0.043	0.059	0.057	
Median	1.55	0.01	1	0.85	0.85	0.004	0.007	0.013	0.015	
Min.	0	-0.003	0.287	0.069	0.063	0.001	0.002	0.003	0.005	
N	34	39	39	39	39	39	39	39	39	
Pct1	0	-0.003	0.287	0.069	0.063	0.001	0.002	0.003	0.005	
Pct10	0	0	0.537	0.344	0.339	0.001	0.003	0.005	0.007	
Pct20	0.5	0	0.645	0.499	0.491	0.001	0.004	0.007	0.011	
Pct25	1	0.001	0.657	0.528	0.525	0.001	0.005	0.008	0.011	
Pct30	1	0.003	0.771	0.552	0.549	0.002	0.006	0.009	0.012	
Pct40	1	0.008	0.952	0.777	0.77	0.003	0.006	0.011	0.013	
Pct5	0	0	0.462	0.249	0.244	0.001	0.003	0.005	0.005	
Pct50	1.55	0.01	1	0.85	0.85	0.004	0.007	0.013	0.015	
Pct60	3	0.014	1.101	0.928	0.92	0.004	0.008	0.014	0.017	
Pct70	4.86	0.017	1.2	1.092	1.091	0.005	0.01	0.015	0.019	
Pct75	5	0.021	1.3	1.108	1.106	0.006	0.01	0.016	0.025	
Pct80	7.13	0.021	1.4	1.155	1.152	0.007	0.01	0.017	0.027	
Pct90	14.9	0.027	1.58	1.46	1.458	0.007	0.012	0.019	0.037	
Pct95	27.8	0.031	1.687	1.522	1.517	0.008	0.015	0.028	0.046	
Pct99	43	0.052	1.8	1.736	1.73	0.01	0.043	0.059	0.057	
SE ave	1.603	0.002	0.062	0.065	0.065	0	0.001	0.001	0.002	
Std. dev.	9.347	0.012	0.388	0.404	0.405	0.003	0.007	0.009	0.012	

MAN2												
Statistic	**E. coli**	**Entero.**	**Tot. coli**	**Clarity**	**Temp.**	**DO sat.**	**DO**	**EC**	**pH**	**Tot. SS**	**Turb.**	**VM**
Average	563.852		4837.217	1.487	13.96	106.07	10.785	131.159	7.709	12.898	6.593	2.01
Max.	15000		34000	3.1	22.4	143	17.32	411	8.94	370	209	9
Median	163		1733	1.2	13.705	103.7	10.655	116.1	7.6	3	1.5	1.5
Min.	17		333	0.1	5.41	92.1	5.41	73	5.83	0	0.41	0
N	61		23	27	60	44	60	54	61	61	61	51
Pct1	17.99		333	0.1	5.719	92.1	5.616	73.324	5.894	0	0.41	0
Pct10	49		495.4	0.44	9	93.53	8.965	88.12	7.058	0.5	0.622	0
Pct20	75		938.9	0.69	9.92	97.37	9.49	102.27	7.14	1	0.707	0.85
Pct25	95.25		1125.75	0.963	10.5	98.35	9.845	104.9	7.255	1.95	0.813	1
Pct30	109.6		1281.8	1	11.6	98.84	10.045	106.8	7.31	2	0.948	1
Pct40	139.8		1625	1.1	12.9	101.67	10.3	113.62	7.46	2	1.238	1.5
Pct5	30.55		374.6	0.313	8.55	92.55	7.645	82.16	6.816	0	0.502	0
Pct50	163		1733	1.2	13.705	103.7	10.655	116.1	7.6	3	1.5	1.5
Pct60	201		2000	1.64	15.3	105.33	10.935	122.81	7.834	4	2.338	2
Pct70	274.2		2420	1.81	16.85	107.51	11.585	131.6	8.136	5.2	3.2	2.68
Pct75	331.5		2420	1.975	17.545	109.1	11.815	150.4	8.268	6.85	3.385	3
Pct80	446.3		5192	2.24	17.885	113.85	12.02	160.67	8.38	8.5	4.273	3
Pct90	846		15400	2.96	18.65	125.05	12.615	174.5	8.518	21.4	9.194	4
Pct95	2031.5		28150	3.1	19.05	131.24	13.84	214.4	8.72	43.4	16.25	5
Pct99	13619.72		34000	3.1	22.124	143	17.203	403.24	8.927	335.35	188.683	8.98
SE ave	248.406		1744.969	0.167	0.485	1.742	0.244	7.044	0.082	6.113	3.419	0.251
Std. dev.	1940.111		8368.58	0.867	3.757	11.556	1.888	51.765	0.637	47.742	26.701	1.789

MAN2										
STATISTICS	**SS**	**NH4-N**	**TN**	**TON**	**Nitrate-N**	**Nitrite-N**	**DRP**	**TDP**	**TP**	**CBOD5**
Average	6.865	0.014	1.127	0.919	0.914	0.004	0.012	0.03	0.031	0.846
Max.	46	0.076	2.8	1.925	1.918	0.011	0.14	0.144	0.46	1
Median	2	0.012	1.094	0.897	0.872	0.003	0.008	0.013	0.02	1
Min.	0	0	0.39	0.132	0.13	0.001	0.002	0.007	0.007	0.5
N	34	61	61	61	49	49	61	16	61	13
Pct1	0	0	0.404	0.133	0.13	0.001	0.002	0.007	0.007	0.5
Pct10	0	0.002	0.653	0.45	0.44	0.001	0.003	0.009	0.012	0.5
Pct20	1	0.003	0.787	0.601	0.583	0.001	0.006	0.01	0.014	0.5
Pct25	1	0.005	0.825	0.623	0.614	0.002	0.006	0.01	0.016	0.5
Pct30	1	0.006	0.928	0.731	0.698	0.002	0.007	0.01	0.017	0.7
Pct40	1.55	0.008	1	0.841	0.82	0.003	0.007	0.012	0.018	1
Pct5	0	0	0.582	0.381	0.368	0.001	0.003	0.008	0.009	0.5
Pct50	2	0.012	1.094	0.897	0.872	0.003	0.008	0.013	0.02	1
Pct60	2.72	0.014	1.154	0.976	0.962	0.004	0.01	0.013	0.023	1
Pct70	4	0.016	1.302	1.104	1.099	0.005	0.011	0.015	0.024	1
Pct75	4	0.018	1.346	1.137	1.137	0.006	0.011	0.018	0.028	1
Pct80	7.33	0.02	1.4	1.202	1.249	0.007	0.012	0.036	0.031	1
Pct90	22.9	0.028	1.67	1.404	1.486	0.007	0.017	0.103	0.045	1
Pct95	44	0.039	1.729	1.551	1.585	0.008	0.024	0.133	0.057	1
Pct99	46	0.073	2.723	1.899	1.918	0.011	0.129	0.144	0.419	1
SE ave	2.123	0.002	0.053	0.047	0.056	0	0.002	0.01	0.007	0.067
Std. dev.	12.378	0.014	0.417	0.369	0.391	0.003	0.018	0.041	0.058	0.24

MAN3												
Statistic	**E. coli**	**Entero.**	**Tot. coli**	**Clarity**	**Temp.**	**DO sat.**	**DO**	**EC**	**pH**	**Tot. SS**	**Turb.**	**VM**
Average	366.504	10	3114.241	2.298	14.32	105.328	10.832	111.467	7.799	8.775	8.004	2.589
Max.	16000	10	26000	6	26.2	141.5	14.81	216.1	9.1	191	379	20
Median	80	10	1733	2.1	14.1	102.3	10.725	110.6	7.73	3	1.52	1.5
Min.	3	10	214	0.1	7	79.1	7.31	52	6.5	0	0.39	0
N	119	2	29	67	155	54	76	142	138	73	73	55
Pct1	5.07	10	214	0.117	7.34	79.436	7.333	61.2	6.588	0	0.392	0
Pct10	22	10	303.4	0.51	9.3	93.86	9.453	82.65	7.1	0.5	0.56	0
Pct20	31.9	10	506	1.1	10.3	96.72	9.8	93.26	7.3	1	0.773	1
Pct25	39	10	564.25	1.275	11.2	97.7	9.99	96	7.4	1	0.883	1
Pct30	46.4	10	625.4	1.66	11.6	98.95	10.112	101	7.438	1	0.982	1
Pct40	63	10	923	2	12.6	100.52	10.38	104.37	7.6	2	1.229	1.5
Pct5	16.45	10	281.45	0.411	8.533	90.44	8.612	73.8	6.894	0.075	0.415	0
Pct50	80	10	1733	2.1	14.1	102.3	10.725	110.6	7.73	3	1.52	1.5
Pct60	98	10	2360	2.5	15.65	105.99	10.993	116	7.86	3.58	1.8	2
Pct70	128.8	10	2420	2.922	16.7	110.33	11.45	119.09	8.046	4.84	2.434	3
Pct75	165.5	10	2530	3	17.375	111.2	11.645	121	8.2	5.55	3.483	3.55
Pct80	175.8	10	3509	3.4	18.2	113.94	11.912	128	8.354	7.96	4.065	4
Pct90	498.6	10	6836	3.98	19.4	120.23	12.397	142.3	8.688	15.4	7.062	5
Pct95	1144.2	10	12700	5.045	20.45	124.92	13.633	151.2	8.818	26.85	10.483	6.9
Pct99	8931.64	10	26000	5.915	22.057	141.412	14.631	188.776	9.091	168.69	296.936	19.4
SE ave	144.421	0	947.762	0.165	0.314	1.593	0.159	2.032	0.05	2.92	5.173	0.409
Std. dev.	1575.448	0	5103.853	1.354	3.905	11.706	1.386	24.215	0.582	24.952	44.198	3.035

MAN3										
STATISTICS	**SS**	**NH4-N**	**TN**	**TON**	**Nitrate-N**	**Nitrite-N**	**DRP**	**TDP**	**TP**	**CBOD5**
Average	5.32	0.012	1.017	0.856	0.794	0.004	0.007	0.012	0.022	1
Max.	38	0.36	2.21	1.821	1.65	0.018	0.019	0.042	0.445	3
Median	3	0.008	1	0.86	0.825	0.003	0.007	0.011	0.015	1
Min.	0	-0.003	0.23	0.068	0.171	0.001	0	0	0.003	0.5
N	33	156	156	107	140	140	156	79	156	28
Pct1	0	0	0.373	0.13	0.172	0.001	0.001	0.001	0.003	0.5
Pct10	0	0	0.608	0.453	0.37	0.001	0.003	0.006	0.008	0.5
Pct20	1	0.001	0.707	0.568	0.465	0.001	0.004	0.008	0.011	1
Pct25	1	0.003	0.745	0.678	0.529	0.002	0.005	0.008	0.012	1
Pct30	1.3	0.003	0.8	0.714	0.593	0.002	0.005	0.009	0.012	1
Pct40	2	0.006	0.91	0.808	0.745	0.003	0.006	0.009	0.014	1
Pct5	0	0	0.497	0.325	0.249	0.001	0.003	0.005	0.007	0.5
Pct50	3	0.008	1	0.86	0.825	0.003	0.007	0.011	0.015	1
Pct60	3.3	0.01	1.1	0.934	0.897	0.005	0.008	0.012	0.017	1
Pct70	4.8	0.012	1.167	1	0.961	0.005	0.008	0.014	0.02	1
Pct75	5.375	0.014	1.2	1.016	1	0.006	0.009	0.016	0.021	1
Pct80	5.99	0.015	1.3	1.1	1.03	0.006	0.01	0.016	0.023	1
Pct90	12.4	0.024	1.494	1.235	1.146	0.008	0.011	0.019	0.03	1
Pct95	25.65	0.031	1.672	1.428	1.404	0.01	0.012	0.022	0.043	1.2
Pct99	38	0.062	2.01	1.727	1.521	0.014	0.018	0.037	0.141	3
SE ave	1.406	0.002	0.028	0.031	0.027	0	0	0.001	0.003	0.081
Std. dev.	8.075	0.03	0.349	0.322	0.321	0.003	0.003	0.006	0.038	0.43

MAN4												
Statistic	**E. coli**	**Entero.**	**Tot. coli**	**Clarity**	**Temp.**	**DO sat.**	**DO**	**EC**	**pH**	**Tot. SS**	**Turb.**	**VM**
Average	358.129	38.627	2606.579	2.032	14.136	100.419	10.355	135.718	7.606	8.218	2.685	3.335
Max.	4044	344	11370	8	21.6	170.1	15.33	311	10.07	140	25.3	51
Median	135.5	16	1600	2.05	14	97.9	10.44	119.25	7.52	3	1.66	1.75
Min.	3	1	179	0.45	6.02	62.7	6.53	61	6.59	0	0.43	0
N	62	51	19	28	61	47	61	50	63	62	62	46
Pct1	4.8	1	179	0.45	6.282	62.7	6.717	61	6.593	0	0.431	0
Pct10	48.7	2	330	0.7	8.988	91.28	8.716	85.9	6.94	0.5	0.531	0
Pct20	62.8	5.7	463.1	1.11	9.97	93.08	9.255	100	7.211	1	0.747	1
Pct25	78	8	517.75	1.2	10.433	94.425	9.453	101.4	7.253	1	0.96	1
Pct30	85.1	8	588.8	1.29	11.48	95.1	9.616	104.8	7.29	2	1.052	1.43
Pct40	99	13	913	1.44	12.96	96.28	9.956	111.05	7.357	3	1.375	1.5
Pct5	37.6	1.05	215.45	0.54	8.583	88.31	8.583	81.3	6.699	0	0.492	0
Pct50	135.5	16	1600	2.05	14	97.9	10.44	119.25	7.52	3	1.66	1.75
Pct60	164.8	24	2186	2.2	15.511	99.89	10.622	130.5	7.656	4	2.298	2.1
Pct70	194.2	28.4	2420	2.41	17.02	101.72	10.954	147.35	7.776	6	2.991	3
Pct75	222	32	2780	2.55	17.275	102.175	11.193	160	7.858	7	3.37	3.2
Pct80	343.7	41.5	4258	2.6	17.92	104.49	11.271	176.8	8.044	9.1	3.952	4
Pct90	644.8	91.2	7670	3.015	19.24	115.1	11.77	209.05	8.23	15.6	5.618	4.9
Pct95	1762.8	220.15	10326	3.95	19.89	122.19	12.422	213.1	8.721	22.6	6.618	6.92
Pct99	4029.36	343.44	11370	8	21.466	170.1	15.145	311	9.989	131.12	23.224	51
SE ave	96.545	9.594	708.507	0.269	0.494	2.093	0.177	7.22	0.078	2.47	0.438	1.094
Std. dev.	760.192	68.515	3088.312	1.422	3.857	14.346	1.38	51.054	0.615	19.453	3.449	7.419

