Northland River Water Quality Monitoring Network:

State and Trends 2006

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NORTHLAND REGIONAL COUNCIL

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1 Introduction

Northland's River Water Quality Monitoring Network was established in September 1996 and initially included nine river sites throughout Northland. Since 1996 a further 11 sites have been added to the network. The four Northland sites in the National River Water Quality Network monitored by National Institute of Water and Atmospheric Research Limited (NIWA) are also incorporated into our regional network. So there are currently 24 sites throughout Northland monitored monthly for water quality. These sites are shown in table 1 and figure 1 (below).

This report looks at the current state of water quality in 2006 at 21 of these sites (excludes three sites added in August 2006) and compares water quality to the ANZECC guidelines (ANZECC 2000) for aquatic ecosystems and the recreational bathing guidelines (MFE 2002). This report also looks at trends in medians for all 21 sites and presents the results of a formal trend analysis for 18 sites.

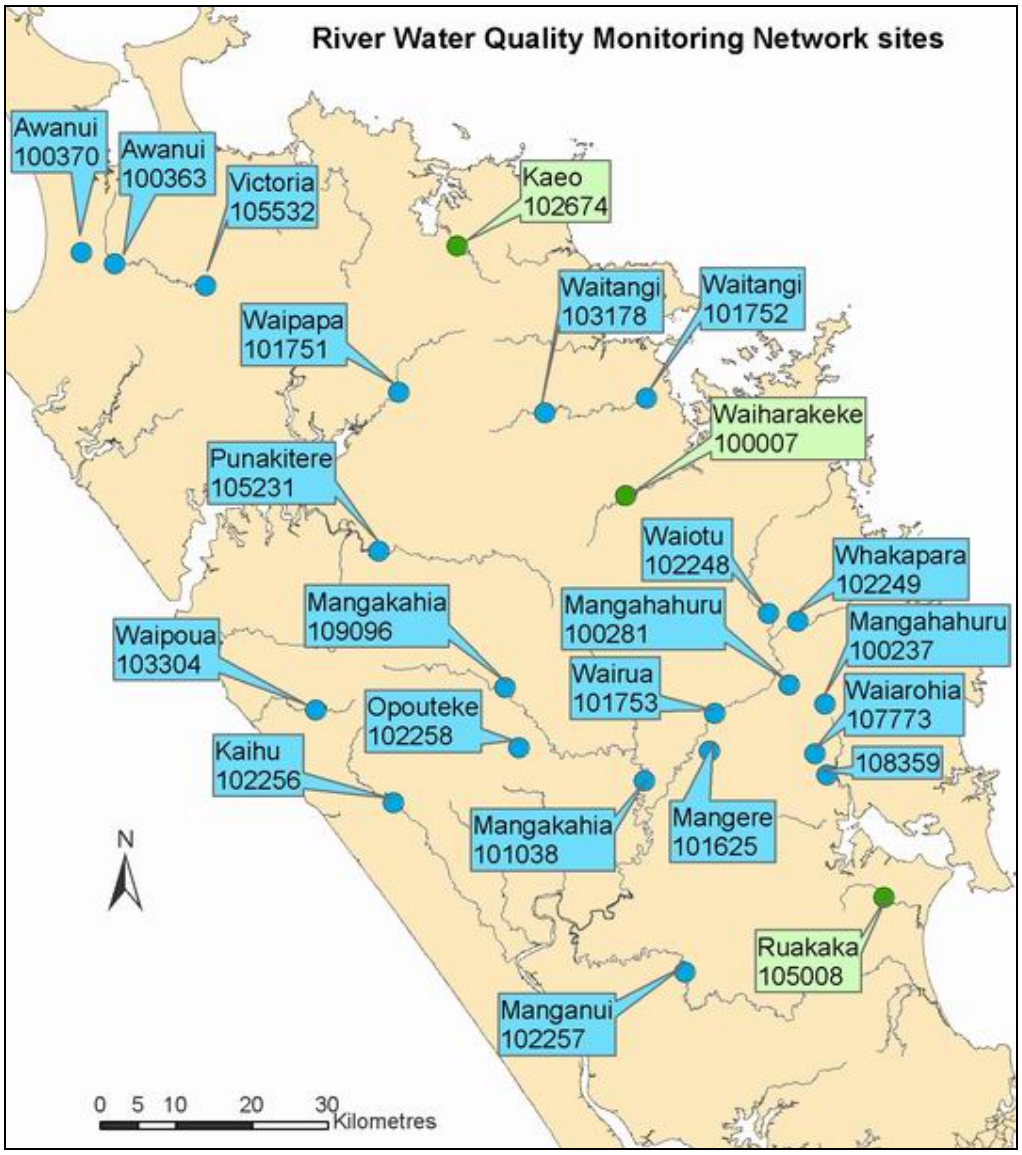

Figure 1: Map showing 24 RWQMN sites. Note: the three sites shown in green were only added to the network in August 2006 and therefore do not have results presented in this report.

Table 1: River sites routinely monitored for water quality in the Northland region, with their catchment land use as a percentage and total catchment area (Ha).

Site name	NRC site no.	Catchment	Sampling began	% Indigenous	% Forestry	% Pasture	% Other	Total (Ha)
Awanui at FNDC water take[1]	100363	Awanui	Oct-96	36	5.6	57.1	1.3	21701.5
Awanui at Waihue Channel	100370	Awanui	Oct-96	31.1	4.3	61.3	3.4	31361.6
Kaeo at Dip Rd bridge	102674	Kaeo	Aug-06	55.6	15.6	28.3	0.7	9933.6
Kaihu at gorge	102256	Kaihu	Jul-02	27.6	16.2	55.7	0.4	11507.4
Mangahahuru at Apotu Road	100281	Wairua	Oct-96	14.6	49.7	32.1	3.8	4554.9
Mangahahuru at Main Rd	100237	Wairua	Jul-05	12.9	82	4	0.9	2103.1
Mangakahia at Titoki[3]	101038	Mangakahia	Jan-89	33.3	29.1	36.9	0.5	80685.9
Mangakahia d/s of Twin bridges	109096	Mangakahia	Oct-96	34.5	29.5	35.7	0.3	24313.5
Manganui at Mititai Rd	102257	Manganui	Aug-01	17	6.1	75.9	0.9	40866
Mangere at Knight Rd	101625	Wairua	Oct-96	21.9	0.6	75.8	1.7	7586.1
Opouteke at suspension bridge	102258	Mangakahia	Oct-96	35.5	58.4	6	0	10806.2
Punakitere at Punakitere Rd	105231	Punakitere	Aug-01	24.7	16.7	54.6	3.9	30268.3
Ruakaka at Flyger Rd	105008	Ruakaka	Aug-06	26.3	1.6	71.5	0.5	4749.8
Victoria at Victoria Valley Rd	105532	Awanui	Oct-96	82	5.2	12.6	0.2	2669.5
Waiarohia at Second Ave	108359	Waiarohia	Jul-05	55.1	1.4	18.7	24.8	1849.7
Waiarohia at Whau Valley Road	107773	Waiarohia	Jul-05	70.7	1.6	23	4.7	1038.3
Waiharakeke at Stringers Rd	100007	Waiharakeke	Aug-06	28.9	23.6	44.8	2.8	23040.5
Waiotu at SH1	102248	Wairua	Mar-00	30.5	4.5	64.2	0.8	12045.2
Waipapa in Puketi Forest[3]	101751	Waipapa	Jan-89	86.6	9.9	3.5	0	12046.5
Waipoua at SH12	103304	Waipoua	Jul-02	90.9	0.6	8.5	0	6446.9
Wairua at Purua[3]	101753	Wairua	Jan-89	23.5	10	64.3	2.2	54301.2
Waitangi at Waimate Nth Rd[2]	103178	Waitangi	Oct-96	29.4	8.1	61.7	0.9	5043.7
Waitangi at Watea[3]	101752	Waitangi	Jan-89	19.5	8	69.2	3.3	29887.2
Whakapara at cableway	102249	Wairua	Oct-96	35.2	11.1	52.7	1	16380.2

1. Site was initially at School cut (Site 100366), 300m downstream from current site. Site was moved in 2002, due to health and safety considerations.
2. Site was initially at Whakataha Road (Site 105533), 500m upstream from current site. Site was moved in 1999, due to health and safety considerations.
3. These four sites are sampled by NIWA as part of the National River Water Quality Network.

2 Methods

All sample and field measurement collection methods follow those documented in the councils Quality Procedures Manual for water quality, air and sediment sampling (NRC 1997). All laboratory sample analysis was carried out following the procedures in the '*Standard Methods for the Examination of Water and Wastewater*' (APHA, 1998).

2.1 Guidelines used for compliance

The ANZECC guidelines have been used to assess water quality for aquatic ecosystems, while the levels of the indicator bacteria, Escherichia coli, have been used to assess water quality for recreational bathing and drinking water. The water clarity guideline from the Regional Water and Soil Plan (RWSP) for Northland (NRC 2007) has also been used to assess water quality for recreational bathing.

2.1.1 ANZECC guidelines

The results are compared to the Australian and New Zealand Environmental and Conservation Council (ANZECC) trigger values for the protection of aquatic ecosystems in New Zealand (ANZECC 2000).

It is important to note that the trigger values are used to assess the risk of adverse effects on the ecosystem and when results are outside trigger values further investigation is required to determine whether there is adverse effects on the environment and to what extent. There are two sets of trigger values; one for upland rivers, which only includes one site in the network (Waipoua River), and one for lowland rivers as shown in table 2 (below).

Table 2: Trigger values for NZ lowland and upland rivers (ANZECC 2000)

Parameter	**Trigger values for lowland rivers**	**Trigger values for upland rivers**
Dissolved oxygen (% Saturation)	98 - 105	99 – 103
Water clarity (m)	> 0.6	> 0.8
Turbidity (NTU)	< 5.6	< 4.1
Dissolved reactive phosphorus (mg/L)	< 0.01	< 0.009
Total phosphorus (mg/L)	< 0.033	< 0.026
Nitrate, nitrite nitrogen (mg/L)	<0.444	<0.167
Ammoniacal nitrogen (mg/L)	< 0.021	< 0.01
Total nitrogen (mg/L)	< 0.614	< 0.295
pH	7.2 – 7.8	7.3 – 8.0

2.1.2 Escherichia coli (bacteria)

The levels of the bacteria, *Escherichia coli* are used as indicator for the presence of pathogen causing bacteria, which can be a health risk for humans and stock. The levels of E. coli can be compared to the microbiological water quality guidelines for recreational users (MFE 2003), to determine whether the water is safe for recreational use. The majority of rivers in Northland are used for recreational purposes. The guideline is less than 550 E. coli/100mL of sample.

Similarly the levels of E. coli can be compared to the NZ drinking water standard of less than 1 E.coli/100mL (MoH 2005) to determine whether the water is safe for human consumption. Note this standard is the Maximum Acceptable Value (MAV) for microbiological contamination for drinking water leaving a treatment plant. Untreated water from surface water systems will rarely meet this standard and therefore it is recommended that surface water is treated to ensure it meets the drinking water standards. On the other hand groundwater is rarely contaminated by harmful pathogens and therefore more likely to be suitable for human consumption without treatment. For more information on bacterial levels in groundwater check out the groundwater section of this report.