MAN4										
STATISTICS	**SS**	**NH4-N**	**TN**	**TON**	**Nitrate-N**	**Nitrite-N**	**DRP**	**TDP**	**TP**	**CBOD5**
Average	6.333	0.076	1.327	0.974	0.982	0.009	0.035	0.016	0.068	0.771
Max.	52	1.8	5.31	2.8	2.7	0.13	0.381	0.068	0.682	1
Median	2	0.013	1.096	0.87	0.869	0.003	0.011	0.014	0.024	1
Min.	0	-0.003	0.396	0.214	0.206	0.001	0	0	0.005	0.25
N	30	62	62	62	51	51	62	16	62	35
Pct1	0	-0.003	0.402	0.219	0.207	0.001	0	0	0.006	0.25
Pct10	0.85	0.001	0.671	0.48	0.47	0.001	0.004	0.006	0.012	0.25
Pct20	1	0.003	0.767	0.619	0.593	0.002	0.007	0.009	0.016	0.25
Pct25	1	0.005	0.87	0.642	0.644	0.003	0.007	0.011	0.017	0.5
Pct30	1.3	0.008	0.922	0.742	0.747	0.003	0.007	0.011	0.019	0.5
Pct40	2	0.011	1.015	0.816	0.821	0.003	0.009	0.012	0.02	1
Pct5	0	0	0.555	0.349	0.331	0.001	0.003	0.002	0.011	0.25
Pct50	2	0.013	1.096	0.87	0.869	0.003	0.011	0.014	0.024	1
Pct60	3	0.014	1.207	0.958	0.966	0.005	0.014	0.014	0.029	1
Pct70	3.8	0.016	1.393	1.113	1.114	0.007	0.02	0.015	0.034	1
Pct75	4	0.018	1.41	1.172	1.135	0.008	0.03	0.016	0.052	1
Pct80	8.25	0.024	1.521	1.31	1.304	0.009	0.036	0.017	0.058	1
Pct90	16	0.054	1.709	1.485	1.558	0.011	0.088	0.021	0.178	1
Pct95	37	0.293	4	2.142	2.119	0.041	0.155	0.054	0.363	1
Pct99	52	1.752	5.297	2.733	2.695	0.129	0.371	0.068	0.658	1
SE ave	2.067	0.037	0.123	0.062	0.071	0.003	0.008	0.004	0.016	0.056
Std. dev.	11.324	0.292	0.966	0.49	0.509	0.021	0.067	0.015	0.123	0.329

MAN5												
Statistic	**E. coli**	**Entero.**	**Tot. coli**	**Clarity**	**Temp.**	**DO sat.**	**DO**	**EC**	**pH**	**Tot. SS**	**Turb.**	**VM**
Average	241.206	35.529	2999.952	2.274	14.246	102.743	10.519	119.737	7.584	5.176	2.525	2.561
Max.	3448	365	16000	6	21.68	141.9	15.1	261	9.49	49	22	12
Median	91	11	1500	2.2	14	101.4	10.445	111.2	7.495	3	1.59	1.5
Min.	11	0.5	170	0.42	5.66	84.6	7.98	70	6.42	0	0.34	0
N	63	52	21	45	63	49	62	51	64	59	59	44
Pct1	11.39	0.51	170	0.42	6.029	84.6	8.021	70.031	6.476	0	0.341	0
Pct10	40.4	1.7	392.8	1.05	9.278	89.78	8.986	80.06	7.096	0.5	0.53	0
Pct20	57.1	4	629	1.1	10.175	94.76	9.376	96.09	7.226	0.5	0.728	1
Pct25	63.25	5	755	1.25	10.7	95.85	9.52	98.9	7.28	1	1.033	1
Pct30	68.4	8	846	1.75	11.7	96.98	9.697	102.88	7.314	1	1.184	1.35
Pct40	82.7	9	1118	1.95	12.953	99.21	10.099	106.01	7.392	2	1.403	1.5
Pct5	29.65	1	256.9	0.675	8.676	87.92	8.546	77.56	6.924	0	0.383	0
Pct50	91	11	1500	2.2	14	101.4	10.445	111.2	7.495	3	1.59	1.5
Pct60	141.5	13	1743.9	2.5	15.5	102.73	10.918	115.5	7.62	3.18	1.861	2.18
Pct70	169.4	31.7	2460	2.7	16.9	104.42	11.227	125.48	7.742	4	2.508	3.12
Pct75	196.25	40	3275	2.763	17.483	106.25	11.41	130.9	7.82	5	3.088	3.4
Pct80	251.4	44	5138	2.845	18.06	107.64	11.523	145.88	7.907	6.7	3.732	4
Pct90	491.2	70.4	8526	3.75	19.24	115.78	11.993	163.52	8.21	11	5.472	5.1
Pct95	781.5	170.6	12628.5	4.815	19.905	134.485	12.552	192.955	8.328	21.65	6.757	7.88
Pct99	3259.76	362.66	16000	6	21.485	141.9	14.832	260.354	9.354	48.1	20.7	12
SE ave	62.96	9.094	856.682	0.178	0.478	1.678	0.165	4.961	0.06	1.127	0.407	0.367
Std. dev.	499.729	65.581	3925.81	1.196	3.79	11.743	1.3	35.425	0.483	8.657	3.123	2.431

MAN5										
STATISTICS	**SS**	**NH4-N**	**TN**	**TON**	**Nitrate-N**	**Nitrite-N**	**DRP**	**TDP**	**TP**	**CBOD5**
Average	5.234	0.015	1.06	0.877	0.861	0.004	0.017	0.01	0.029	0.743
Max.	69	0.2	1.9	1.713	1.71	0.026	0.146	0.016	0.175	1
Median	2	0.009	1	0.863	0.854	0.003	0.007	0.01	0.015	1
Min.	0	-0.002	0.404	0.247	0.241	0.001	0	0.003	0.007	0.25
N	28	63	63	63	52	52	63	16	63	37
Pct1	0	-0.002	0.423	0.248	0.242	0.001	0	0.003	0.007	0.25
Pct10	0.825	0	0.685	0.497	0.483	0.001	0.003	0.006	0.011	0.25
Pct20	1	0.003	0.751	0.579	0.551	0.001	0.006	0.007	0.012	0.25
Pct25	1	0.003	0.808	0.633	0.595	0.002	0.006	0.008	0.012	0.25
Pct30	1	0.004	0.884	0.712	0.637	0.002	0.006	0.009	0.012	0.5
Pct40	2	0.007	0.974	0.805	0.796	0.003	0.007	0.01	0.013	1
Pct5	0	0	0.628	0.403	0.332	0.001	0.002	0.004	0.01	0.25
Pct50	2	0.009	1	0.863	0.854	0.003	0.007	0.01	0.015	1
Pct60	2.58	0.011	1.074	0.91	0.893	0.004	0.009	0.011	0.019	1
Pct70	3	0.014	1.2	0.985	0.982	0.005	0.01	0.011	0.023	1
Pct75	3.15	0.016	1.288	1.093	1.085	0.006	0.012	0.012	0.029	1
Pct80	4.2	0.018	1.327	1.126	1.112	0.006	0.017	0.012	0.032	1
Pct90	8.37	0.031	1.458	1.403	1.403	0.008	0.054	0.014	0.076	1
Pct95	19.5	0.053	1.718	1.477	1.494	0.01	0.081	0.015	0.11	1
Pct99	69	0.182	1.9	1.704	1.709	0.026	0.145	0.016	0.17	1
SE ave	2.428	0.003	0.041	0.041	0.047	0.001	0.004	0.001	0.004	0.056
Std. dev.	12.847	0.027	0.329	0.326	0.337	0.004	0.029	0.003	0.033	0.341

MAN6												
Statistic	**E. coli**	**Entero.**	**Tot. coli**	**Clarity**	**Temp.**	**DO sat.**	**DO**	**EC**	**pH**	**Tot. SS**	**Turb.**	**VM**
Average	432.22		3776	1.897	13.895	100.966	10.365	103.96	7.302	324.375	186.971	120.75
Max.	12000		21000	6	22.5	156.7	15.54	226	9.68	3120	1973	222
Median	60.5		2330	1.875	13.95	100.9	10.35	104.7	7.235	18	8.5	98.5
Min.	7		261	0.1	7.09	70.5	7.05	41.3	6.18	0	0.28	31
N	50		24	34	84	55	69	57	68	173	187	12
Pct1	7		261	0.1	7.121	70.875	7.158	42.329	6.27	0	0.379	31
Pct10	20.5		399.7	0.49	8.99	87.3	8.636	68.44	6.926	0.9	0.61	31
Pct20	29		605.6	0.59	10.26	92.4	9.331	80.92	7.002	2	1.075	53.5
Pct25	34		805	0.8	10.8	93.775	9.583	89.8	7.045	2	1.343	58
Pct30	38.5		1171	1.37	11.81	94.3	9.7	92.18	7.078	3	1.884	60.2
Pct40	44.5		1733	1.505	13.21	96.7	10.09	100.49	7.15	5.82	3.186	68
Pct5	15		356.2	0.32	8.52	81.9	7.884	58.855	6.794	0.5	0.469	31
Pct50	60.5		2330	1.875	13.95	100.9	10.35	104.7	7.235	18	8.5	98.5
Pct60	93		2400	2	14.69	102.6	10.695	111.1	7.29	66.9	36.54	150
Pct70	123		3195	2.29	16.06	104.81	10.928	113.04	7.382	217.4	124	202.8
Pct75	138		4320	2.5	16.6	105.475	11.065	114.525	7.425	310	166.75	207.5
Pct80	189.5		4624.6	2.88	17.182	107.65	11.237	121.36	7.466	467.2	237.4	208.2
Pct90	562.5		13100	3.01	18.624	112.4	11.808	134	7.667	1002.6	503.8	213.6
Pct95	1090		16100	4.62	19.55	126.95	13.033	141.615	8.227	2228.9	1389.7	220.8
Pct99	12000		21000	6	22.466	155.48	15.31	221.1	9.586	3015.9	1889.38	222
SE ave	243.415		1036.875	0.219	0.394	1.812	0.175	3.753	0.061	49.373	30.163	22.055
Std. dev.	1721.207		5079.63	1.276	3.611	13.439	1.456	28.337	0.5	649.405	412.476	76.4

MAN6										
STATISTICS	**SS**	**NH4-N**	**TN**	**TON**	**Nitrate-N**	**Nitrite-N**	**DRP**	**TDP**	**TP**	**CBOD5**
Average	171.64	0.022	1.447	0.795	0.813	0.003	0.007	0.014	0.165	
Max.	1900	0.365	5.7	1.675	1.67	0.016	0.048	0.048	1.409	
Median	40	0.01	1.149	0.82	0.84	0.003	0.007	0.011	0.019	
Min.	0	0	0.386	0.232	0.23	0.001	0.002	0	0.005	
N	91	72	72	67	71	71	72	69	72	
Pct1	0	0	0.396	0.233	0.23	0.001	0.002	0.001	0.005	
Pct10	1	0	0.706	0.314	0.316	0.001	0.003	0.006	0.009	
Pct20	2	0.003	0.856	0.496	0.503	0.001	0.003	0.008	0.011	
Pct25	3	0.003	0.924	0.528	0.533	0.001	0.003	0.009	0.012	
Pct30	4.92	0.004	0.956	0.571	0.58	0.002	0.003	0.01	0.013	
Pct40	9.93	0.006	1.025	0.719	0.779	0.002	0.006	0.011	0.015	
Pct5	0	0	0.64	0.253	0.251	0.001	0.003	0.005	0.008	
Pct50	40	0.01	1.149	0.82	0.84	0.003	0.007	0.011	0.019	
Pct60	76	0.015	1.321	0.891	0.9	0.003	0.007	0.013	0.022	
Pct70	151.6	0.019	1.5	0.938	0.971	0.004	0.009	0.016	0.028	
Pct75	211.5	0.024	1.6	1.001	1.038	0.005	0.009	0.018	0.073	
Pct80	288.1	0.041	1.7	1.086	1.101	0.005	0.009	0.019	0.234	
Pct90	568	0.049	2.36	1.18	1.2	0.007	0.01	0.022	0.555	
Pct95	798.95	0.072	3.94	1.455	1.457	0.008	0.013	0.024	1.256	
Pct99	1501.48	0.302	5.502	1.657	1.649	0.015	0.042	0.047	1.394	
SE ave	31.303	0.005	0.114	0.042	0.042	0	0.001	0.001	0.04	
Std. dev.	298.612	0.046	0.971	0.346	0.35	0.003	0.006	0.008	0.342	