2.1.3 Water clarity

Water clarity is also important for recreational users, partly for aesthetic reasons but also because elevated bacterial levels are often associated with turbid water. Water clarity readings can be used as a measure of the aesthetic appeal of water. Public perception of water quality is typically based on colour and clarity. The RMA requires that there be no conspicuous change in colour and clarity under sections 70 and 107. The Regional Water and Soil Plan has a guideline for the management of waters for contact recreation purposes of a visual clarity greater than 1.6 m (NRC 2007, p53). This guideline comes from the *'Water Quality Guidelines No. 2: Colour and Clarity'* (MFE 1994), which is currently the only water clarity guideline for the purposes of contact recreation and aesthetics in New Zealand.

2.2 Trend analysis

For the trend analysis all values below detection limit or denoted with a less than value, were replaced with half of the detection limit. Because of this, caution should be taken when interpreting results where more than 15% of the samples were below detection (Gilbert 1987).

The trend analysis was carried out on both the raw water quality data and flow adjusted data. All data was flow adjusted in WQstat plus™ - see the manual for more information on the method used (IDT 1998). Where there was no flow record for a sample, the sample was deleted from the analysis. The Seasonal Kendal test in WQstat plus™ was used for the trend analysis.

3 Results

These results exclude the following three sites added in August 2006; Ruakaka, Waiharakeke and Kaeo Rivers.

The site medians for all years of data and for the 2006 data for each parameter are in tables 5 and 6 in Appendix A.

3.1 Current State in 2006

Median values for 2006 were calculated based on the monthly data for all parameters at each site, except the three sites added in August 2006. The 21 site medians for each parameter were then further summarised as 5th, 20th, 50th, 80th and 95th percentile values to give a summary at the regional scale, following the presentation of Scarsbrook (2006).

These results are presented as maps in figures 2 to 15 (below). In all the maps the points correspond to the following values:

- minimum – 5th percentile
- >5 – 20th percentile
- >20 – 50th percentile
- >50 – 80th percentile
- >80-95th percentile and
- >95th percentile to maximum

Where applicable the colours of the points represent the quality, with red being the worse and blue the best i.e. lower temperatures and conductivity are better (blue), while lower water clarity is worse (red). Dissolved oxygen and pH have an ideal range, so therefore the colours for these two figures do not represent better or worse.

3.1.1 Temperature

The sites with the lowest median temperature for 2006 are the two “pristine” indigenous forest sites; Waipapa River in Puketi Forest and Waipoua River at SH12. These sites are reasonably high in their respective catchments. The other sites with relatively low median temperatures are those situated in upper catchments, including Victoria River in Victoria Valley, Waitangi River at Waimate and Mangahahuru Stream at Main Road.

The site with the highest median temperature in 2006 was Wairua River at Purua with a median of 17.1°C, followed by Waiarohia at Second Ave with a median of 17.05°C.

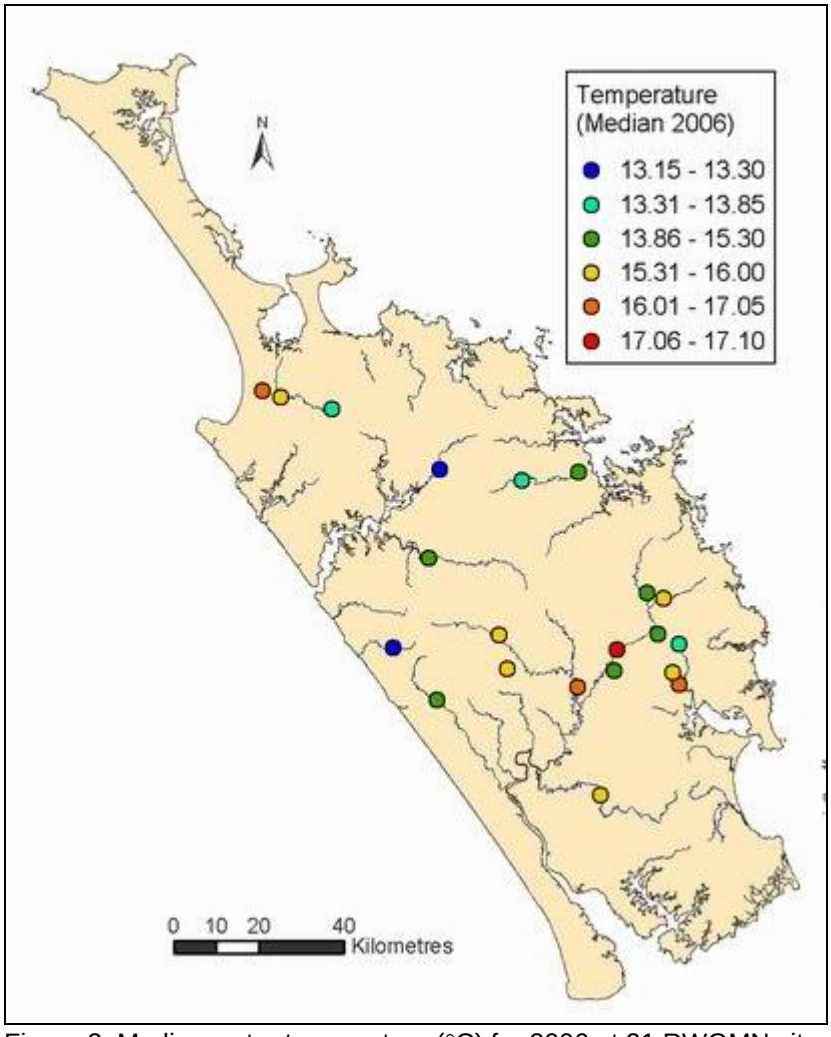

Figure 2: Median water temperature (°C) for 2006 at 21 RWQMN sites

3.1.2 Dissolved oxygen

Many of Northlands rivers fall outside the ideal range for dissolved oxygen for the protection of aquatic ecosystems of 98 to 105% for lowland rivers (ANZECC 2000, see section 3.4.1 for more information). The Awanui River site above Waihue channel has the lowest median dissolved oxygen for 2006 of 85%.

Waiarohia Stream has the highest median for 2006 of 111.2%. Sites with high dissolved oxygen are as much of a concern as those with low dissolved oxygen because DO often has strong diurnal cycles. Super-saturated oxygen conditions during the day are usually followed by low oxygen (anoxic) levels at night. (See section 3.2).

The overall regional median for dissolved oxygen (% saturation) in 2006 was 99.2%, which is inside the ideal range (ANZECC 2000) but is lower than the national median for 2005 of 101% (Scarsbrook 2006).

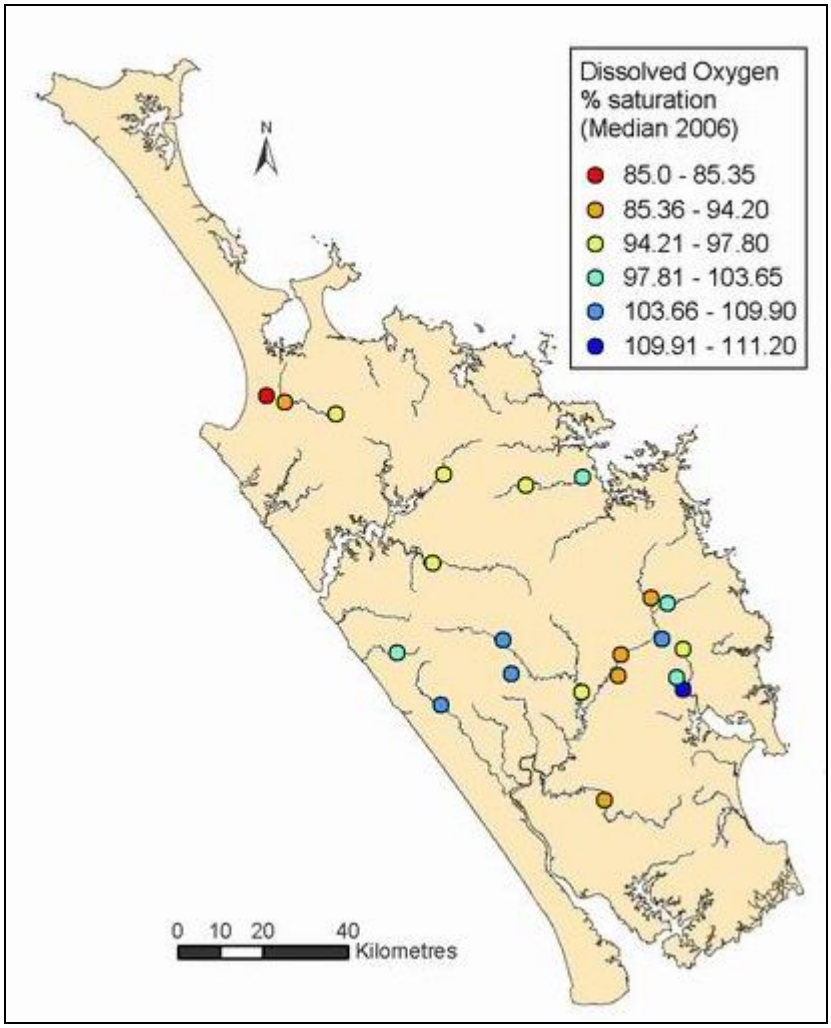

Figure 3: Median dissolved oxygen (% saturation) for 2006 at 21 RWQMN sites

3.1.3 Conductivity

Conductivity can be an indicator of nutrients in the water but also catchment geology, for example volcanic rock geology can cause high water conductivity. The sites with the lowest median conductivities for 2006 are the sites with the lowest nutrient levels; Waipoua, Waipapa and Victoria River. The sites with the highest median conductivities were Waiarohia Stream in Whau Valley and Wairua River at Purua.

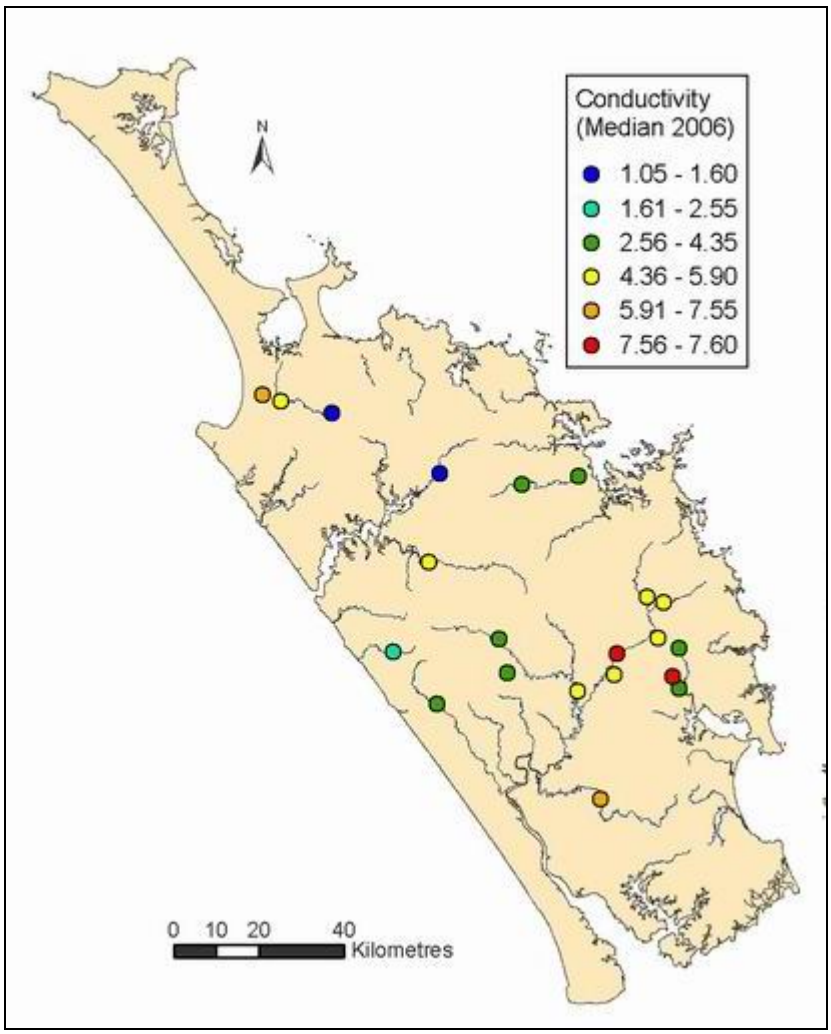

Figure 4: Median conductivity (mSm@25°C) for 2006 at 21 RWQMN sites

3.1.4 pH

Median pH in 2006 was highest (more alkaline) in the Waipapa River site in Puketi Forest and lowest at the Manganui River and Wairua River at Purua sites. None of the rivers had an annual median pH in 2006 less than 7.0 or greater than 7.8. The median for 17 of the 21 sites was within the ideal pH range for the protection of aquatic ecosystems of 7.2 to 7.8 for lowland rivers (ANZECC 2000), see section 2.1.1 for more information.

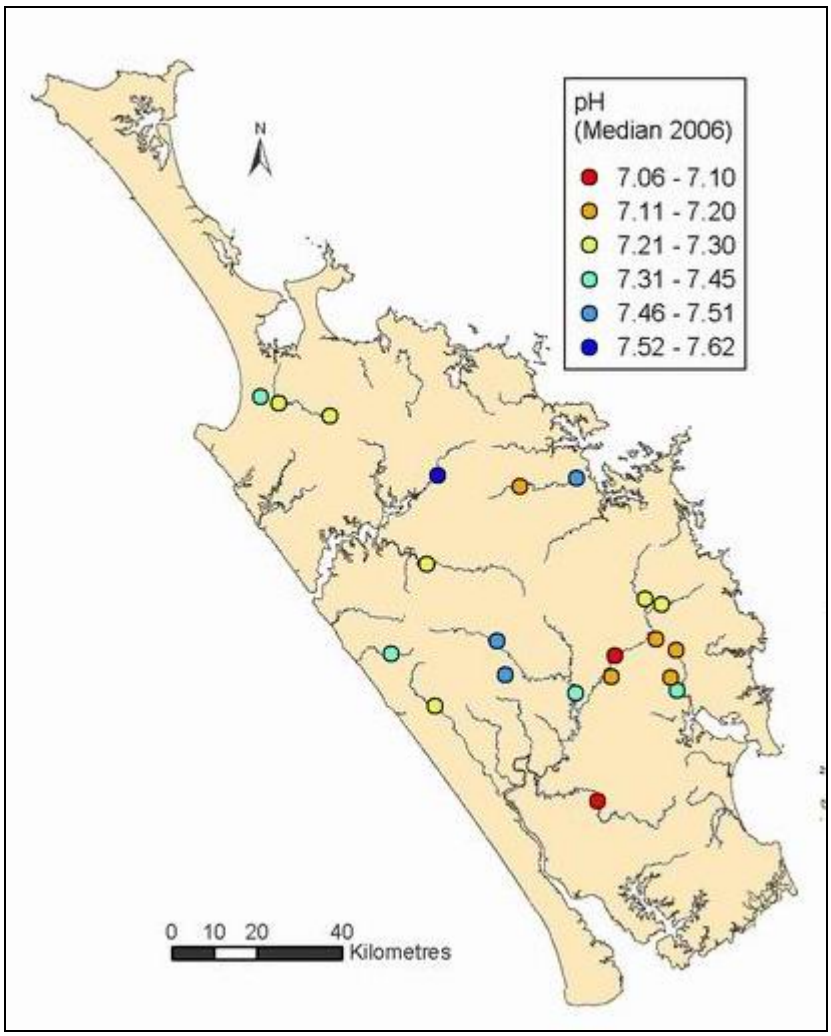

Figure 5: Median pH for 2006 at 21 RWQMN sites

3.1.5 Water clarity

The regional median water clarity in 2005 was 1.24 m and in 2006 was 1.35 m. The national median clarity in 2005 for the 77 National River Water Quality Monitoring Network sites was 2.85 m (Scarsbrook 2006).

Highest median water clarity in 2006 was 2.13 m in Waipoua River and Mangahahuru Stream at Main Rd, followed by Waipapa River and then Victoria River. The lowest median water clarity in 2006 was 0.55 m at the Awanui River above Waihue channel site, followed by the Mangakahia River at Titoki Bridge site.

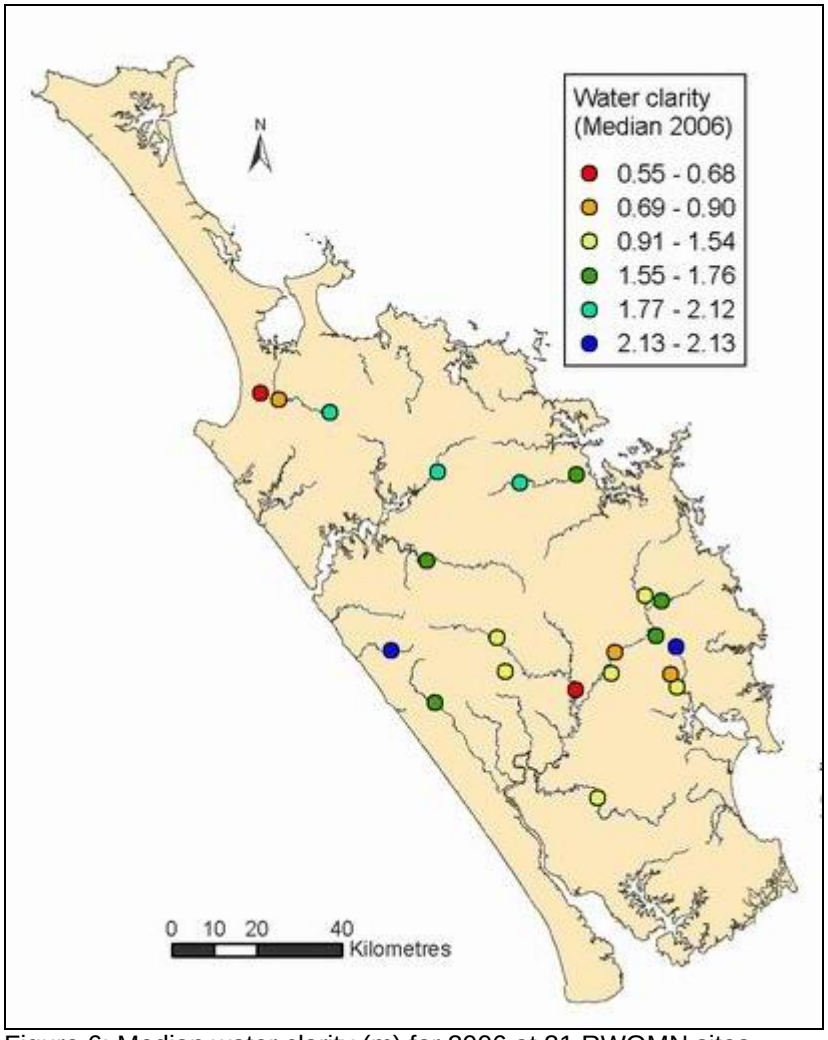

Figure 6: Median water clarity (m) for 2006 at 21 RWQMN sites

3.1.6 Turbidity

Median turbidity in 2006 was lowest at the Victoria River site, followed by the Waipapa River site, while the Manganui River had the highest median turbidity levels. The medians for the majority of sites (16 of 21) were below the upper limit for the protection of aquatic ecosystems of 5.6 ntu (ANZECC 2000).

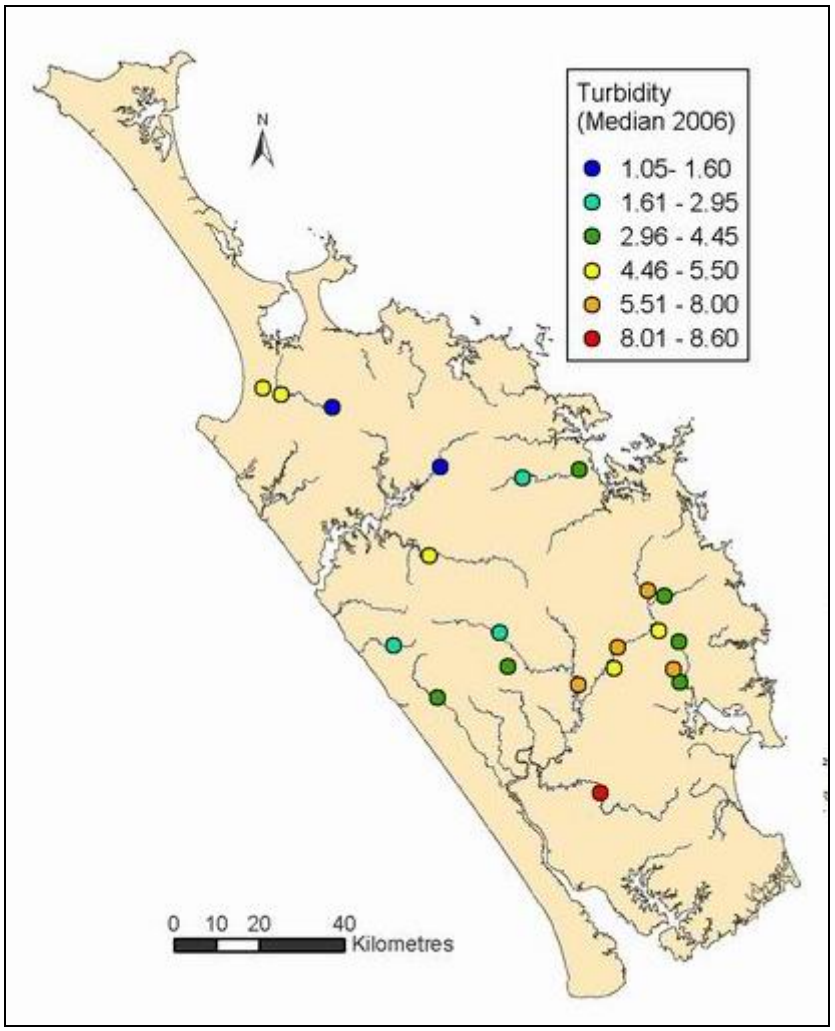

Figure 7: Median turbidity (ntu) for 2006 at 21 RWQMN sites

3.1.7 Dissolved colour

Similarly to water clarity and turbidity the lowest median dissolved colour for 2006 was found at the Victoria, Waipoua and Waipapa River sites and the highest was in the Manganui River. This is consistent with the visual appearance of these rivers, with the first three sites having frequently clear bluer coloured water, while Manganui River is often turbid and brown.