MAN7												
Statistic	**E. coli**	**Entero.**	**Tot. coli**	**Clarity**	**Temp.**	**DO sat.**	**DO**	**EC**	**pH**	**Tot. SS**	**Turb.**	**VM**
Average	725.205		5522.478	2.23	14.904	101.448	10.175	91.782	7.285	7.159	4.186	0
Max.	22000		52000	5.9	21.5	127.9	12.01	133.5	8.04	56	59.4	0
Median	43		1100	2.2	14.6	102.2	10.34	90.9	7.28	2	1.035	0
Min.	7		238	0.25	9.2	84.2	7.96	42	6.46	0	0.35	0
N	39		23	38	45	42	42	45	44	39	40	0
Pct1	7		238	0.25	9.2	84.2	7.96	42	6.46	0	0.35	0
Pct10	12		417	0.8	10.3	89.31	8.981	67.9	6.982	0.5	0.465	0
Pct20	16		551.2	1.473	11.55	94	9.198	76.6	7.073	0.5	0.505	0
Pct25	17.5		607.5	1.5	12.05	96.2	9.37	78.575	7.095	1	0.525	0
Pct30	23.4		762	1.77	12.9	98.62	9.721	84.1	7.141	1	0.6	0
Pct40	34		905	2	13.95	99.73	10.123	87.15	7.2	1.02	0.88	0
Pct5	10		307.55	0.27	9.875	85.9	8.458	61.925	6.823	0	0.42	0
Pct50	43		1100	2.2	14.6	102.2	10.34	90.9	7.28	2	1.035	0
Pct60	63.4		1490	2.5	15.9	103.24	10.487	95.2	7.357	3	1.355	0
Pct70	105.2		2582	2.633	16.9	104.26	10.697	99.7	7.413	5	1.93	0
Pct75	160.5		2772.5	2.8	17.55	105.9	10.75	101.025	7.455	5.15	2.365	0
Pct80	279.4		2818	2.99	17.9	106.47	10.965	105.1	7.525	6.7	3.01	0
Pct90	562.8		14028	3.443	20	112.93	11.319	119.9	7.662	21.4	11.09	0
Pct95	1275		44889	3.812	20.725	115.26	11.472	123.35	7.722	45.25	20.45	0
Pct99	22000		52000	5.9	21.5	127.9	12.01	133.5	8.04	56	59.4	0
SE ave	561.894		2738.902	0.179	0.511	1.373	0.144	2.864	0.044	2.113	1.619	0
Std. dev.	3509.025		13135.314	1.106	3.425	8.897	0.933	19.209	0.29	13.197	10.242	0

MAN7										
STATISTICS	**SS**	**NH4-N**	**TN**	**TON**	**Nitrate-N**	**Nitrite-N**	**DRP**	**TDP**	**TP**	**CBOD5**
Average	7.285	0.01	1.14	0.948	0.985	0.004	0.006	0.009	0.018	
Max.	63	0.089	1.9	1.975	1.97	0.015	0.015	0.019	0.096	
Median	1.5	0.006	1.1	0.907	0.944	0.003	0.005	0.008	0.013	
Min.	0	-0.001	0.297	0.152	0.15	0.001	0.001	0.003	0.003	
N	34	45	45	40	44	44	45	44	45	
Pct1	0	-0.001	0.297	0.152	0.15	0.001	0.001	0.003	0.003	
Pct10	0	0	0.57	0.443	0.479	0.001	0.003	0.005	0.006	
Pct20	0.5	0.001	0.82	0.608	0.653	0.001	0.003	0.005	0.008	
Pct25	0.5	0.002	0.931	0.727	0.752	0.001	0.003	0.005	0.01	
Pct30	0.57	0.003	0.945	0.778	0.814	0.001	0.003	0.005	0.01	
Pct40	1	0.003	1.034	0.872	0.888	0.002	0.005	0.007	0.011	
Pct5	0	0	0.478	0.227	0.253	0.001	0.002	0.004	0.005	
Pct50	1.5	0.006	1.1	0.907	0.944	0.003	0.005	0.008	0.013	
Pct60	2	0.007	1.192	1	0.998	0.004	0.006	0.009	0.014	
Pct70	3	0.011	1.4	1.081	1.101	0.005	0.007	0.01	0.016	
Pct75	4	0.012	1.423	1.103	1.263	0.006	0.008	0.012	0.018	
Pct80	6.7	0.013	1.5	1.266	1.373	0.007	0.008	0.012	0.021	
Pct90	20.9	0.032	1.7	1.528	1.657	0.008	0.009	0.015	0.036	
Pct95	50.8	0.04	1.825	1.694	1.696	0.01	0.011	0.016	0.05	
Pct99	63	0.089	1.9	1.975	1.97	0.015	0.015	0.019	0.096	
SE ave	2.586	0.002	0.061	0.065	0.064	0	0	0.001	0.003	
Std. dev.	15.078	0.016	0.406	0.411	0.424	0.003	0.003	0.004	0.018	

MAN8												
Statistic	**E. coli**	**Entero.**	**Tot. coli**	**Clarity**	**Temp.**	**DO sat.**	**DO**	**EC**	**pH**	**Tot. SS**	**Turb.**	**VM**
Average	540.764		3210	3.882	11.831	99.619	10.801	53.371	7.36	4.782	2.471	5
Max.	17329		36540	9	20.49	112	19.03	95	9.65	123	74.6	12
Median	49.5		1040	3	11.41	100.55	10.785	55.4	7.37	1	0.495	1.5
Min.	3		184	0.05	6.1	82.4	7.95	21	5.71	0	0.16	1.5
N	72		24	69	78	54	76	66	77	66	74	3
Pct1	3.66		184	0.098	6.156	82.564	8.051	22.6	5.799	0	0.165	1.5
Pct10	16		321	1.4	7.244	92.11	9.143	36.17	6.776	0	0.247	1.5
Pct20	27.8		460.7	2	8.4	94.69	9.623	43.7	7.047	0.5	0.333	1.5
Pct25	31		594.5	2.288	8.76	95.7	9.745	48	7.148	0.5	0.34	1.5
Pct30	34.1		663.9	2.76	9.459	96.27	9.901	50.18	7.22	0.5	0.377	1.5
Pct40	40.3		883	3	10.349	98.77	10.532	53.9	7.3	0.5	0.46	1.5
Pct5	11.1		248.4	1.095	6.54	88.52	8.878	34.7	6.564	0	0.2	1.5
Pct50	49.5		1040	3	11.41	100.55	10.785	55.4	7.37	1	0.495	1.5
Pct60	66.7		1928.8	3.982	12.23	101.9	11.085	57.33	7.49	1.04	0.599	4.65
Pct70	98.4		2126	5	13.811	103.11	11.421	58.74	7.594	2	0.703	7.8
Pct75	105		2460	5.001	14.7	104	11.65	59.1	7.66	2	0.76	9.375
Pct80	128.1		2570	5.371	15.39	104.34	11.869	60.73	7.691	2.44	0.901	10.95
Pct90	438.8		4186	8	17.11	107.14	12.039	63.96	7.778	3	2.241	12
Pct95	1157		18844	8	18.452	108.66	12.447	66.78	7.93	10.8	3.252	12
Pct99	15542.38		36540	8.81	20.185	111.904	17.743	90.84	9.202	117.4	67.712	12
SE ave	275.788		1518.639	0.267	0.415	0.833	0.175	1.396	0.057	2.277	1.176	3.5
Std. dev.	2340.137		7439.782	2.214	3.665	6.123	1.528	11.341	0.497	18.495	10.119	6.062

MAN8										
STATISTICS	**SS**	**NH4-N**	**TN**	**TON**	**Nitrate-N**	**Nitrite-N**	**DRP**	**TDP**	**TP**	**CBOD5**
Average	5.613	0.006	0.151	0.057	0.056	0.002	0.004	0.009	0.011	0.714
Max.	154	0.045	0.934	0.161	0.157	0.007	0.013	0.048	0.075	2
Median	0.75	0.003	0.13	0.044	0.049	0.002	0.003	0.008	0.009	0.5
Min.	0	0	0.025	0	0	0	0.002	0.003	0.003	0.5
N	35	78	78	73	61	61	78	68	78	7
Pct1	0	0	0.025	0	0	0	0.002	0.003	0.003	0.5
Pct10	0	0.001	0.075	0.008	0.004	0.001	0.003	0.005	0.005	0.5
Pct20	0	0.003	0.088	0.013	0.015	0.001	0.003	0.005	0.006	0.5
Pct25	0	0.003	0.094	0.018	0.02	0.001	0.003	0.006	0.006	0.5
Pct30	0	0.003	0.1	0.024	0.024	0.001	0.003	0.007	0.007	0.5
Pct40	0.5	0.003	0.112	0.032	0.038	0.001	0.003	0.007	0.008	0.5
Pct5	0	0	0.058	0.005	0.002	0.001	0.002	0.003	0.005	0.5
Pct50	0.75	0.003	0.13	0.044	0.049	0.002	0.003	0.008	0.009	0.5
Pct60	1	0.005	0.149	0.066	0.065	0.003	0.003	0.01	0.01	0.5
Pct70	2	0.006	0.16	0.079	0.08	0.003	0.006	0.01	0.011	0.5
Pct75	2	0.007	0.18	0.088	0.089	0.003	0.006	0.01	0.012	0.5
Pct80	3.1	0.008	0.19	0.094	0.094	0.003	0.007	0.011	0.014	0.65
Pct90	4	0.013	0.224	0.121	0.122	0.003	0.009	0.013	0.017	1.7
Pct95	4.525	0.024	0.296	0.149	0.144	0.005	0.01	0.018	0.022	2
Pct99	154	0.043	0.788	0.161	0.156	0.007	0.013	0.043	0.062	2
SE ave	4.371	0.001	0.013	0.005	0.006	0	0	0.001	0.001	0.214
Std. dev.	25.861	0.008	0.113	0.045	0.044	0.001	0.003	0.006	0.009	0.567

MAN9												
Statistic	**E. coli**	**Entero.**	**Tot. coli**	**Clarity**	**Temp.**	**DO sat.**	**DO**	**EC**	**pH**	**Tot. SS**	**Turb.**	**VM**
Average	42.455		256.207	3.672	9.443	100.176	11.382	49.947	7.567	2.837	2.632	7
Max.	1733		1300	10	18.13	111.8	17	69	9.84	100	62.9	18
Median	4.5		160	3	9.44	99.8	11.3	51.7	7.66	0.5	0.66	1.5
Min.	0		40	0.05	4.6	88.4	8.71	14	4.47	0	0.23	1.5
N	112		29	64	147	54	69	135	135	65	66	3
Pct1	0		40	0.127	4.6	88.424	8.803	22.5	4.47	0	0.23	1.5
Pct10	1		90	2	6.1	93.86	9.998	38	6.81	0	0.331	1.5
Pct20	2		110	2.41	6.89	95.89	10.35	44.5	7.06	0.5	0.407	1.5
Pct25	2		110	2.815	7.103	96.4	10.44	46.1	7.2	0.5	0.45	1.5
Pct30	3		118.4	2.955	7.4	97.57	10.734	47.9	7.3	0.5	0.516	1.5
Pct40	4		141	3	8.7	98.8	10.902	49	7.495	0.5	0.57	1.5
Pct5	0.05		55.2	1.105	5.385	89.56	9.506	29.65	6.395	0	0.264	1.5
Pct50	4.5		160	3	9.44	99.8	11.3	51.7	7.66	0.5	0.66	1.5
Pct60	8		190	3.28	10.053	101.64	11.476	53	7.73	1	0.746	6.45
Pct70	12		257.6	4	10.8	103.42	11.92	54.7	7.85	2	0.91	11.4
Pct75	16		295	4.175	11.275	103.9	12.153	56	7.9	2	1.12	13.875
Pct80	21.4		377	5	12.21	104.51	12.314	57	8.01	2	1.237	16.35
Pct90	44.9		579	7.006	13.38	107.05	12.994	60	8.4	3	3.071	18
Pct95	72		647.35	8	13.93	110.24	13.599	63	8.95	5.55	5.124	18
Pct99	1501.74		1300	9.72	15.288	111.776	16.422	66.45	9.789	86.35	60.1	18
SE ave	19.6		47.328	0.244	0.229	0.734	0.16	0.792	0.07	1.531	1.156	5.5
Std. dev.	207.425		254.868	1.955	2.778	5.392	1.326	9.204	0.816	12.342	9.39	9.526

MAN9										
STATISTICS	**SS**	**NH4-N**	**TN**	**TON**	**Nitrate-N**	**Nitrite-N**	**DRP**	**TDP**	**TP**	**CBOD5**
Average	1.776	0.005	0.079	0.013	0.01	0.002	0.004	0.009	0.009	0.5
Max.	20	0.057	0.63	0.13	0.12	0.011	0.02	0.089	0.21	0.5
Median	1	0.003	0.069	0.01	0.009	0.001	0.004	0.007	0.007	0.5
Min.	0	0	0	0	0	0	0	0	0.002	0.5
N	34	149	149	100	139	139	149	111	149	1
Pct1	0	0	0.01	0	0	0	0	0	0.002	0
Pct10	0	0	0.032	0.003	0.001	0.001	0.003	0.004	0.003	0
Pct20	0	0.001	0.04	0.005	0.003	0.001	0.003	0.005	0.005	0
Pct25	0	0.002	0.048	0.007	0.003	0.001	0.003	0.005	0.005	0
Pct30	0	0.003	0.052	0.007	0.004	0.001	0.003	0.005	0.005	0
Pct40	0.55	0.003	0.059	0.008	0.006	0.001	0.003	0.006	0.006	0
Pct5	0	0	0.025	0.002	0	0	0.003	0.003	0.003	0
Pct50	1	0.003	0.069	0.01	0.009	0.001	0.004	0.007	0.007	0
Pct60	1.19	0.003	0.073	0.012	0.011	0.002	0.005	0.008	0.008	0
Pct70	2	0.005	0.084	0.013	0.012	0.002	0.005	0.009	0.009	0
Pct75	2	0.006	0.09	0.015	0.013	0.003	0.005	0.01	0.009	0
Pct80	2	0.008	0.096	0.016	0.014	0.003	0.006	0.01	0.01	0
Pct90	4.1	0.012	0.12	0.022	0.019	0.004	0.007	0.013	0.012	0
Pct95	5	0.019	0.151	0.026	0.024	0.005	0.008	0.017	0.014	0
Pct99	20	0.047	0.345	0.093	0.107	0.009	0.015	0.062	0.073	0
SE ave	0.601	0.001	0.006	0.001	0.001	0	0	0.001	0.002	0
Std. dev.	3.503	0.008	0.069	0.014	0.014	0.002	0.003	0.01	0.018	0