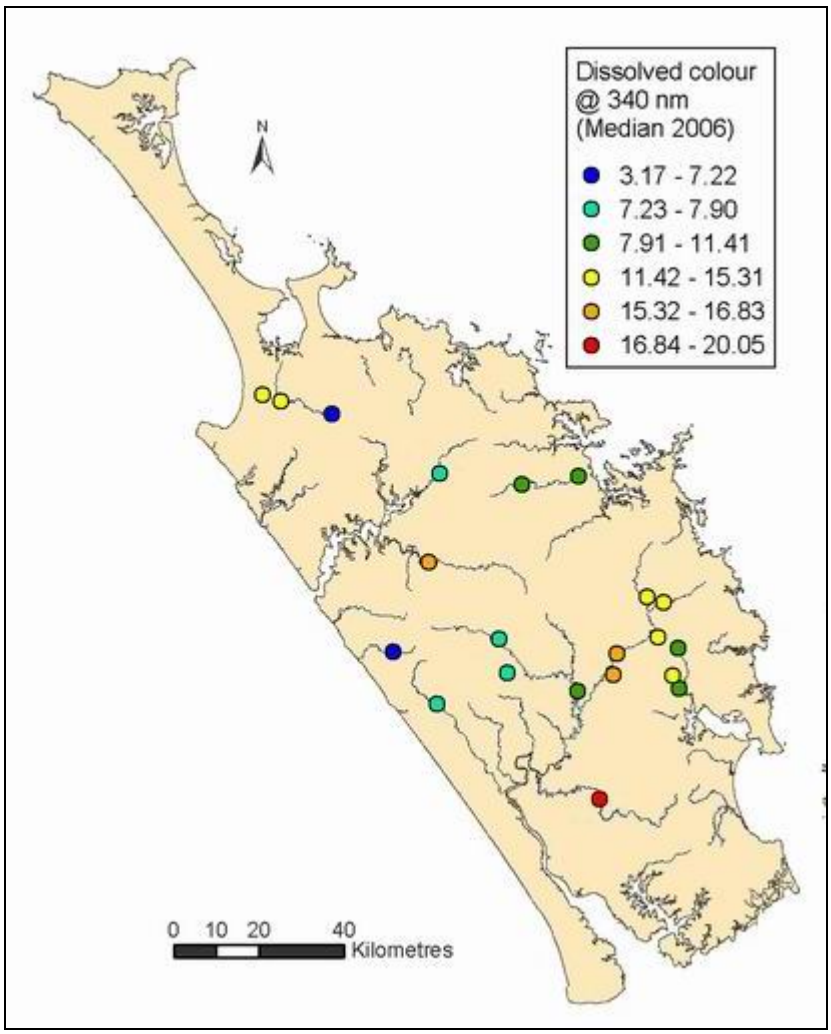

Figure 8: Median dissolved colour (@ 340 nm) for 2006 at 21 RWQMN sites

3.1.8 Total kjedahl nitrogen

Total kjedahl nitrogen (TKN) is basically organic nitrogen. Note: the results presented below for the four NRWQN sites have been calculated by subtracting the concentration of nitrate from the concentration of total nitrogen (i.e. TN – NO_3 = TKN)

Waiarohia Stream in Whau Valley had the highest median Total Kjedahl nitrogen (organic nitrogen) in 2006 of 0.55 g/m^3, while the Waipoua and Victoria River sites had the lowest median TKN in 2006 of 0.05 g/m^3.

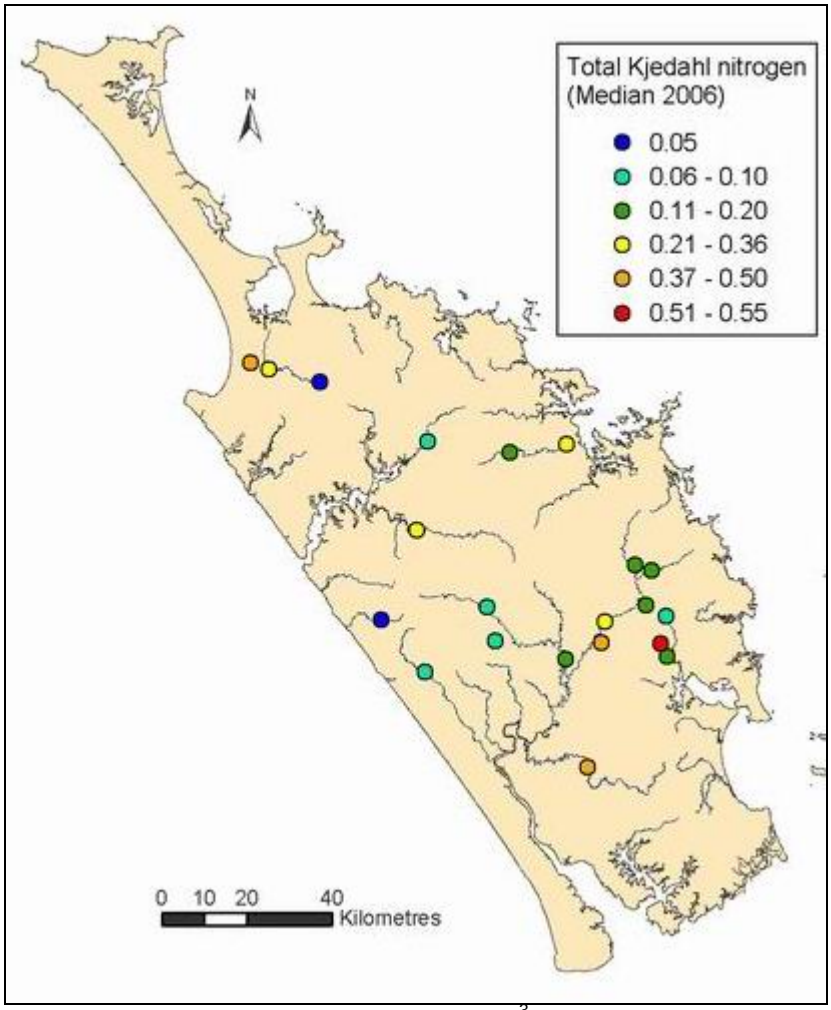

Figure 9: Median total kjedahl nitrogen (g/m^3) for 2006 at 21 RWQMN sites

3.1.9 Nitrate nitrite nitrogen

Nitrate/nitrite nitrogen is also known as oxides of nitrogen (NO_x). Note: the results presented in the figure below for the four NRWQN are nitrate (NO_3) only, not oxides of nitrogen.

Median nitrate/nitrite nitrogen (NNN) is highest at Mangere Stream at Knight Road and lowest at the Victoria and Opouteke River sites. The regional annual median NNN was 0.142 g/m^3 for both 2005 and 2006, while the national median in 2005 was 0.116 g/m^3 (Scarsbrook 2006).

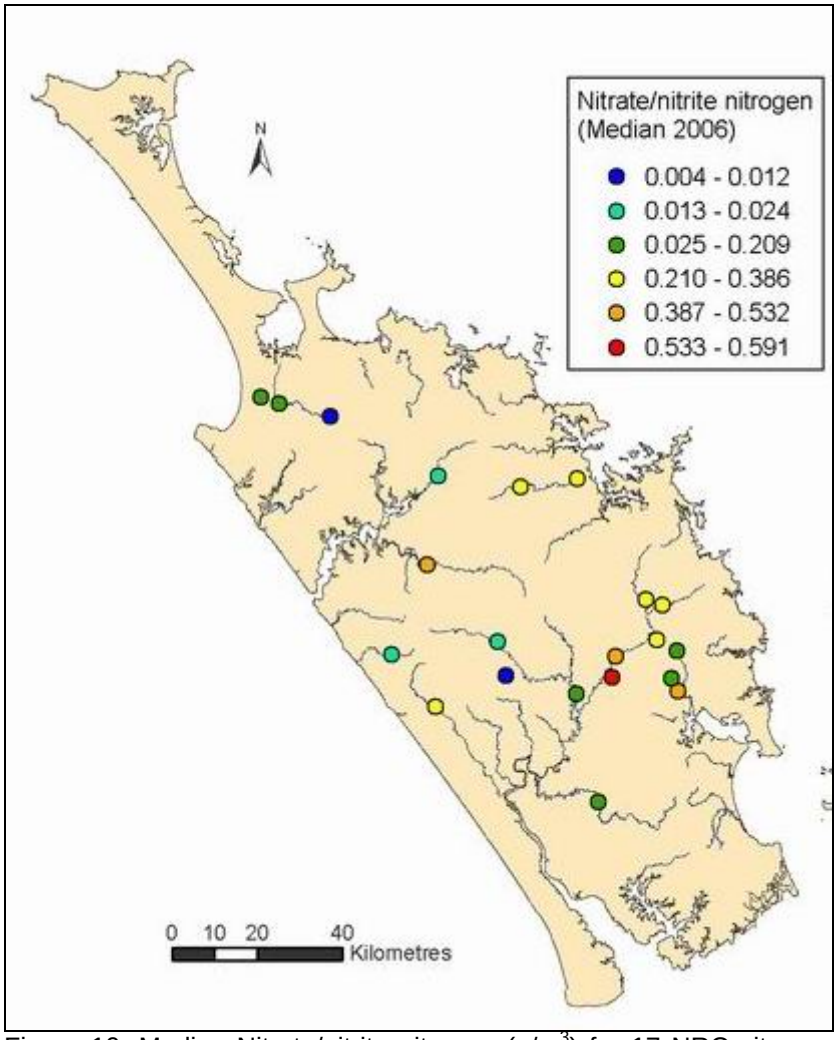

Figure 10: Median Nitrate/nitrite nitrogen (g/m^3) for 17 NRC sites and median nitrate (g/m^3) for 4 NRWQN sites (NIWA) for 2006

3.1.10 Ammoniacal nitrogen

Many of the sites have median ammoniacal nitrogen (NH_4) of 0.005 g/m^3 because NH_4 is below the detection limit of 0.01 g/m^3 on the majority of sampling occasions for these sites. This is consistent with the low concentrations of NH_4 found in most rivers nationally (Scarsbrook 2006). Ammoniacal nitrogen is highest at the Mangere Stream site.

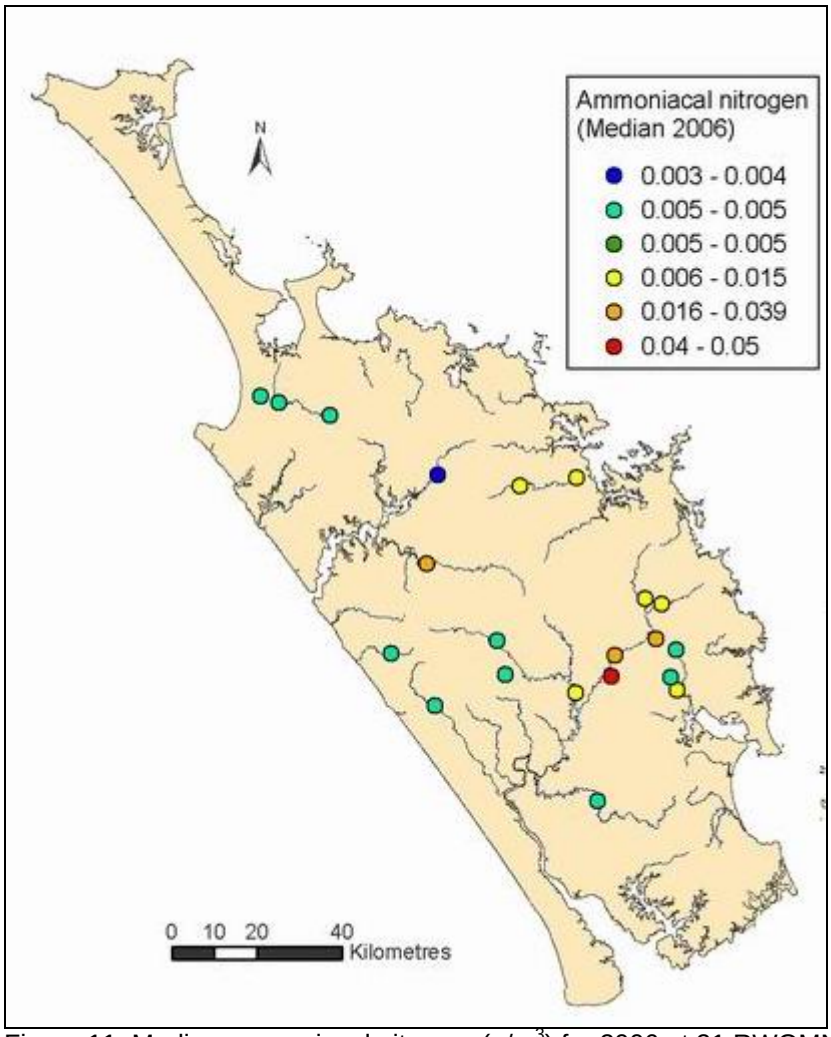

Figure 11: Median ammoniacal nitrogen (g/m^3) for 2006 at 21 RWQMN sites

3.1.11 Total nitrogen

Victoria and Waipoua River sites had the lowest median total nitrogen (TN) concentrations in 2006, while Mangere Stream and Punakitere River had the highest. The regional median for TN in 2005 was 0.417 g/m^3 and 0.405 g/m^3 in 2006, compared to the national median for 2005 of 0.280 g/m^3 (Scarsbrook 2006).

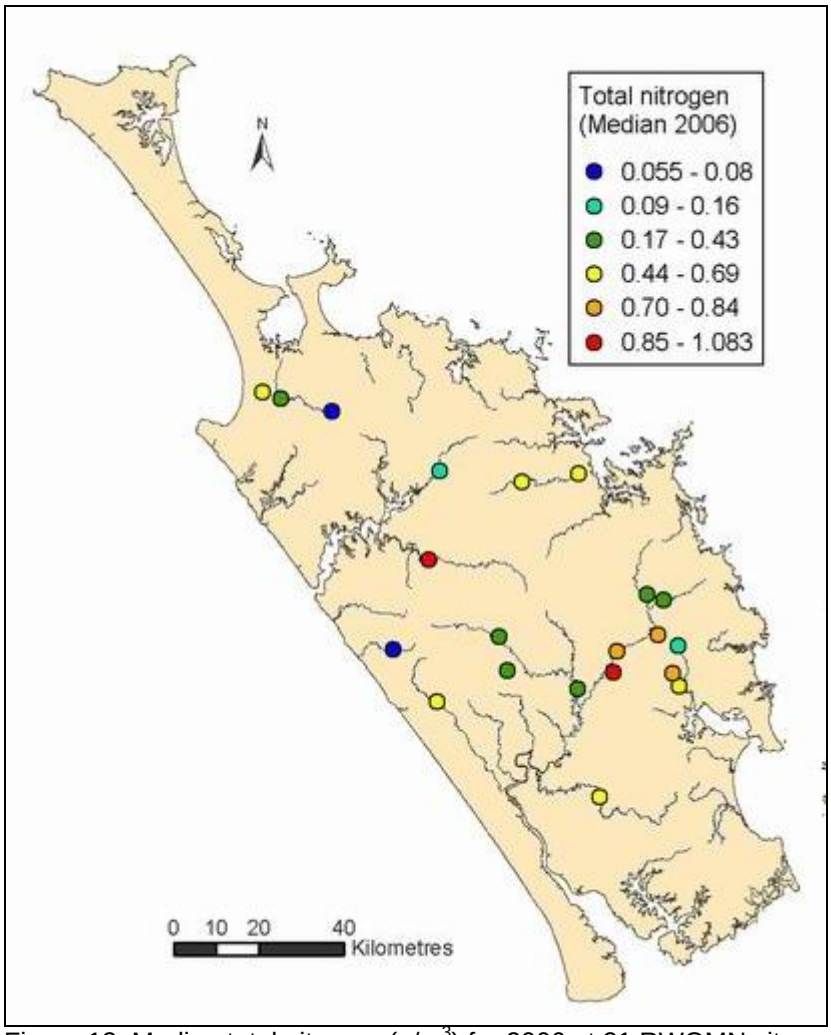

Figure 12: Median total nitrogen (g/m^3) for 2006 at 21 RWQMN sites

3.1.12 Dissolved reactive phosphorus

The median dissolved reactive phosphorus (DRP) for 2006 was lowest at the Waitangi River at Waimate and Waiarohia Stream at Whau Valley sites, with several monthly results below the detection limit of 0.004 g/m^3. The highest median DRP concentration was found in the Mangere Stream. Regional median for DRP was 0.019 and 0.016 g/m^3 in 2005 and 2006 respectively, compared to the national median in 2005 of 0.005 g/m^3.

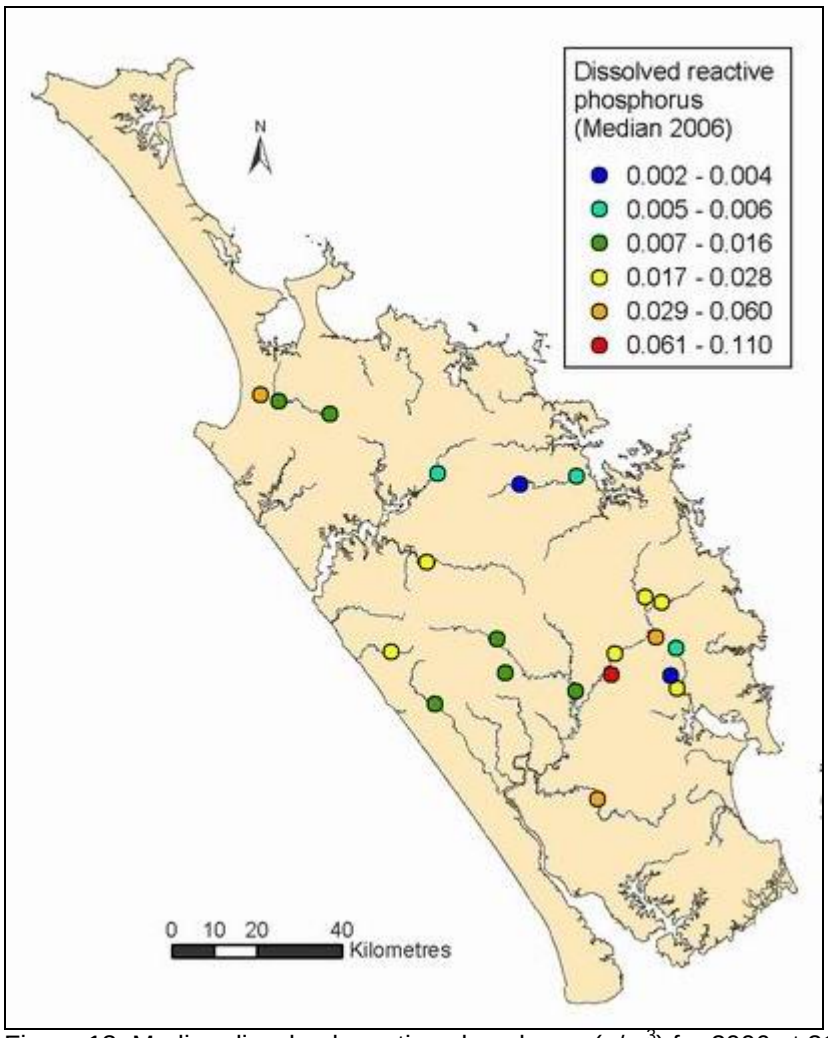

Figure 13: Median dissolved reactive phosphorus (g/m^3) for 2006 at 21 RWQMN sites

3.1.13 Total phosphorus

Median total phosphorus (TP) concentrations were lowest at the Waipapa River and Mangahahuru Stream at Main Road sites. Similarly to DRP, TN, NH_4 and NNN, Mangere Stream also has the highest median TP levels for 2006. The regional medians for TP were 0.048 and 0.044 g/m^3 in 2005 and 2006 respectively, compared to the national median in 2005 of 0.016 g/m^3.

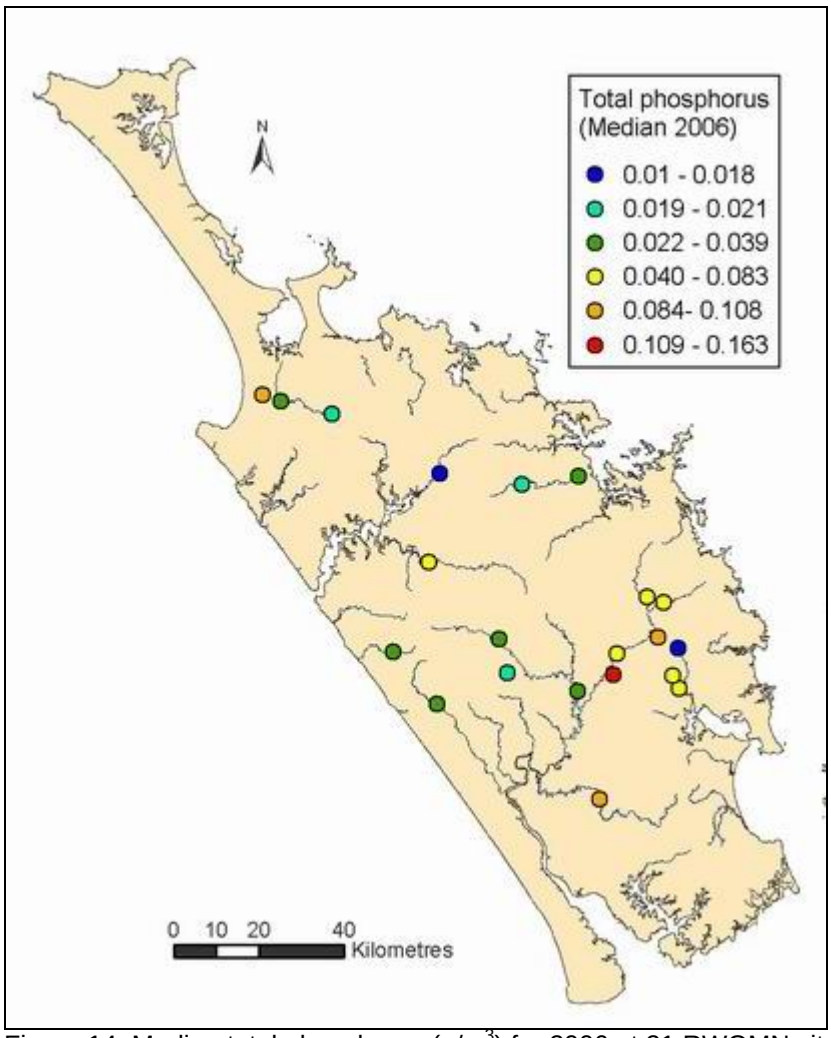

Figure 14: Median total phosphorus (g/m^3) for 2006 at 21 RWQMN sites

3.1.14 *Escherichia coli* (bacteria)

The sites with the lowest median *Escherichia coli* were the two indigenous forest sites; Waipoua and Waipapa Rivers, followed by Wairua at Purua. The site with the highest median *E. coli* for 2006 was Mangere Stream. The median E. coli results for Northland in 2005 and 2006 were 286 and 235 MPN/100ml respectively, compared to the national median for 2005 of 49 MPN/100ml.