6.3 Summary Statistics for Pahiatua WWTP Discharge

YYYY	STATISTICS	ECOLI	ENTERO	TCOLI	TSS	TURB	VM	S_S	NH4	TN	TON	NITRA	NITRI	DRP	TDP	TP	CBOD5
2008	N of Cases	12			12	12	12		12	12	12			12		12	12
2008	Minimum	594			13	18.8	13		0.005	7.95	0.001			0.531		2.69	0.5
2008	Maximum	260250			140	173	135		15	28.3	4.622			6.317		7	5
2008	Median	4362.5			71.5	29.85	65		6.07	14.95	0.3505			2.517		4.225	2.25
2008	Arithmetic Mean	74188.2			78.7	60.1	72		6.9	15.5	1			3.2		4.7	2.3
2008	Standard Deviation	100568.4			38.1	58.2	35.7		6.6	5.9	1.6			1.9		1.6	1.5
2009	N of Cases	12	8		12	12	4		12	12	12	8	8	12		12	12
2009	Minimum	472	27		6	3.99	66		0.288	3.15	0.037	0.033	0.0025	0.202		0.286	0.5
2009	Maximum	461110	36540		115	60.7	110		21	31	4.3265	2.001	0.231	4.76		6.79	3
2009	Median	146440.5	8015.5		71	36.1	77.5		14.35	22.45	0.209	0.0865	0.0565	3.23		4.495	1.75
2009	Arithmetic Mean	160164.3	9575.1		67.8	33.2	82.8		13.2	21	0.9	0.3	0.1	3.4		4.4	2.1
2009	Standard Deviation	159534.8	12062.6		36.1	15.9	20.2		5.9	7.1	1.3	0.7	0.1	1.3		1.7	0.9
2010	N of Cases	12	12	3	12	12	3		12	12	12	12	12	12		12	12
2010	Minimum	0.5	0.5	4840	0.5	0.98	7		0.058	3.9	0.034	0.0025	0.002	0.035		0.146	
2010	Maximum	2142	12033	12240	110	49.4	28		14.4	20.5	2.871	2.86	0.593	3.46		4.75	4.3
2010	Median	308	382.5		22	15.15	8		2.09	9.68	1.517	1.12	0.04	2.033		2.815	2.9
2010	Arithmetic Mean	611.3	1731.2	7447	42.3	20.9	14.3		4.8	10.8	1.4	1.3	0.2	1.8		2.5	2.4
2010	Standard Deviation	697.9	3416.3	4156.2	43.1	17.6	11.8		5.1	6.1	1	1	0.2	1.3		1.8	1.2
2011	N of Cases	12	12	12	12	12	12	10	12	12	12	12	12	12		12	12
2011	Minimum	0.5	0.5	3	0.5	1.5	0.5	2	0.129	2.4	0.58	0.47	0.001	0.026		0.131	0.25
2011	Maximum	5300	980	240000	124	95.2	70	101	17	22	2.977	2.97	0.11	3.034		4	1.5
2011	Median	2	0.75		6	4.9	5	3.5	1.7	4.45	2.257	2.255	0.0055	0.0875		0.174	0.75
2011	Arithmetic Mean	659.6	179.6	25754.8	16.1	12.2	10.2	14.1	3.8	6.9	1.9	1.9		0.8		1	0.8
2011	Standard Deviation	1560	329.8	69132.1	34.2	26.2	19	30.7	5.5	5.9	0.8	0.9		1.3		1.6	0.4
2012	N of Cases	12	12	8	12	12	12	12	12	12	12	12	12	12	4	12	12
2012	Minimum	0.5	0.5	18		1.75			0.7	2.9	0.23	0.18	0.0031	0.006	0.043	0.12	0.25
2012	Maximum	1200	2100	61000	19	9.5	18	35	13	26	2.6	2.6	0.3244	3.101	3.128	3.227	2
2012	Median	51	5		4.5	4.255	3.4	3.4	1.91	4.8825	2.0012	1.99895	0.02695	0.1015	1.5495	0.315	0.485
2012	Arithmetic Mean	245.4	206.5	13767.3	6.1	4.5	5	6.7	3.8	8	1.9	1.8	0.1	1	1.6	1.1	0.7
2012	Standard Deviation	399	598.6	21848.8	5.5	2.2	5	9.7	3.7	6.8	0.6	0.6	0.1	1.3	1.7	1.3	0.6
2013	N of Cases	12	12		12	12	12	12	12	12	12	12	12	12	12	12	12
2013	Minimum					1.96				3.384	1.0684	1.0592			0.007	0.046	1
2013	Maximum	105	36		5	22.7	2	2	2.099	4.86	2.5794	2.5716	0.0131	0.045	0.113	0.123	3
2013	Median	0	0		1	5.205	0.5	1	1.7765	3.945	2.001	1.99175	0.00645	0.0275	0.043	0.1075	1
2013	Arithmetic Mean	13.3	5.7		1.2	7.5	0.6	1.3	1.6	4.1	2	2			0.1	0.1	1.3
2013	Standard Deviation	30.3	10.7		1.6	6.5	0.7	0.8	0.5	0.4	0.5	0.5					0.6

6.4 Annual Summary Statistics for the Pahiatua Wastewater Treatment Plant Discharge

Stat.	*E. coli* (n/100 mL)	Entero. (cfu/100 mL)	TSS	Turb. (NTU)	VM	SS	Amm. N	TN	TO N	NO$_3$.-N	NO$_2$-N	DRP	TP	cBOD$_5$
2008														
No.	12	0	12	12	12	0	12	12	12	0	0	12	12	12
Min.	594		13	18.8	13		0.005	7.95	0.001			0.531	2.69	0.5
Max.	260250		140	173	135		15	28.3	4.622			6.317	7	5
Avg.	74188.2		78.7	60.1	72		6.9	15.5	1			3.2	4.7	2.3
Std. dev.	100568.4		38.1	58.2	35.7		6.6	5.9	1.6			1.9	1.6	1.5
P1	594		13	18.8	13		0.005	7.95	0.001			0.531	2.69	0.5
P5	644.6		15.8	18.95	15.7		0.0072	8.109	0.0014			0.5818	2.724	0.5
P10	948.2		32.6	19.85	31.9		0.0204	9.063	0.0038			0.8866	2.928	0.5
P20	1325		50.9	22.73	45.4		0.1656	10.134	0.0563			1.79635	3.525	0.5
P25	1950		59	23.6	52.5		0.224	10.7	0.0845			1.93875	3.595	1
P30	2583.2		66.3	24.5	59.2		0.4293	11.24	0.1177			2.045	3.616	1.5
P40	2984.9		69.3	27.89	61.9		2.127	12.32	0.25			2.4881	3.67	1.5
P50	4362.5		71.5	29.85	65		6.07	14.95	0.3505			2.517	4.225	2.25
P60	62627		74.4	34.33	68.8		10.853	15.97	0.4678			2.7216	5.473	3
P70	104299.1		84	48.7	74.5		12.845	19.78	0.65725			3.9942	5.959	3
P75	139749		105	88.05	90		13.7	20.25	0.75525			4.97	6.19	3.5
P80	180580.1		126	129.7	107.5		14.44	20.3	1.184			5.8264	6.438	4
P90	250415		136.5	166	131.5		14.86	22.7	4.4015			6.0517	6.846	4.3
P95	258845		139.5	172	134.5		14.98	27.5	4.5905			6.2791	6.978	4.9
P99	260250		140	173	135		15	28.3	4.622			6.317	7	5

Stat.	***E. coli*** **(n/100 mL)**	**Entero. (cfu/100 mL)**	**TSS**	**Turb. (NTU)**	**VM**	**SS**	**Amm. N**	**TN**	**TO N**	**NO_3.-N**	**NO_2-N**	**DRP**	**TP**	**$cBOD_5$**
2009														
No.	12	8	12	12	4	0	12	12	12	8	8	12	12	12
Min.	472	27	6	3.99	66		0.288	3.15	0.037	0.033	0.0025	0.202	0.286	0.5
Max.	461110	36540	115	60.7	110		21	31	4.3265	2.001	0.231	4.76	6.79	3
Avg.	160164.3	9575.1	67.8	33.2	82.8		13.2	21	0.9	0.3	0.1	3.4	4.4	2.1
Std. dev.	159534.8	12062.6	36.1	15.9	20.2		5.9	7.1	1.3	0.7	0.1	1.3	1.7	0.9
P1	472	27	6	3.99	66		0.288	3.15	0.037	0.033	0.0025	0.202	0.286	0.5
P5	558.2	27	7.7	5.061	66		0.8412	4.475	0.0402	0.033	0.0025	0.4206	0.6144	0.6
P10	1075.4	37.2	17.9	11.487	66		4.1604	12.425	0.0594	0.0357	0.00895	1.7322	2.5848	1.2
P20	2887.4	75.1	23	19.02	66.9		8.484	17.57	0.0879	0.0423	0.0256	2.9091	3.786	1.5
P25	13555	131.5	38	20.3	67.5		9.79	17.95	0.1145	0.0435	0.032	2.9985	3.81	1.5
P30	27772	187.9	54.3	22.14	68.1		11.05	18.25	0.1399	0.0447	0.0384	3.0429	3.812	1.5
P40	85297.3	4566.5	67.5	32.64	70.7		13.57	19.81	0.1531	0.059	0.0456	3.1611	3.986	1.5
P50	146440.5	8015.5	71	36.1	77.5		14.35	22.45	0.209	0.0865	0.0565	3.23	4.495	1.75
P60	162321	10015.8	76.6	40.33	84.3		15.69	23.13	0.3153	0.1173	0.0677	3.9562	4.773	2.7
P70	177372	11174	85.3	42.07	93.2		17.01	24.75	0.5076	0.1439	0.0869	4.2904	5.226	3
P75	271965	11870	98	42.75	98		17.7	25.7	1.3565	0.1635	0.1385	4.376	5.48	3
P80	365551.5	12566	110	43.8	102.8		18.31	26.55	2.1914	0.1831	0.1901	4.4833	5.734	3
P90	395173.5	29400	111.5	51.39	110		19.18	28.2	2.85965	1.4571	0.2226	4.7383	6.328	3
P95	451690.5	36540	114.5	59.37	110		20.74	30.6	4.11695	2.001	0.231	4.7569	6.724	3
P99	461110	36540	115	60.7	110		21	31	4.3265	2.001	0.231	4.76	6.79	3

Stat.	*E. coli* (n/100 mL)	Entero. (cfu/100 mL)	TSS	Turb. (NTU)	VM	SS	Amm. N	TN	TO N	NO_3.-N	NO_2-N	DRP	TP	$cBOD_5$
2010														
No.	12	12	12	12	3	0	12	12	12	12	12	12	12	12
Min.	0.5	0.5	0.5	0.98	7		0.058	3.9	0.034	0.0025	0.002	0.035	0.146	0
Max.	2142	12033	110	49.4	28		14.4	20.5	2.871	2.86	0.593	3.46	4.75	4.3
Avg.	611.3	1731.2	42.3	20.9	14.3		4.8	10.8	1.4	1.3	0.2	1.8	2.5	2.4
Std. dev.	697.9	3416.3	43.1	17.6	11.8		5.1	6.1	1	1	0.2	1.3	1.8	1.2
P1	0.5	0.5	0.5	0.98	7		0.058	3.9	0.034	0.0025	0.002	0.035	0.146	0
P5	0.5	0.5	0.5	1.001	7		0.0672	3.90265	0.0431	0.00975	0.002	0.0387	0.1465	0.1
P10	0.5	0.5	0.5	1.127	7		0.1224	3.91855	0.0977	0.05325	0.002	0.0609	0.1495	0.7
P20	1.85	4.55	0.95	4.142	7.1		1.131	4.08265	0.6335	0.2739	0.00245	0.0873	0.1591	1.45
P25	27	5	4	6.575	7.25		1.365	4.269	0.723	0.391	0.0025	0.106	0.5	1.5
P30	63.8	6.2	7.3	8.739	7.4		1.502	4.8712	0.7684	0.4954	0.00335	0.2804	0.944	1.5
P40	210.8	115.4	10.6	9.579	7.7		1.634	8.956	0.9397	0.625	0.0167	1.7003	1.919	1.89
P50	308	382.5	22	15.15	8		2.09	9.68	1.517	1.12	0.04	2.033	2.815	2.9
P60	580.9	697.2	59.3	25.46	14		3.673	12.791	2.0145	1.881	0.092	2.5771	3.697	3
P70	1038.1	1599	79.1	35.9	20		6.601	15.71	2.1426	2.1345	0.146	2.6881	3.946	3
P75	1094	1866	82	37.75	23		9.035	15.95	2.192	2.1875	0.2975	2.8525	4.16	3
P80	1147.5	2181.4	85.6	39.2	26		11.27	16.28	2.2554	2.2545	0.4465	3.0243	4.359	3.07
P90	1669.5	5989.9	103	45.41	28		12.65	19.31	2.6001	2.5905	0.4999	3.2136	4.533	3.88
P95	2074.5	11169.7	109	48.83	28		14.15	20.33	2.8323	2.8215	0.5797	3.4248	4.719	4.24
P99	2142	12033	110	49.4	28		14.4	20.5	2.871	2.86	0.593	3.46	4.75	4.3

Stat.	***E. coli*** **(n/100 mL)**	**Entero. (cfu/100 mL)**	**TSS**	**Turb. (NTU)**	**VM**	**SS**	**Amm. N**	**TN**	**TO N**	**NO_3.-N**	**NO_2-N**	**DRP**	**TP**	**$cBOD_5$**
2011														
No.	12	12	12	12	12	10	12	12	12	12	12	12	12	12
Min.	0.5	0.5	0.5	1.5	0.5	2	0.129	2.4	0.58	0.47	0.001	0.026	0.131	0.25
Max.	5300	980	124	95.2	70	101	17	22	2.977	2.97	0.11	3.034	4	1.5
Avg.	659.6	179.6	16.1	12.2	10.2	14.1	3.8	6.9	1.9	1.9		0.8	1	0.8
Std. dev.	1560	329.8	34.2	26.2	19	30.7	5.5	5.9	0.8	0.9		1.3	1.6	0.4
P1	0.5	0.5	0.5	1.5	0.5	2	0.129	2.4	0.58	0.47	0.001	0.026	0.131	0.25
P5	0.5	0.5	0.75	1.552	0.75	2	0.2561	2.53	0.58	0.479	0.001	0.0277	0.1313	0.25
P10	0.5	0.5	2.25	1.864	2.25	2	1.0187	3.31	0.58	0.533	0.001	0.0379	0.1331	0.25
P20	0.5	0.5	3	2.29	3	2	1.49	4.06	0.6862	0.5942	0.001	0.0475	0.1511	0.475
P25	0.5	0.5	4	3.13	3	2	1.5	4.14	1.246	1.194	0.0015	0.0585	0.155	0.5
P30	0.55	0.5	5	4.022	3.1	2	1.52	4.192	1.8108	1.807	0.002	0.0705	0.1574	0.5
P40	1.3	0.5	5.3	4.799	4.3	2.5	1.7	4.33	2.025	2.023	0.0026	0.0843	0.1649	0.5
P50	2	0.75	6	4.9	5	3.5	1.7	4.45	2.257	2.255	0.0055	0.0875	0.174	0.75
P60	3.4	6.6	6.7	5.127	5.7	5	1.7	4.78	2.349	2.347	0.007	0.1033	0.1747	1
P70	58.9	189.9	9.7	6.129	6	7	1.7	4.99	2.4744	2.467	0.0079	0.109	0.2191	1
P75	377.5	217.5	10	6.415	6.8	8	1.75	6.4	2.5175	2.51	0.0165	1.4995	1.582	1
P80	806	275.2	10.4	6.847	7.74	9.5	3.02	8.62	2.5555	2.549	0.0325	2.891	3.029	1
P90	2885	802.9	47	34.909	27.3	56	14.9	17.8	2.7355	2.732	0.103	2.9402	3.881	1.15
P95	4955	954.7	113	86.587	63.9	101	16.7	21.4	2.9425	2.936	0.109	3.0206	3.983	1.45
P99	5300	980	124	95.2	70	101	17	22	2.977	2.97	0.11	3.034	4	1.5

Stat.	*E. coli* (n/100 mL)	Entero. (cfu/100 mL)	TSS	Turb. (NTU)	VM	SS	Amm. N	TN	TO N	NO$_3$.-N	NO$_2$-N	DRP	TP	cBOD$_5$
2012														
No.	12	12	12	12	12	12	12	12	12	12	12	12	12	12
Min.	0.5	0.5	0	1.75	0	0	0.7	2.9	0.23	0.18	0.0031	0.006	0.12	0.25
Max.	1200	2100	19	9.5	18	35	13	26	2.6	2.6	0.3244	3.101	3.227	2
Avg.	245.4	206.5	6.1	4.5	5	6.7	3.8	8	1.9	1.8	0.1	1	1.1	0.7
Std. dev.	399	598.6	5.5	2.2	5	9.7	3.7	6.8	0.6	0.6	0.1	1.3	1.3	0.6
P1	0.5	0.5	0	1.75	0	0	0.7	2.9	0.23	0.18	0.0031	0.006	0.12	0.25
P5	0.55	0.5	0.1	1.775	0.1	0.05	0.81	2.9474	0.33808	0.28293	0.00324	0.0084	0.1207	0.25
P10	0.85	0.5	0.7	1.925	0.7	0.35	1.47	3.2318	0.98656	0.90051	0.00408	0.0228	0.1249	0.25
P20	1.9	0.5	1.72	2.981	1.18	0.95	1.89	3.5774	1.66108	1.56093	0.00585	0.0687	0.1387	0.25
P25	3	2.25	2.1	3.225	1.5	1.05	1.9	3.85	1.7	1.6	0.007	0.0765	0.15	0.25
P30	4	4	2.52	3.404	1.86	1.16	1.9	4.17	1.71	1.61	0.00812	0.0804	0.1625	0.25
P40	14.5	4	3.66	3.887	2.64	2.09	1.9006	4.8195	1.86	1.78937	0.00941	0.0867	0.1955	0.25
P50	51	5	4.5	4.255	3.4	3.4	1.91	4.8825	2.0012	1.99895	0.02695	0.1015	0.315	0.485
P60	151.9	7.4	5.76	4.441	5.28	4.64	2.2554	5.11	2.07072	2.0336	0.0685	0.369	0.585	0.916
P70	191.8	82.7	7.8	5.314	6	7.7	3.39	9.3202	2.19	2.0948	0.0808	1.668	2.226	1
P75	261	100.5	9	5.62	6.6	8.05	4.7605	10.6755	2.2862	2.15	0.09125	2.3	2.7	1
P80	389	114	10.2	5.933	7.48	8.59	6.3092	11.9157	2.37745	2.2213	0.10235	2.8038	3.0059	1.01
P90	1004	735	14.1	7.652	12.4	19.6	10.1321	18.3	2.47603	2.4691	0.17432	2.9169	3.1094	1.37
P95	1172	1905	18.3	9.236	17.2	32.8	12.5903	24.9	2.58229	2.5813	0.30296	3.0747	3.2102	1.91
P99	1200	2100	19	9.5	18	35	13	26	2.6	2.6	0.3244	3.101	3.227	2

Stat.	*E. coli* (n/100 mL)	Entero. (cfu/100 mL)	TSS	Turb. (NTU)	VM	SS	Amm. N	TN	TO N	NO_3.-N	NO_2-N	DRP	TP	$cBOD_5$
2013														
No.	12	12	12	12	12	12	12	12	12	12	12	12	12	12
Min.	0	0	0	1.96	0	0	0	3.384	1.0684	1.0592	0	0	0.046	1
Max.	105	36	5	22.7	2	2	2.099	4.86	2.5794	2.5716	0.0131	0.045	0.123	3
Avg.	13.3	5.7	1.2	7.5	0.6	1.3	1.6	4.1	2	2			0.1	1.3
Std. dev.	30.3	10.7	1.6	6.5	0.7	0.8	0.5	0.4	0.5	0.5				0.6
P1	0	0	0	1.96	0	0	0	3.384	1.0684	1.0592	0	0	0.046	1
P5	0	0	0	2.002	0	0	0.1566	3.4103	1.08468	1.07593	0.00047	0.0012	0.0488	1
P10	0	0	0	2.254	0	0	1.0962	3.5681	1.18236	1.17631	0.00329	0.0084	0.0656	1
P20	0	0	0	2.56	0	0.9	1.7064	3.8351	1.68408	1.67416	0.00524	0.0129	0.0839	1
P25	0	0	0	3.565	0	1	1.729	3.8725	1.7833	1.7726	0.00555	0.0165	0.0905	1
P30	0	0	0	4.597	0	1	1.7384	3.8905	1.84206	1.83163	0.0058	0.0203	0.0966	1
P40	0	0	0.3	5.029	0	1	1.7633	3.9097	1.94154	1.93327	0.00592	0.0236	0.1032	1
P50	0	0	1	5.205	0.5	1	1.7765	3.945	2.00095	1.99175	0.00645	0.0275	0.1075	1
P60	2.8	2.8	1	5.549	1	1.7	1.7862	4.0874	2.17166	2.17007	0.00747	0.0314	0.109	1
P70	4	4	1	7.052	1	2	1.806	4.2335	2.24531	2.24009	0.00906	0.0356	0.1126	1
P75	10	6	1	7.985	1	2	1.819	4.259	2.28505	2.2788	0.00985	0.0385	0.1145	1
P80	17.4	8.8	1.3	9.744	1	2	1.8308	4.2993	2.32764	2.32103	0.01054	0.041	0.1161	1.1
P90	52.5	22	4.3	19.83	1.3	2	1.9163	4.6269	2.43177	2.42537	0.01156	0.0422	0.1188	2.3
P95	97.5	34	4.9	22.29	1.9	2	2.0729	4.8267	2.55831	2.55071	0.01288	0.0446	0.1224	2.9
P99	105	36	5	22.7	2	2	2.099	4.86	2.5794	2.5716	0.0131	0.045	0.123	3

6.5 Material Related to Periphyton and Cyanobacteria Cover

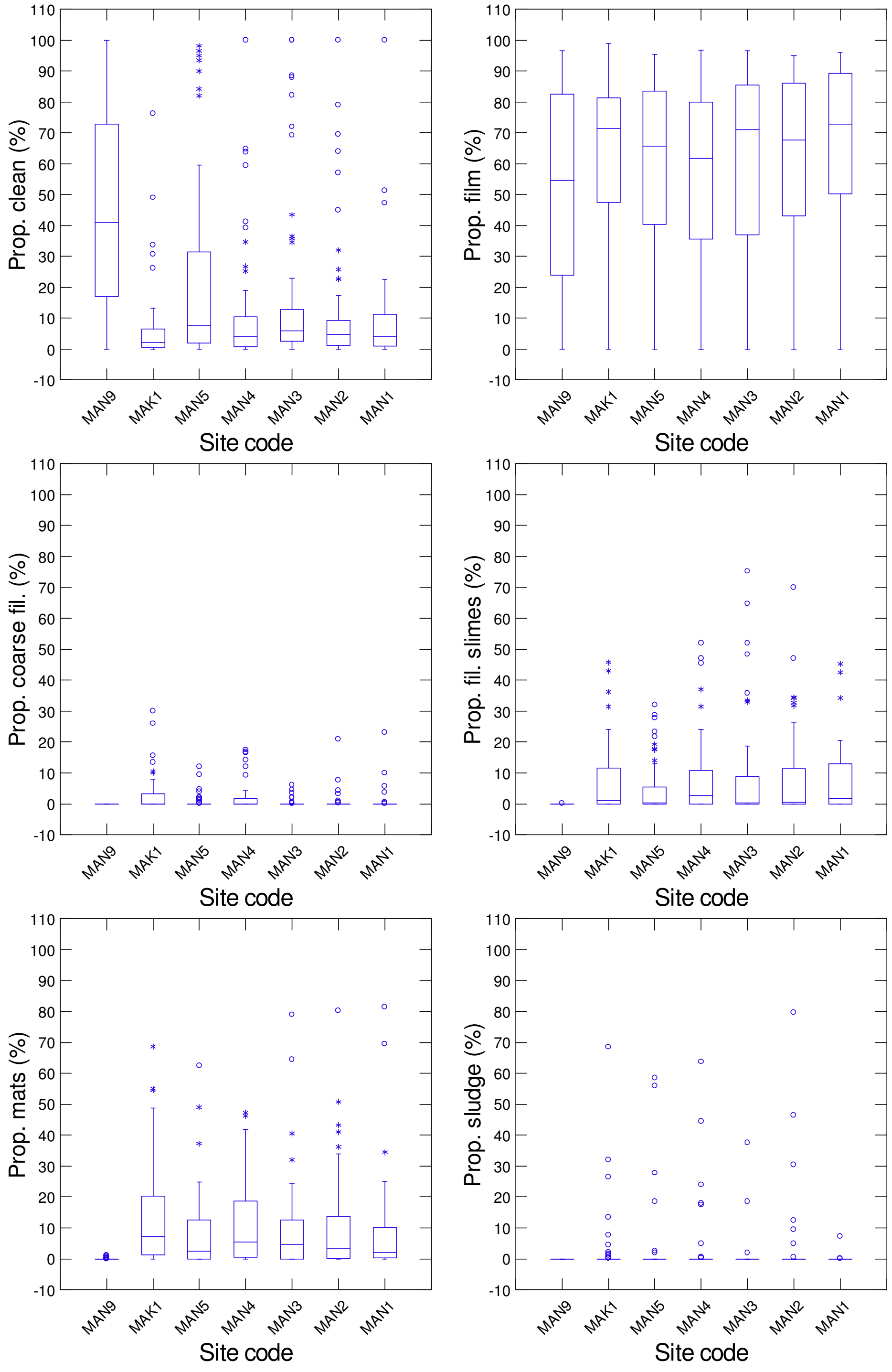


Figure 44: Results of visual assessment of periphyton cover, Mangatainoka River and Makakahi River

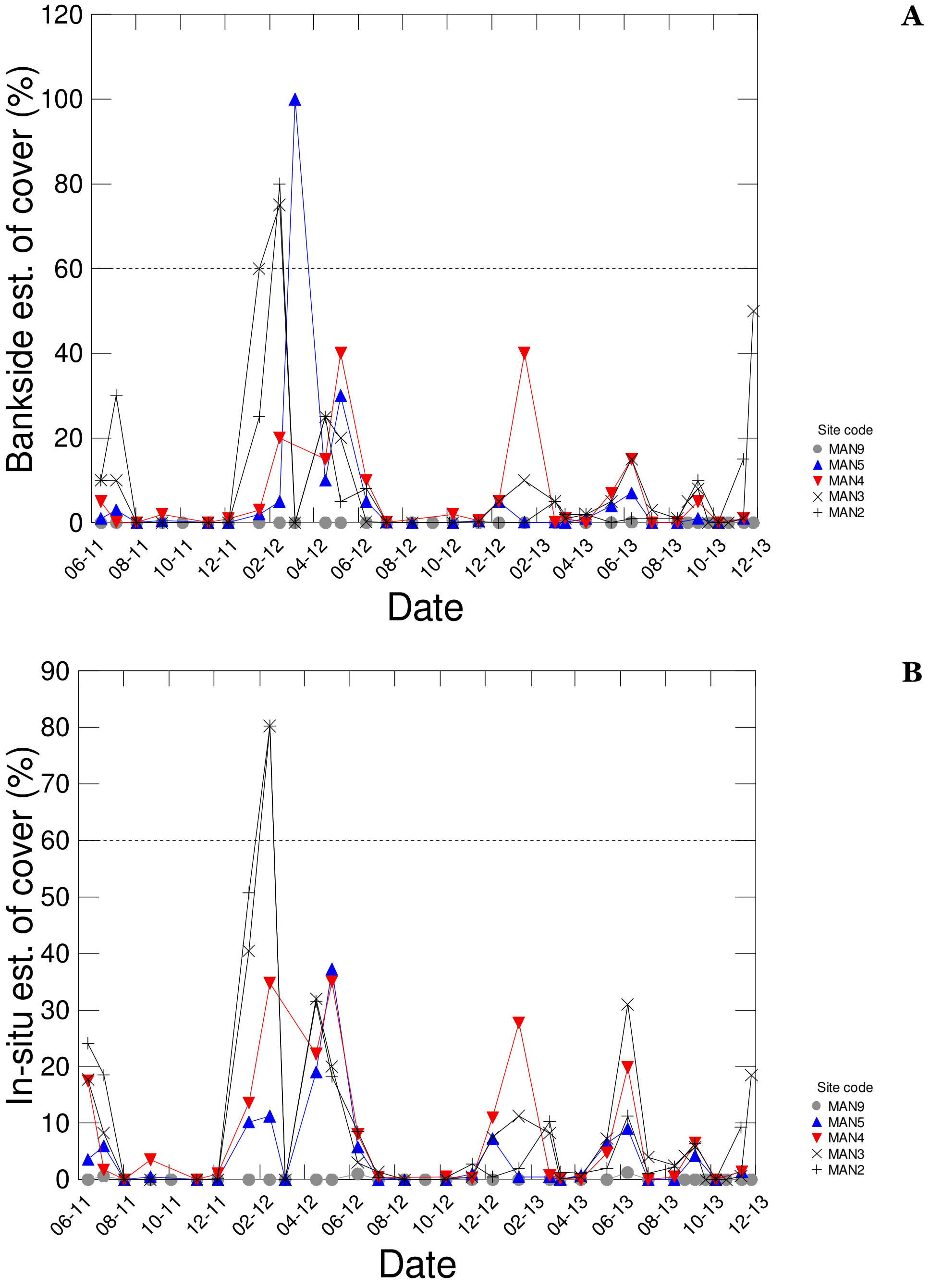


Figure 45: Results of visual assessment of cyanobacteria cover – bankside assessment (A), within river quadrat inspection (B). Horizontal dashed line is 60% target value