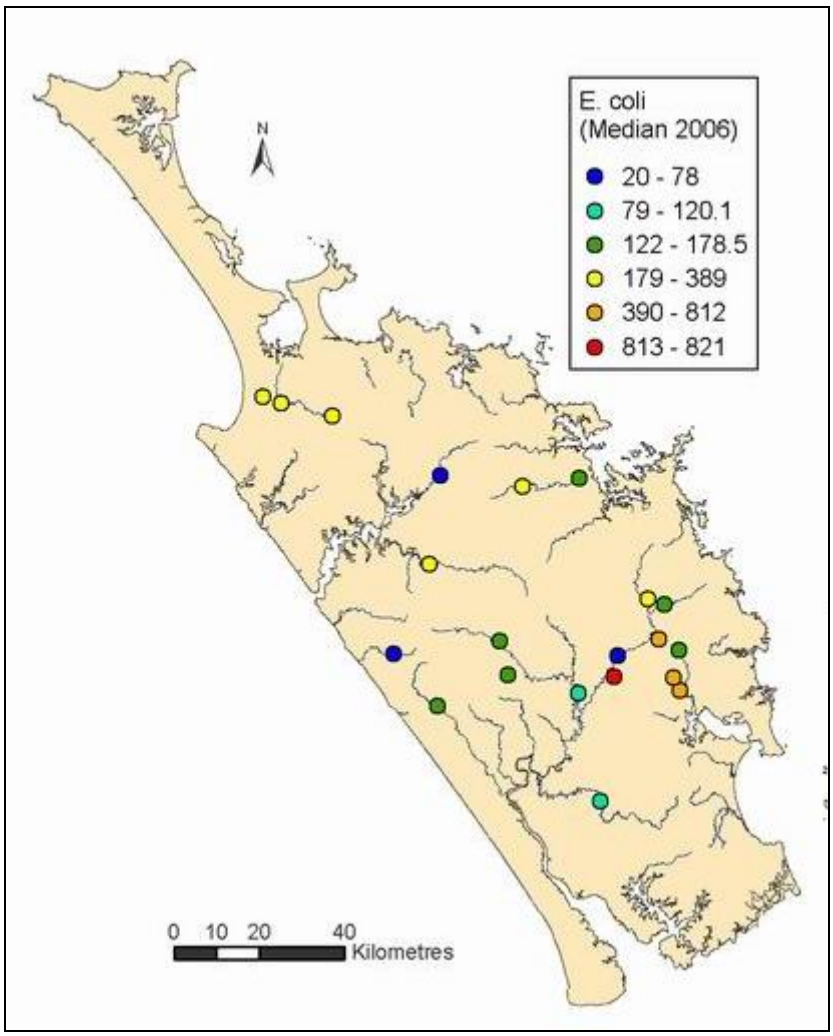

Figure 15: Median E. coli (MPN/100ml) for 2006 at 21 RWQMN sites

3.2 Diurnal patterns in Dissolved oxygen

Dataloggers were deployed at the two RWQMN sites on the Mangahahuru Stream, one at Main Road in the headwaters and the other at Apotu Road further downstream. The dataloggers were deployed for approximately a week at both sites simultaneously and programmed to take dissolved oxygen measurements every 30 minutes. The results for dissolved oxygen (% saturation) at the two sites are shown in figures 16 and 17 (below).

Both figures show a clear diurnal cycle in dissolved oxygen (DO) with peaks between 3 and 4 pm and lows between 6 and 7 am.

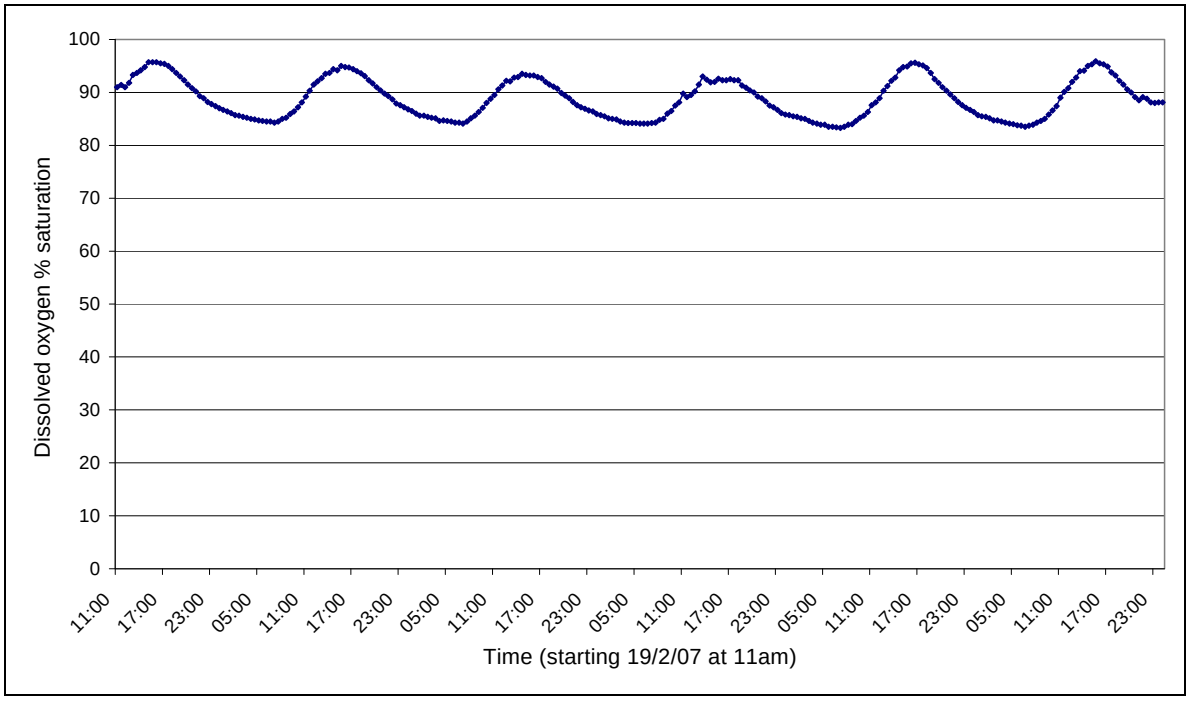

Figure 16: Dissolved oxygen (% saturation) at the Mangahahuru Stream Main Road site starting at 11 am on 19 February 2007.

But more importantly these results highlight the difference in DO cycles between the two sites. The less impacted and shaded Main Road site has a small range with its dissolved oxygen fluctuating by about 10% throughout the cycle, while the Apotu Road site has a much greater range of about 75%. This is most likely a result of the large mats of oxygen weed at the Apotu Road site, which produce copious amounts of oxygen during the production (day time) phase of photosynthesis but consume oxygen during the respiration (night time) phase of photosynthesis. These extremes in dissolved oxygen are a concern as oxygen levels as low as 50% saturation are occurring in the early morning at the Apotu Road site.

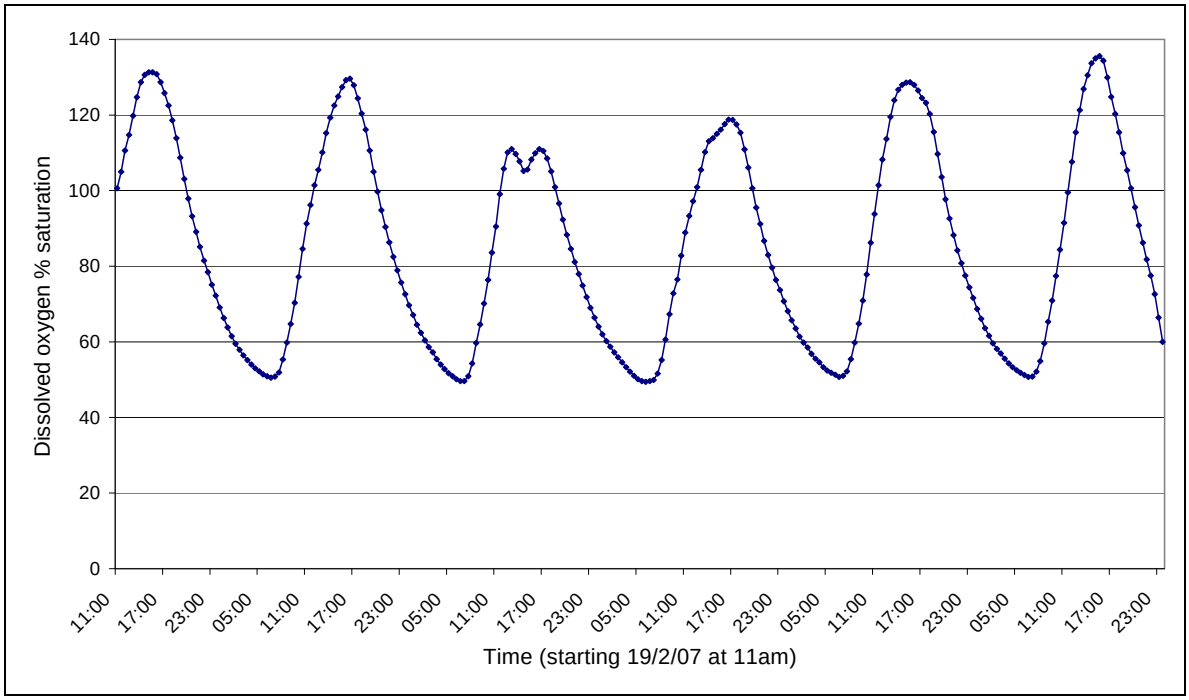

Figure 17: Dissolved oxygen (% saturation) at the Mangahahuru Stream Apotu Road site starting at 11 am on 19 February 2007.

3.3 Heavy metals in an urban catchment

Sampling for heavy metals in stream sediments was established in November 2006 for the Waiarohia Stream in Whangarei to investigate the effects of urban land use. Two sites are sampled; one at Whau valley which is the upstream or background site and the other at Second Avenue, which is the downstream site. The Waiarohia Stream between these two sites is heavily influenced by road run-off and urban stormwater. Sediment samples are collected every three months and analysed for the typical suite of heavy metals.