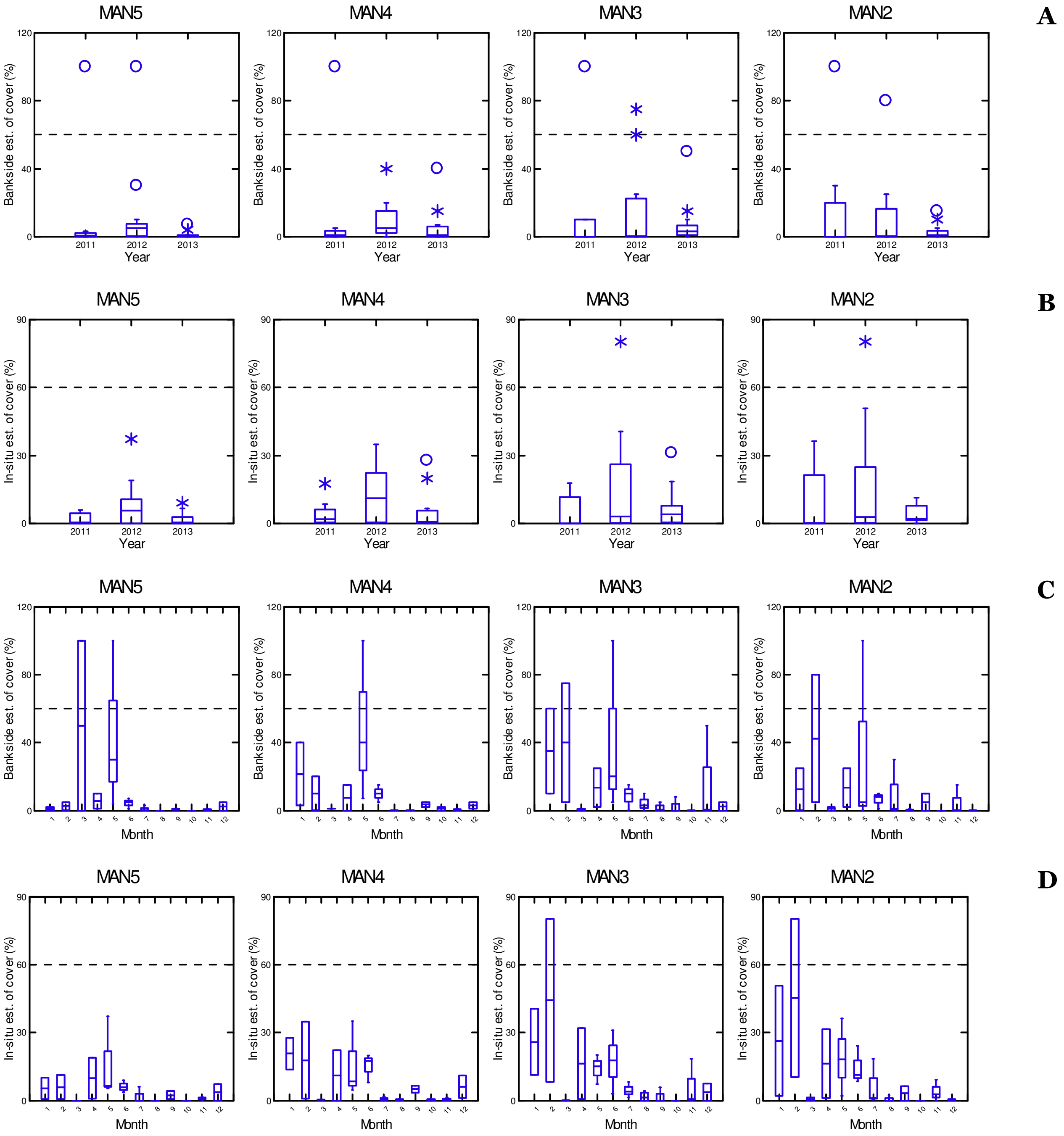


Figure 46: Trend in results of visual assessment of cyanobacteria cover. Annual trend - bankside assessment (A), within river quadrat inspection (B). Seasonal trend - bankside assessment (C), within river quadrat inspection (D). Horizontal dashed line is 60% target value

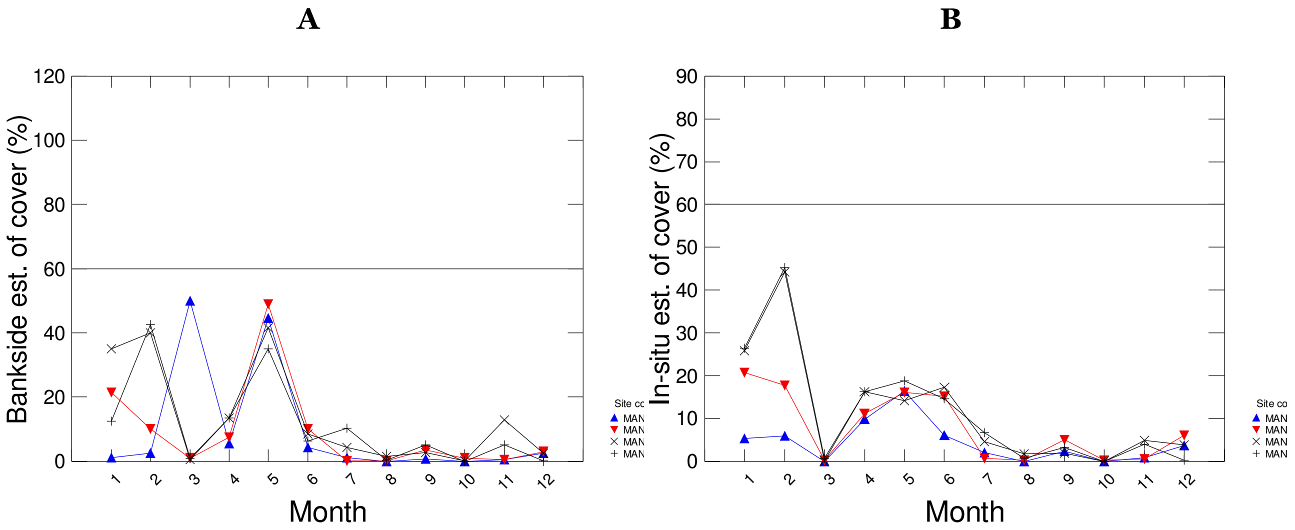


Figure 47: Seasonal trend in results of visual assessment of cyanobacteria cover. Median results for bankside assessment (A), within river quadrat inspection (B). Horizontal dashed line is 60% target value

6.6 Results of Formal Statistical Tests - DRP

TimeTrends 2/06/2014

File: I:\Projects\Pahiatua WWW\NAH files\MangaWW wide\MangaWW wide 2 SYSTAT plus Q SYSTAT out.xlsx: Worksheet: Trends (2)

Equivalence test of paired samples

Equivalence limits are -10.000 to 10.000 of data

DRP_MAN4 is greater than DRP_MAN5. No practically important difference (difference may be trivial compared to the limits)

Variable: Value			
Grouping variable	**DRP_MAN4**	**DRP_MAN5**	**Sum of paired diff.**
N	60	60	
Means	0.036	0.018	0.018
SD	0.068	0.029	0.055
t,df	2.455,59		
H_0: no difference	**Reject, P = 0.017**		
H_i: difference lies beyond limits (inequivalence)	Reject, P = 0.000		
H_e: difference lies within limits (equivalence)	**Accept, P = 1.000**		
Bayesian posterior probability (%) that difference is within limits	100.000		

Equivalence test of paired samples

Equivalence limits are -20.000 to 20.000 of data

DRP_MAN4 is greater than DRP_MAN5. No practically important difference (difference may be trivial compared to the limits)

Variable: Value			
Grouping variable	**DRP_MAN4**	**DRP_MAN5**	**Sum of paired diff.**
N	60	60	
Means	0.036	0.018	0.018
SD	0.068	0.029	0.055
t,df	2.455,59		
H_0: no difference	**Reject, P = 0.017**		
H_i: difference lies beyond limits (inequivalence)	Reject, P = 0.000		
H_e: difference lies within limits (equivalence)	**Accept, P = 1.000**		
Bayesian posterior probability (%) that difference is within limits	100.000		

Group DRP_MAN4 Value: Group DRP_MAN4 Period analysed 6 years for calendar years 2008 to 2013

Season	January	February	March	April	May	June	July	August	September	October	November	December
N	4	6	4	6	6	6	6	4	3	4	5	6
Mean	0.073	0.024	0.018	0.019	0.089	0.094	0.024	0.007	0.009	0.020	0.009	0.016
Median	0.073	0.011	0.017	0.014	0.023	0.013	0.018	0.007	0.009	0.020	0.009	0.012
25%	0.016	0.007	0.010	0.007	0.010	0.010	0.005	0.007	0.008	0.010	0.008	0.008
75%	0.131	0.033	0.025	0.019	0.139	0.108	0.042	0.007	0.010	0.030	0.009	0.017
Minimum	0.003	0.007	0.009	0.006	0.003	0.007	0.002	0.006	0.007	0.007	0.003	0.004
Maximum	0.143	0.071	0.030	0.052	0.300	0.381	0.054	0.007	0.011	0.031	0.014	0.044

Group DRP_MAN5 Value: Group DRP_MAN5 Period analysed 6 years for calendar years 2008 to 2013

Season	January	February	March	April	May	June	July	August	September	October	November	December
N	4	6	4	6	6	6	6	4	3	4	5	6
Mean	0.051	0.015	0.011	0.019	0.030	0.022	0.022	0.007	0.009	0.011	0.008	0.008
Median	0.028	0.007	0.009	0.007	0.010	0.009	0.008	0.007	0.010	0.009	0.008	0.007
25%	0.003	0.005	0.007	0.006	0.004	0.007	0.007	0.006	0.009	0.008	0.006	0.005
75%	0.076	0.012	0.013	0.008	0.018	0.018	0.027	0.007	0.010	0.013	0.009	0.011
Minimum	0.003	0.003	0.006	0.003	0.002	0.007	0.002	0.006	0.007	0.006	0.006	0.003
Maximum	0.146	0.057	0.020	0.083	0.135	0.080	0.072	0.007	0.010	0.021	0.009	0.017

Seasonal Kendall test for Group DRP_MAN4 for Value

Seasons used in analysis are: January February March April May June July August September October November December

0 values excluded because of multiple values in a season

Covariate adjustment method is log-log explaining -9.41% of variance in Value

Period analysed 6 years for calendar years 2008 to 2013

60 observations from 15/01/2008 to 10/12/2013 with 0 ties

Value	Median value	Kendall statistic	Variance	Z	P	Median annual Sen slope	5% confidence limit	95% confidence limit
Unadjusted	0.011	-15.000	216.333	-0.952	0.341	-0.001	-0.003	0.000
Flow adjusted	0.007	-25.000	225.000	-1.600	0.110	-0.001	-0.003	0.000

Seasonal Kendall test for Group DRP_MAN5 for Value

Seasons used in analysis are: January February March April May June July August September October November December

0 values excluded because of multiple values in a season

Covariate adjustment method is log-log explaining -8.64% of variance in Value

Period analysed 6 years for calendar years 2008 to 2013

60 observations from 15/01/2008 to 10/12/2013 with 1 ties

Value	Median value	Kendall statistic	Variance	Z	P	Median annual Sen slope	5% confidence limit	95% confidence limit
Unadjusted	0.007	-5.000	215.000	-0.273	0.785	0.000	-0.001	0.001
Flow adjusted	0.005	-3.000	225.000	-0.133	0.894	0.000	-0.001	0.001

DeSeasonalised trend analysis Group DRP_MAN4

Trend removed by subtracting seasonal variation derived by fitting a generalised additive model with 7 degrees of freedom to seasonal data for Value

Equivalence test of deseasonalised slope Group DRP_MAN4

Equivalence limits are -10.000 to 10.000 per year for Value

Significance level is 0.050

The slope of the trend line fitted to deseasonalised data is 0.000 (-0.002 per year or -6.998% per year)

No practically important slope

Variable	Number of years	Slope per year	Std Error	df
Value	5.8	-0.002	0.005	58.00
H_0: no slope	Fail to reject, P = 0.589			
H_i: slope lies beyond limits	Reject, P = 0.000			
H_e: slope lies within limits	**Accept, P = 1.000**			
Bayesian posterior probability (%) that slope is within limits	100.000			

DeSeasonalised trend analysis Group DRP_MAN5

Trend removed by subtracting seasonal variation derived by fitting a generalised additive model with 7 degrees of freedom to seasonal data for Value

Equivalence test of deseasonalised slope Group DRP_MAN5

Equivalence limits are -10.000 to 10.000 per year for Value

Significance level is 0.050

The slope of the trend line fitted to deseasonalised data is 0.000 (0.000 per year or -0.937% per year)

No practically important slope

Variable	Number of years	Slope per year	Std Error	df
Value	5.8	0.000	0.002	58.00
H_0: no slope	Fail to reject, P = 0.933			
H_i: slope lies beyond limits	Reject, P = 0.000			
H_e: slope lies within limits	**Accept, P = 1.000**			
Bayesian posterior probability (%) that slope is within limits	100.000			

TimeTrends 2/06/2014

File: I:\Projects\Pahiatua WWW\NAH files\MangaWW wide\MangaWW wide 2 SYSTAT plus Q SYSTAT out.xlsx: Worksheet: Trends (2)

DeSeasonalised trend analysis Group DRP_MAN4

Trend removed by subtracting seasonal variation derived by fitting a generalised additive model with 7 degrees of freedom to seasonal data for Value

Equivalence test of deseasonalised slope Group DRP_MAN4

Equivalence limits are -10.000 to 10.000 per year for Value

Significance level is 0.050

The slope of the trend line fitted to deseasonalised data is 0.000 (-0.003 per year or -9.190% per year)

No practically important slope

Variable	Number of years	Slope per year	Std Error	df
Value	5.8	-0.003	0.005	58.00
H_0: no slope	Fail to reject, P = 0.483			
H_i: slope lies beyond limits	Reject, P = 0.000			
H_e: slope lies within limits	**Accept, P = 1.000**			
Bayesian posterior probability (%) that slope is within limits	100.000			

DeSeasonalised trend analysis Group DRP_MAN5

Trend removed by subtracting seasonal variation derived by fitting a generalised additive model with 7 degrees of freedom to seasonal data for Value

Equivalence test of deseasonalised slope Group DRP_MAN5

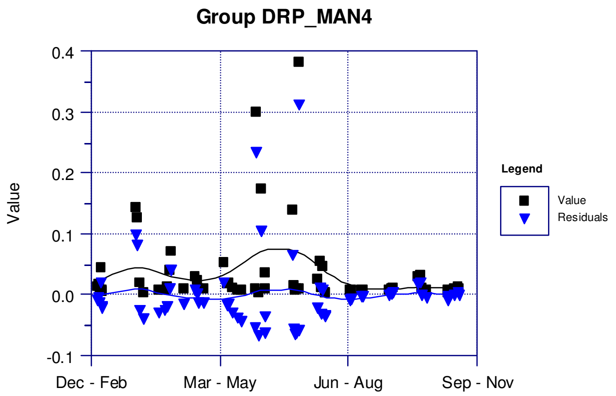
Equivalence limits are -10.000 to 10.000 per year for Value

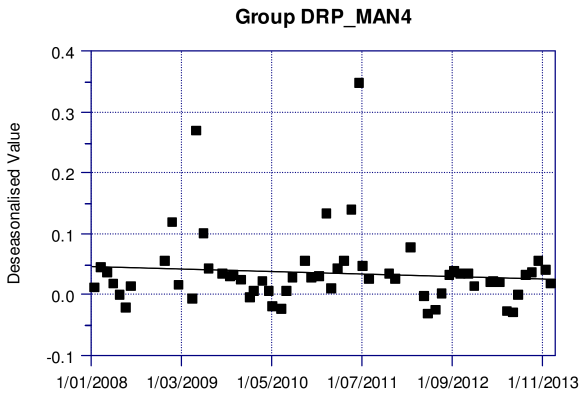
Significance level is 0.050

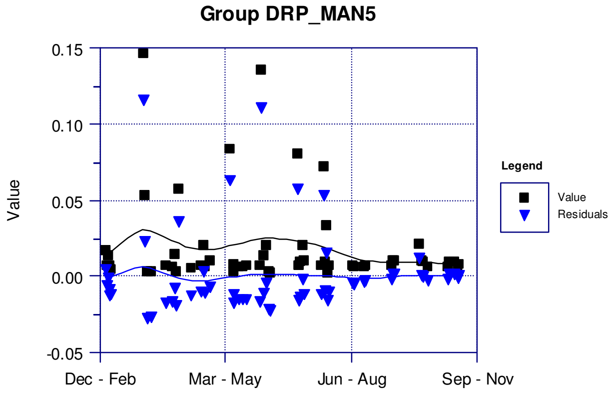
The slope of the trend line fitted to deseasonalised data is 0.000 (-0.001 per year or -4.257% per year)

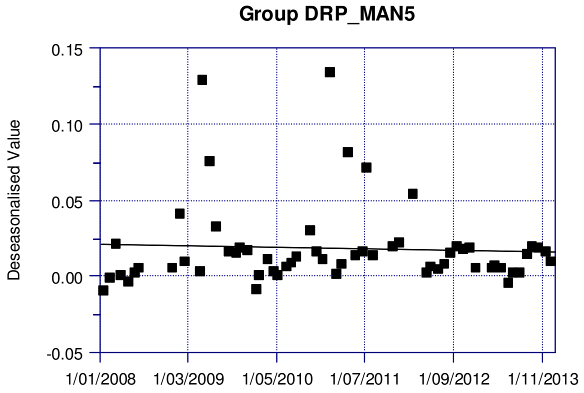
No practically important slope

Variable	Number of years	Slope per year	Std Error	df
Value	5.8	-0.001	0.002	58.00
H_0: no slope	Fail to reject, P = 0.712			
H_i: slope lies beyond limits	Reject, P = 0.000			
H_e: slope lies within limits	**Accept, P = 1.000**			
Bayesian posterior probability (%) that slope is within limits	100.000			









6.7 Results of Formal Statistical Tests - SIN

TimeTrends 2/06/2014

File: I:\Projects\Pahiatua WWW\NAH files\MangaWW wide\MangaWW wide 2 SYSTAT plus Q SYSTAT out.xlsx: Worksheet: sin

Equivalence test of paired samples

Equivalence limits are -10.000 to 10.000 of data

No practically important difference

Variable: Value_SIN			
Grouping variable	**MAN5**	**MAN4**	**Sum of paired diff.**
N	61	61	
Means	0.723	0.885	-0.162
SD	0.462	0.811	0.645
t,df	1.956,60		
H_0: no difference	Fail to reject, P = 0.055		
H_i: difference lies beyond limits (inequivalence)	Reject, P = 0.000		
H_e: difference lies within limits (equivalence)	**Accept, P = 1.000**		
Bayesian posterior probability (%) that difference is within limits	100.000		

Equivalence test of paired samples

DeSeasonalised trend analysis

Trend removed by subtracting seasonal variation derived by fitting a generalised additive model with 7 degrees of freedom to seasonal data for Value_SIN

Equivalence test of independent samples

Equivalence limits are -10.000 to 10.000 of data

No practically important difference

Variable: Value_SIN		
Grouping variable	**MAN5**	**MAN4**
N	61	61
Means	0.723	0.885
SD	0.357	0.774
t,df	1.481,120	
H_0: no difference	Fail to reject, P = 0.141	
H_i: difference lies beyond limits (inequivalence)	Reject, P = 0.000	
H_e: difference lies within limits (equivalence)	**Accept, P = 1.000**	
Bayesian posterior probability (%) that difference is within limits	100.000	

Seasonal Kendall test for Group MAN5 for Value_SIN

Seasons used in analysis are: Dec - Feb Mar - May Jun - Aug Sep - Nov

Covariate adjustment method is lowess explaining 21.15% of variance in Value_SIN

Period analysed 6 years for water years 2007 to 2013 beginning December

61 observations from 15/01/2008 to 10/12/2013 with 0 ties

Value_SIN	Median value	Kendall statistic	Variance	Z	P	Median annual Sen slope	5% confidence limit	95% confidence limit
Unadjusted	0.802	79.000	1785.667	1.846	0.065	0.060	0.004	0.112
Flow adjusted	0.820	62.000	1788.667	1.442	0.149	0.052	-0.009	0.109

Seasonal Kendall test for Group MAN4 for Value_SIN

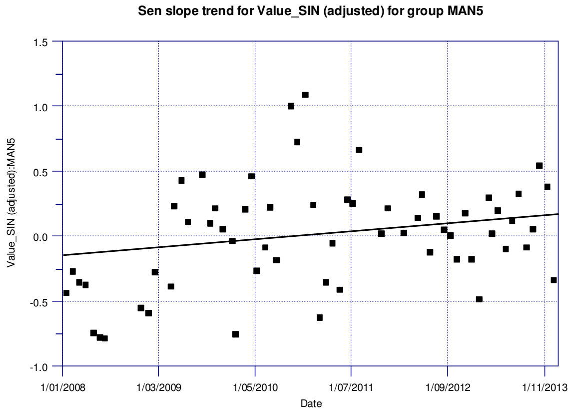
Seasons used in analysis are: Dec - Feb Mar - May Jun - Aug Sep - Nov

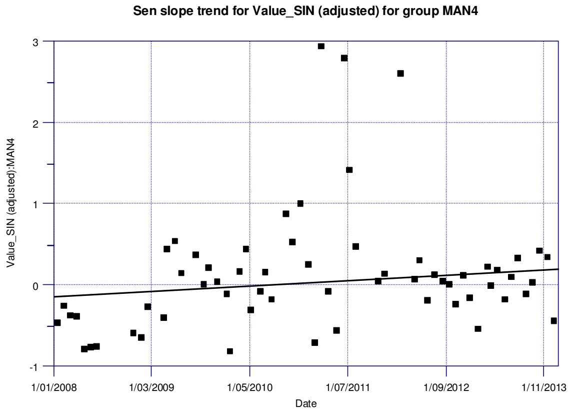
Covariate adjustment method is lowess explaining 12.32% of variance in Value_SIN

Period analysed 6 years for water years 2007 to 2013 beginning December

61 observations from 15/01/2008 to 10/12/2013 with 0 ties

Value_SIN	Median value	Kendall statistic	Variance	Z	P	Median annual Sen slope	5% confidence limit	95% confidence limit
Unadjusted	0.842	94.000	1788.667	2.199	0.028	0.073	0.012	0.119
Flow adjusted	0.872	52.000	1788.667	1.206	0.228	0.056	-0.011	0.112





6.8 Results of Formal Statistical Tests - Ammoniacal-N Concentrations

TimeTrends 2/06/2014

File: I:\Projects\Pahiatua WWW\NAH files\MangaWW wide\MangaWW wide 2 SYSTAT plus Q SYSTAT out.xlsx: Worksheet: NH4

Equivalence test of paired samples

Equivalence limits are -10.000 to 10.000 of data

No practically important difference

Variable: NH4-N			
Grouping variable	**MAN5**	**MAN4**	**Sum of paired diff.**
N	52	52	
Means	0.017	0.089	-0.072
SD	0.028	0.318	0.298
t,df	1.749,51		
H_0: no difference	Fail to reject, P = 0.086		
H_i: difference lies beyond limits (inequivalence)	Reject, P = 0.000		
H_e: difference lies within limits (equivalence)	**Accept, P = 1.000**		
Bayesian posterior probability (%) that difference is within limits	100.000		

Seasonal Kendall test for Group MAN5 for NH4-N

Seasons used in analysis are: Dec - Feb Mar - May Jun - Aug Sep - Nov

Covariate adjustment method is lowess explaining -1.95% of variance in NH4-N

Period analysed 5 years and 9 months for water years 2007 to 2012 beginning December

52 observations from 15/01/2008 to 10/09/2013 with 1 ties

NH4-N	Median value	Kendall statistic	Variance	Z	P	Median annual Sen slope	5% confidence limit	95% confidence limit
Unadjusted	0.010	59.000	1169.000	1.696	0.090	0.002	0.000	0.003
Flow adjusted	0.008	59.000	1187.667	1.683	0.092	0.001	0.000	0.003

Seasonal Kendall test for Group MAN4 for NH4-N

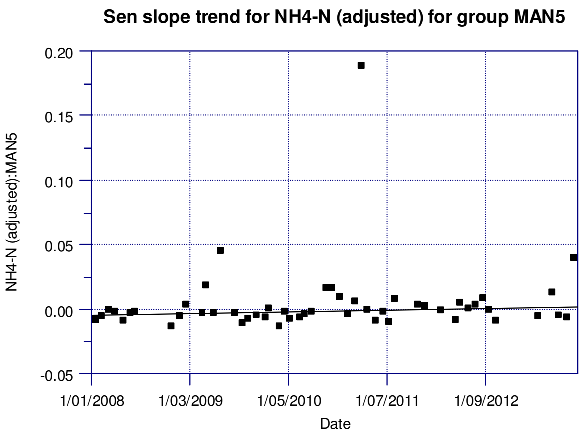
Seasons used in analysis are: Dec - Feb Mar - May Jun - Aug Sep - Nov

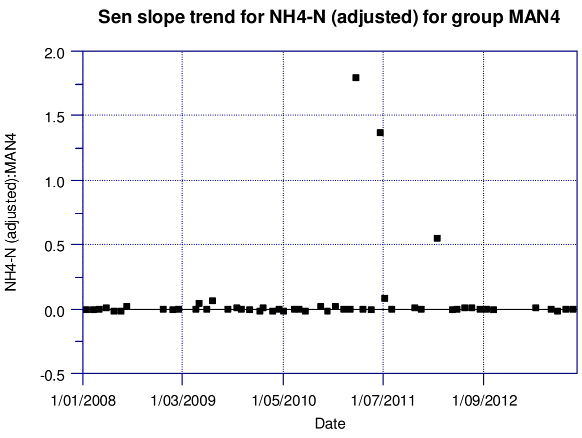
Covariate adjustment method is lowess explaining -4.40% of variance in NH4-N

Period analysed 5 years and 9 months for water years 2007 to 2012 beginning December

52 observations from 15/01/2008 to 10/09/2013 with 0 ties

NH4-N	Median value	Kendall statistic	Variance	Z	P	Median annual Sen slope	5% confidence limit	95% confidence limit
Unadjusted	0.013	19.000	1175.000	0.525	0.600	0.000	-0.001	0.002
Flow adjusted	0.010	29.000	1187.667	0.812	0.417	0.001	-0.001	0.003


Sen slope trend for NH4-N (adjusted) for group MAN5


Sen slope trend for NH4-N (adjusted) for group MAN4

6.9 Results of Formal Statistical Tests - Visual Clarity

TimeTrends 2/06/2014

File: I:\Projects\Pahiatua WWW\NAH files\MangaWW wide\MangaWW wide 2 SYSTAT plus Q SYSTAT out.xlsx: Worksheet: Flow