The results for the first three sampling occasions are presented in table 3 (below). The results are compared to the ANZECC sediment quality guidelines for the protection of aquatic ecosystems (also shown in table 3). None of these initial results exceed the high trigger values for the protection of aquatic ecosystems. However a few results (shown in bold and red) exceed the low trigger values.

Table 3: Heavy metal levels (mg/kg) in stream sediments from two Waiarohia Stream sites, compared to the ANZECC trigger values

	Second Ave site			**Whau valley site**			**ANZECC trigger values**	
Date	Nov 06	Feb 07	May 07	Nov 06	Feb 07	May 07	Low	High
Arsenic	8	5	6	10	9	12	20	70
Cadmium	0.2	0.1	0.1	0.1	0.3	0.1	1.5	10
Chromium	21	21	18	13	20	18	80	370
Copper	42	26	27	18	33	23	65	270
Mercury	**0.3**	<0.1	<0.1	**0.3**	**0.4**	**0.2**	0.15	1
Nickel	15	17	15	10	15	13	21	52
Lead	**50.5**	31.9	35.2	19.3	31	23.1	50	220
Zinc	**338**	**242**	161	99	189	98	200	410

These initial results show that for most heavy metals there is very little difference between the upstream and downstream site. However, both lead and zinc have been slightly higher at the downstream site.

It is likely that the slightly elevated Mercury levels are of natural origin, especially as they are higher at the upstream site. The elevated zinc levels at the downstream site are possibly a result of leaching from galvanised steel in the stream or runoff from roads and roofs, while the slightly elevated lead levels are most likely a result of road run-off.

The dataset is limited, so care should be taken with this interpretation of the results. Sampling will continue at these two sites and other sites will be investigated in the future.

3.4 Compliance with ANZECC guidelines

The site compliances with the ANZECC guidelines for all years of data and for the 2006 data for each parameter are in tables 7 and 8 in Appendix B. For more information on the guidelines check out the methods (section 2).

The following maps (Figures 18 to 26) show the percentage of samples for each site that comply with the ANZECC guidelines for all years. The points are colour coded from worst to best i.e. red - less than 25% of samples comply, green – at least 75% of samples comply and blue – all samples comply.

The points are split into the following categories:

- Minimum to < 25% of samples comply
- 25 to < 50% of samples comply
- 50 to < 75% of samples comply
- 75 to < 100% of samples comply
- All samples comply (100%)

3.4.1 Dissolved oxygen

Only one of the 21 RWQMN sites comply with the ANZECC guideline range for dissolved oxygen on more than 50% of sampling occasions. Waitangi River at Watea complies with the dissolved oxygen guideline range on 71% of sampling occasions.

It should be noted that although Waipoua River is only compliant with the guideline range on 33% of sampling occasions, it is classed as an upland river and therefore has a smaller DO range of 99 to 103% saturation compared to the range for lowland rivers of 98 to 105%.

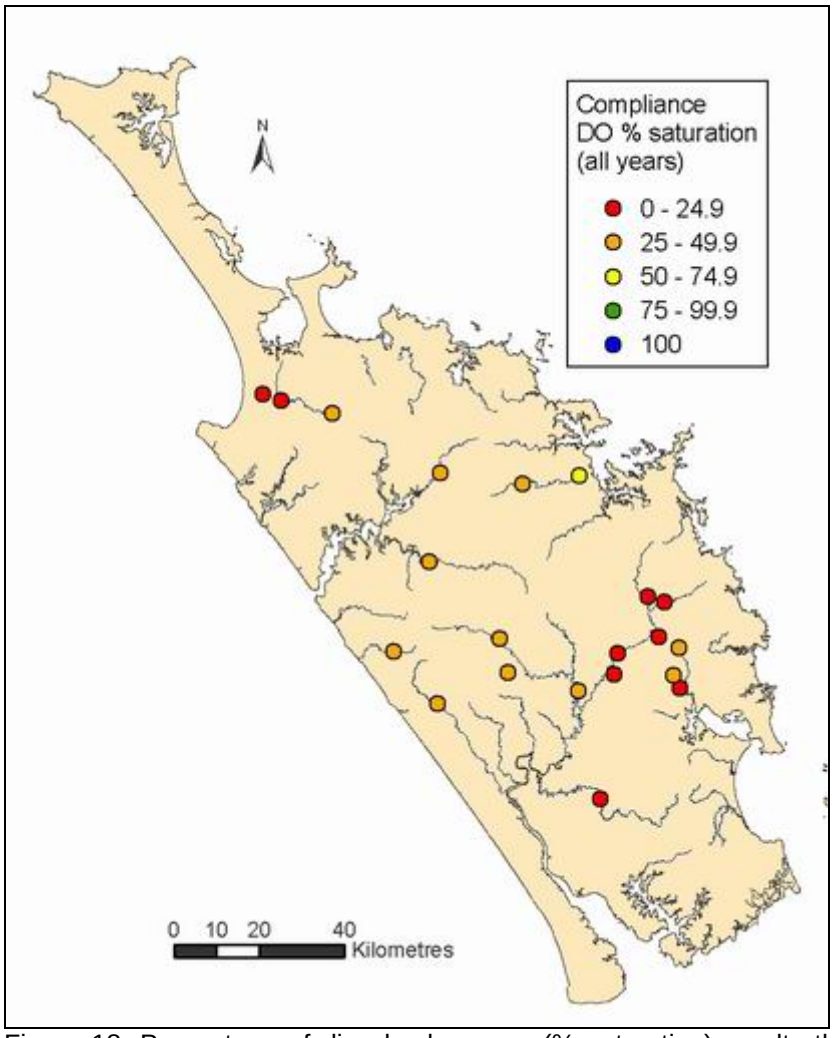

Figure 18: Percentage of dissolved oxygen (% saturation) results that comply with the ANZECC guidelines for 21 RWQMN sites for all years sampled.

3.4.2 pH

Three sites comply with the ANZECC pH range on less than 25% of sampling occasions; Waitangi at Waimate, Wairua at Purua and Mangahahuru Stream at Apotu Road. Five sites comply with the pH range on more than 75% of sampling occasions.

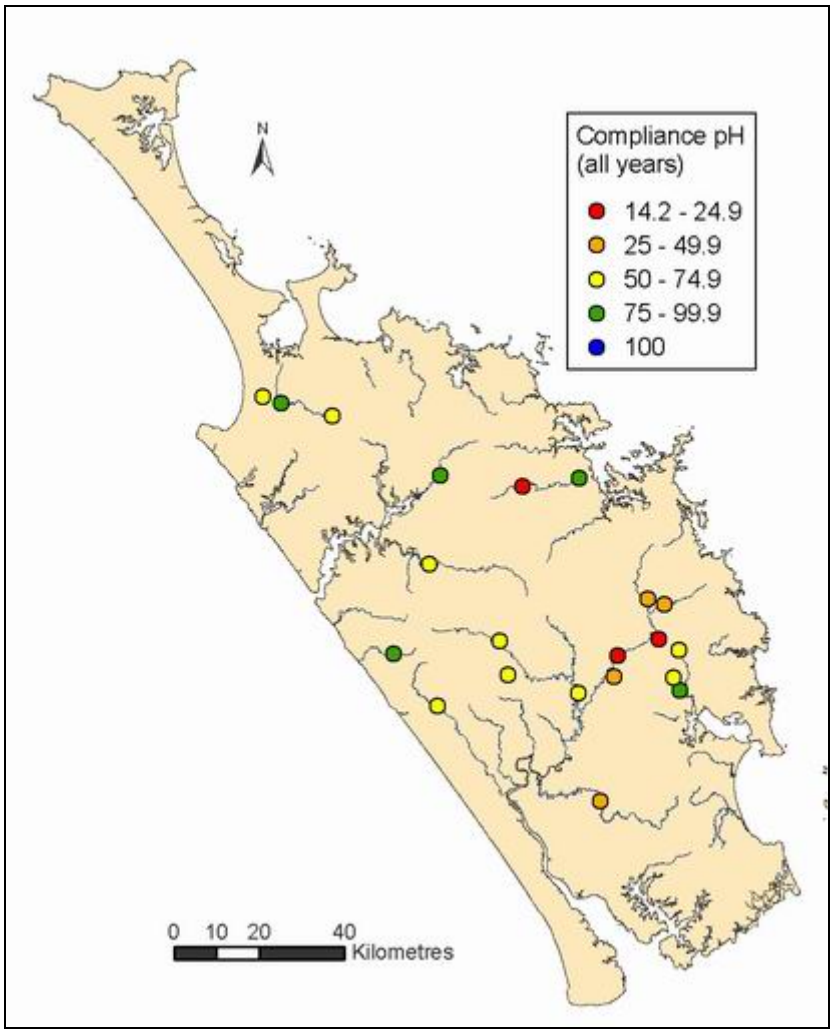

Figure 19: Percentage of pH results that comply with the ANZECC guidelines for 21 RWQMN sites for all years sampled.

3.4.3 Water clarity

Thirteen of the 21 RWQMN sites comply with the ANZECC guidelines for water clarity for the protection of aquatic ecosystems on over 75% of sampling occasions. Only two sites comply with the guideline on less than 50% of sampling occasions; Awanui above Waihue channel and Wairua at Purua.

However tighter guidelines are used for waters classified for the purpose of contact recreation from the RWSP (NRC 2007). Although Northland's rivers have not been classified, many are used for contact recreation. See sections 2.1.3 and 3.5.2 for more information.

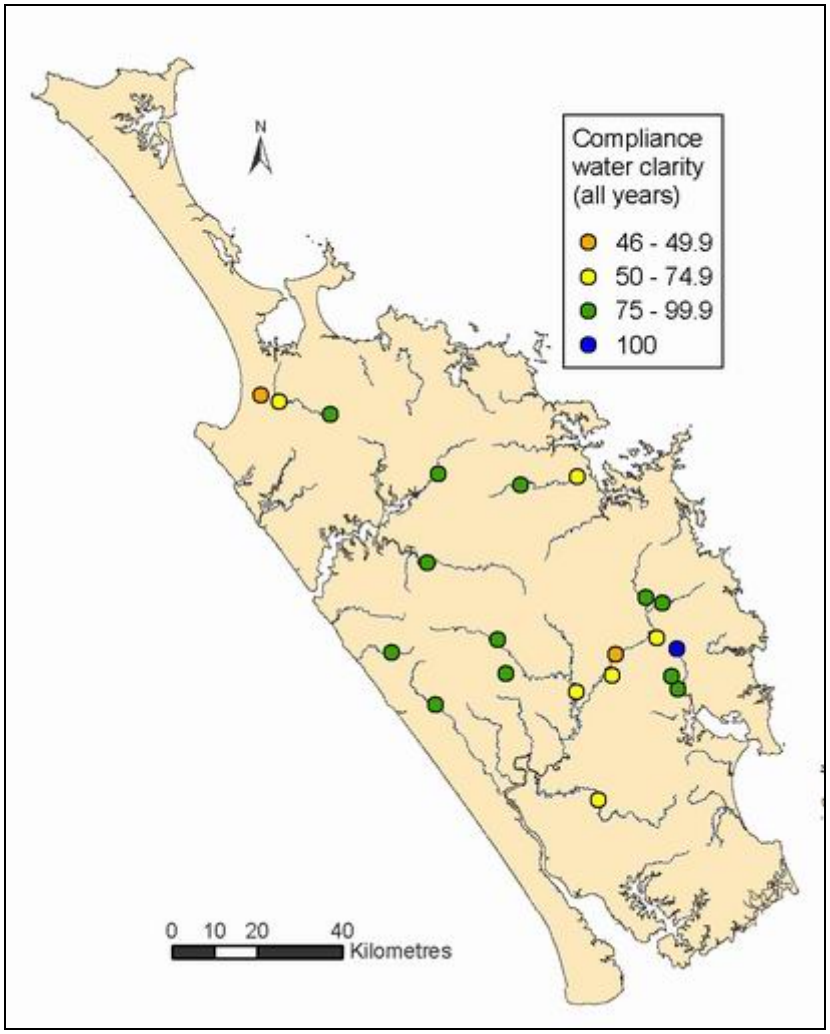

Figure 20: Percentage of water clarity (m) results that comply with the ANZECC guidelines for 21 RWQMN sites for all years sampled.