Equivalence test of paired samples

Equivalence limits are -10.000 to 10.000 of data

No practically important difference

Variable: Clarity			
Grouping variable	**MAN5**	**MAN4**	**Sum of paired diff.**
N	27	27	
Means	2.284	2.070	0.213
SD	1.336	1.435	0.872
t,df	1.271,26		
H_0: no difference	Fail to reject, P = 0.215		
H_i: difference lies beyond limits (inequivalence)	Reject, P = 0.000		
H_e: difference lies within limits (equivalence)	**Accept, P = 1.000**		
Bayesian posterior probability (%) that difference is within limits	100.000		

TimeTrends 2/06/2014

File: I:\Projects\Pahiatua WWW\NAH files\MangaWW wide\MangaWW wide 2 SYSTAT plus Q SYSTAT out.xlsx: Worksheet: Clarity (2)

Equivalence test of paired samples

Equivalence limits are -10.000 to 10.000 of data

No practically important difference

Variable: Clarity			
Grouping variable	**MAN5**	**MAN4**	**Sum of paired diff.**
N	16	16	
Means	2.660	2.403	0.762
SD	1.580	1.733	2.089
t,df	1.459,15		
H_0: no difference	Fail to reject, P = 0.165		
H_i: difference lies beyond limits (inequivalence)	Reject, P = 0.000		
H_e: difference lies within limits (equivalence)	**Accept, P = 1.000**		
Bayesian posterior probability (%) that difference is within limits	100.000		

DeSeasonalised trend analysis Group MAN5

Trend removed by subtracting seasonal variation derived by fitting a generalised additive model with 7 degrees of freedom to seasonal data for Clarity

Equivalence test of deseasonalised slope Group MAN5

Equivalence limits are -10.000 to 10.000 per year for Clarity

Significance level is 0.050

The slope of the trend line fitted to deseasonalised data is 0.000 (0.119 per year or 4.487% per year)

No practically important slope

Variable	Number of years	Slope per year	Std Error	df
Clarity	1.9	0.119	0.221	14.00
H_0: no slope	Fail to reject, P = 0.598			
H_i: slope lies beyond limits	Reject, P = 0.000			
H_e: slope lies within limits	**Accept, P = 1.000**			
Bayesian posterior probability (%) that slope is within limits	100.000			

DeSeasonalised trend analysis Group MAN4

Trend removed by subtracting seasonal variation derived by fitting a generalised additive model with 7 degrees of freedom to seasonal data for Clarity

Equivalence test of deseasonalised slope Group MAN4

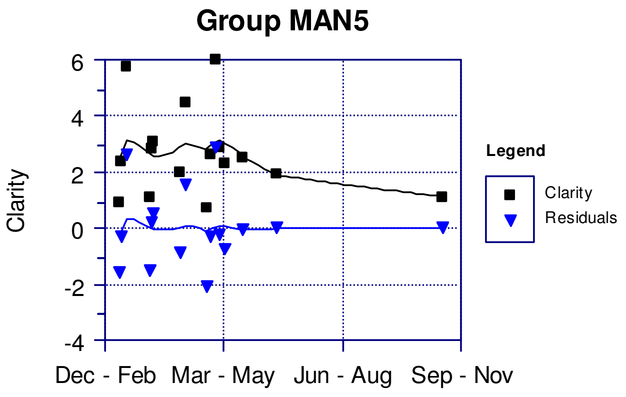
Equivalence limits are -10.000 to 10.000 per year for Clarity

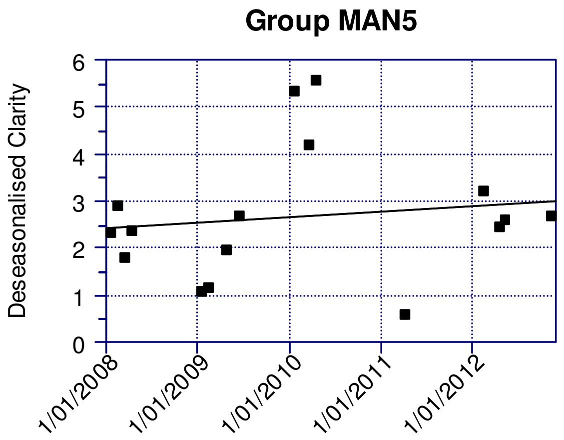
Significance level is 0.050

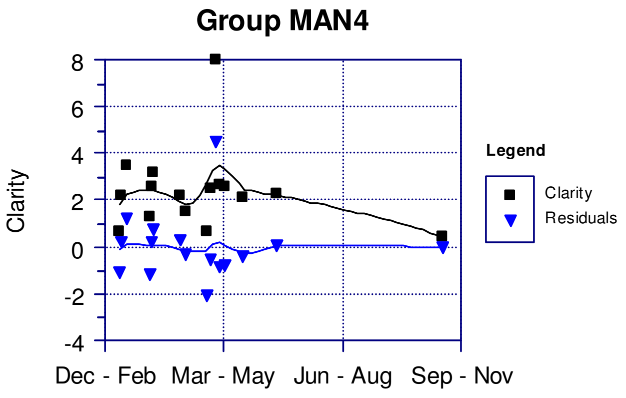
The slope of the trend line fitted to deseasonalised data is 0.000 (-0.009 per year or -0.374% per year)

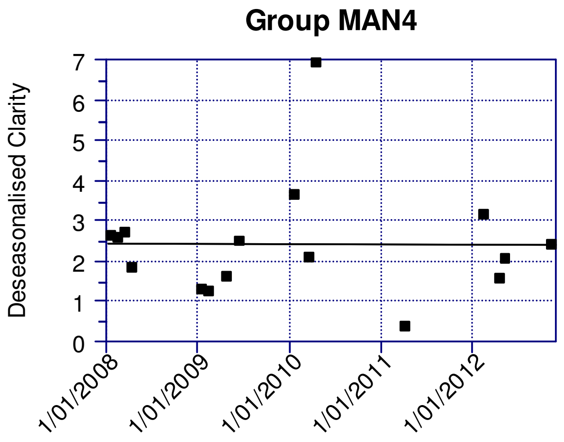
No practically important slope

Variable	Number of years	Slope per year	Std Error	df
Clarity	1.9	-0.009	0.233	14.00
H_0: no slope	Fail to reject, P = 0.970			
H_i: slope lies beyond limits	Reject, P = 0.000			
H_e: slope lies within limits	**Accept, P = 1.000**			
Bayesian posterior probability (%) that slope is within limits	100.000			


Group MAN5


Group MAN5


Group MAN4


Group MAN4

6.10 Supplementary Information for Nutrients

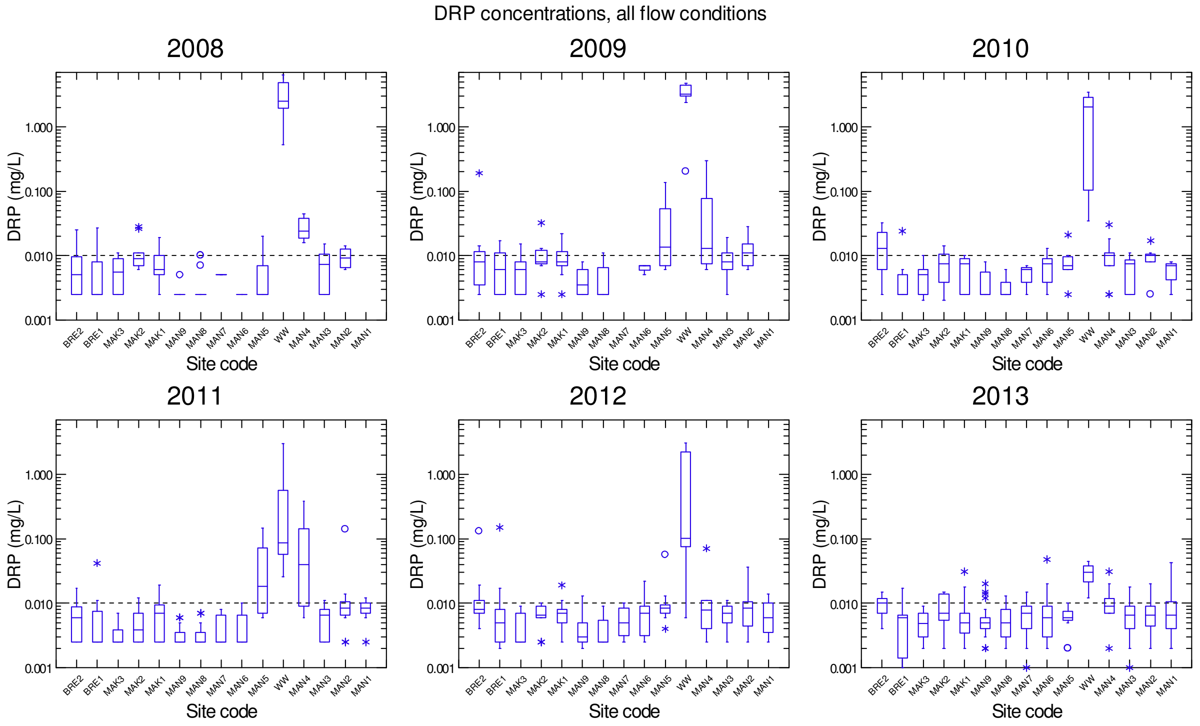
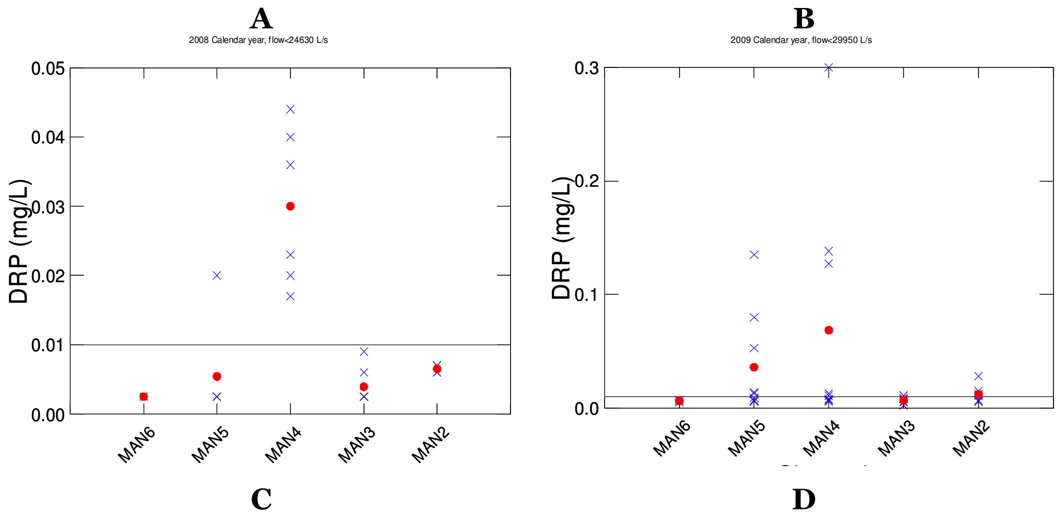


Figure 48. Annual spatial trend in DRP under all flow conditions by year



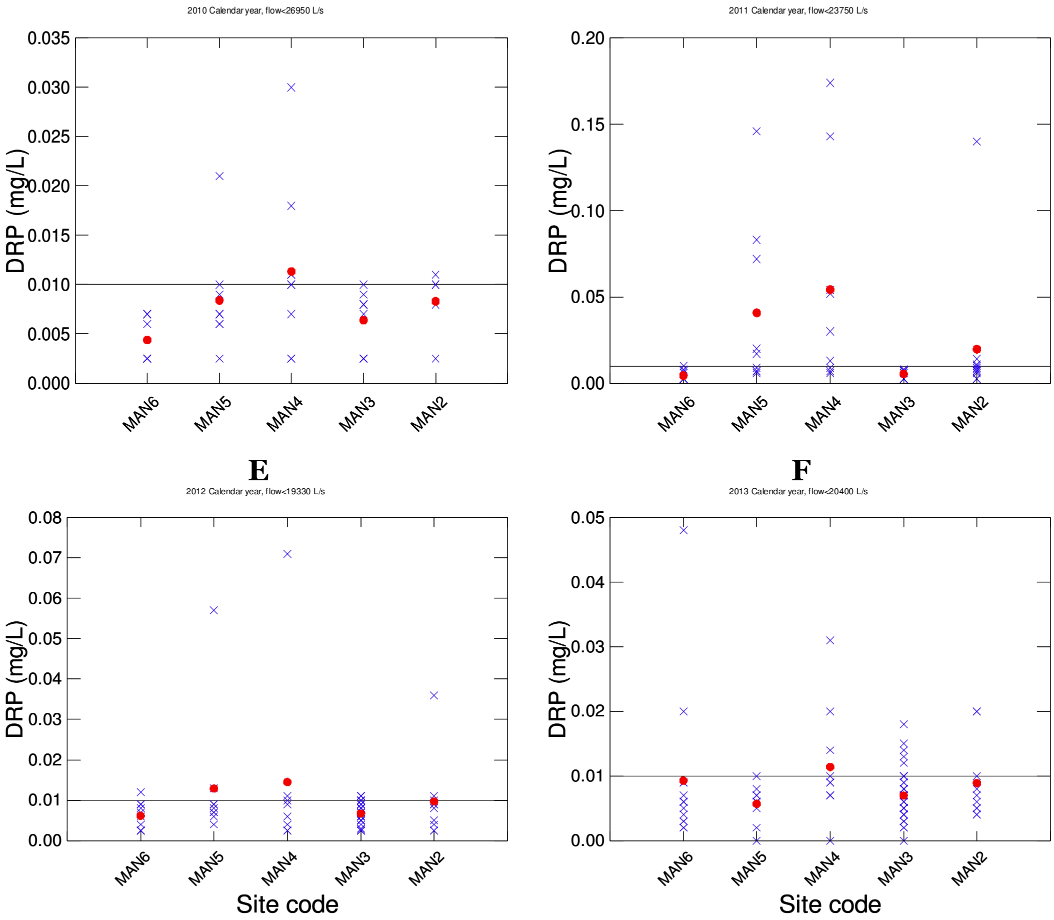


Figure 49. Comparison of individual (crosses) and annual average (red dot) DRP concentrations measured when flows were <20% exceedance value with the HRC water quality target (horizontal dashed line)

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