3.4.4 Turbidity

Less then 25% of sampling occasions for Waiotu River, Wairua at Purua and Waiarohia at Whau Valley comply with the ANZECC guideline for turbidity, while seven sites comply with the ANZECC guidelines over 75% of the time, as shown in figure 21 (below).

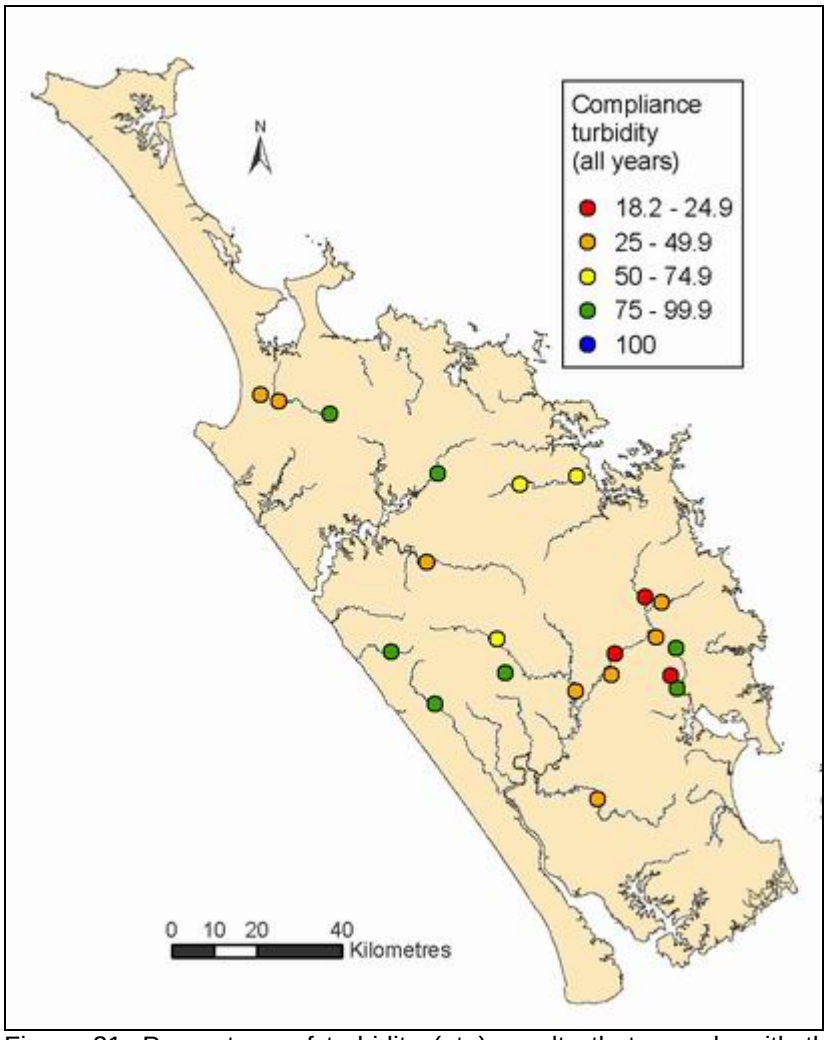

Figure 21: Percentage of turbidity (ntu) results that comply with the ANZECC guidelines for 21 RWQMN sites for all years sampled.

3.4.5 Ammoniacal nitrogen

Three headwater sites comply with the ammoniacal nitrogen ANZECC guideline on all sampling occasions; Waipapa River, Waiarohia Stream at Whau Valley and Mangahahuru Stream at Main Road. Mangere River only complies with the guideline on 13% of sampling occasions. The Waipoua River site does not appear to perform as well as the other headwater sites because it is the only site that has been compared to the ANZECC trigger value for an upland river.

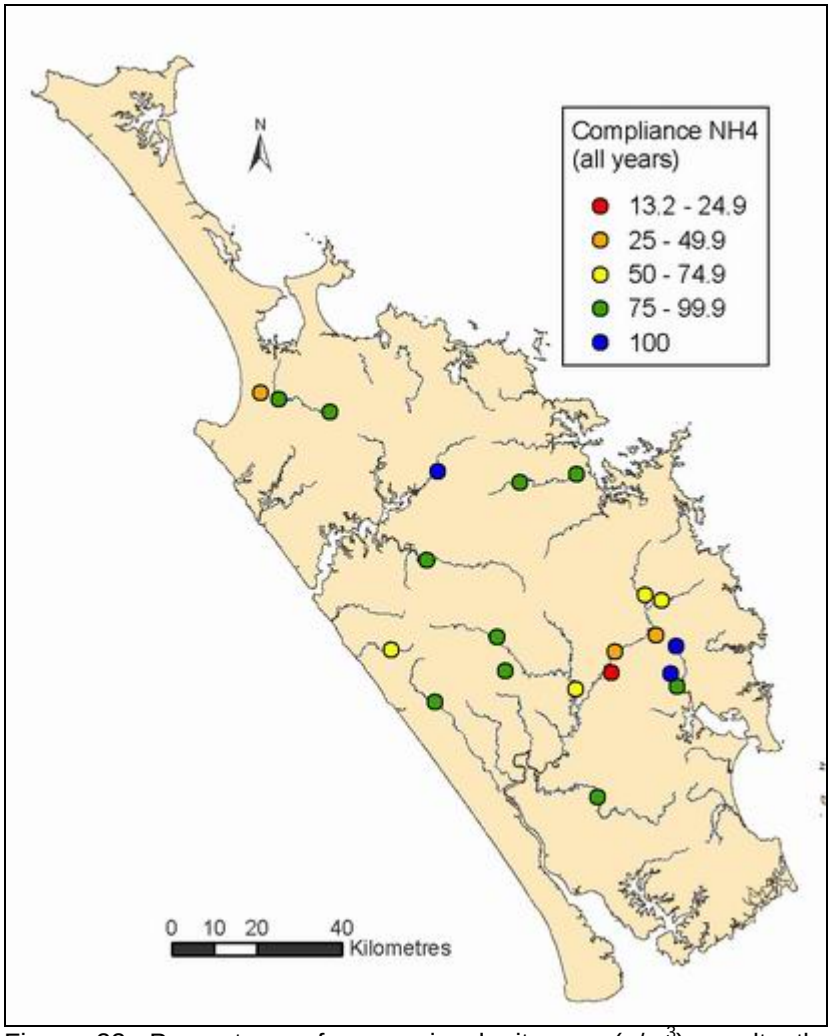

Figure 22: Percentage of ammoniacal nitrogen (g/m^3) results that comply with the ANZECC guidelines for 21 RWQMN sites for all years sampled.

3.4.6 Nitrate/nitrite nitrogen

Five sites comply with the ANZECC guideline for oxides of nitrogen (or otherwise known as NNN) on all sampling occasions. They are Victoria, Waipoua, Waipapa and Opouteke River sites and the site at the FNDC water take on Awanui River. Mangere River only complies with the guideline on 15% of sampling occasions.

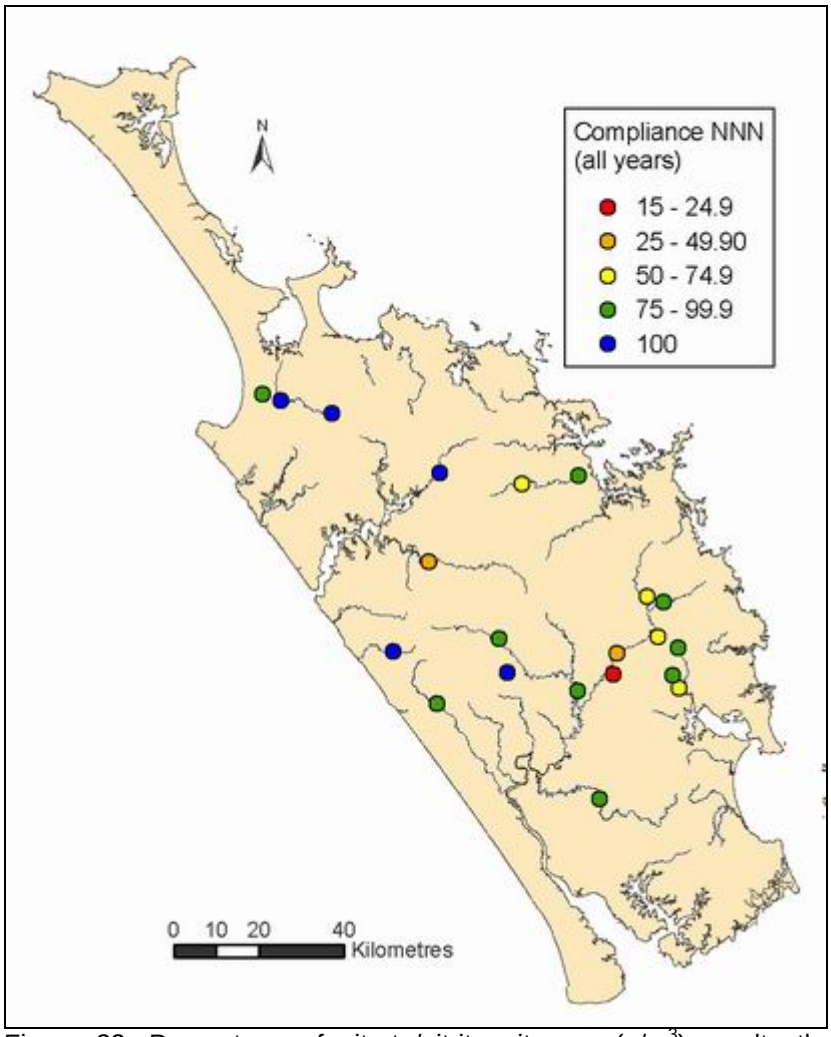

Figure 23: Percentage of nitrate/nitrite nitrogen (g/m^3) results that comply with the ANZECC guidelines for 21 RWQMN sites for all years sampled.

3.4.7 Total nitrogen

Mangahahuru Stream at Main Road is the only site that complies with the ANZECC guideline for TN on all sampling occasions. Three sites exceeded the guideline on over 75% of sampling occasions; Punakitere River, Mangere Stream and Waiarohia Stream at Whau valley.

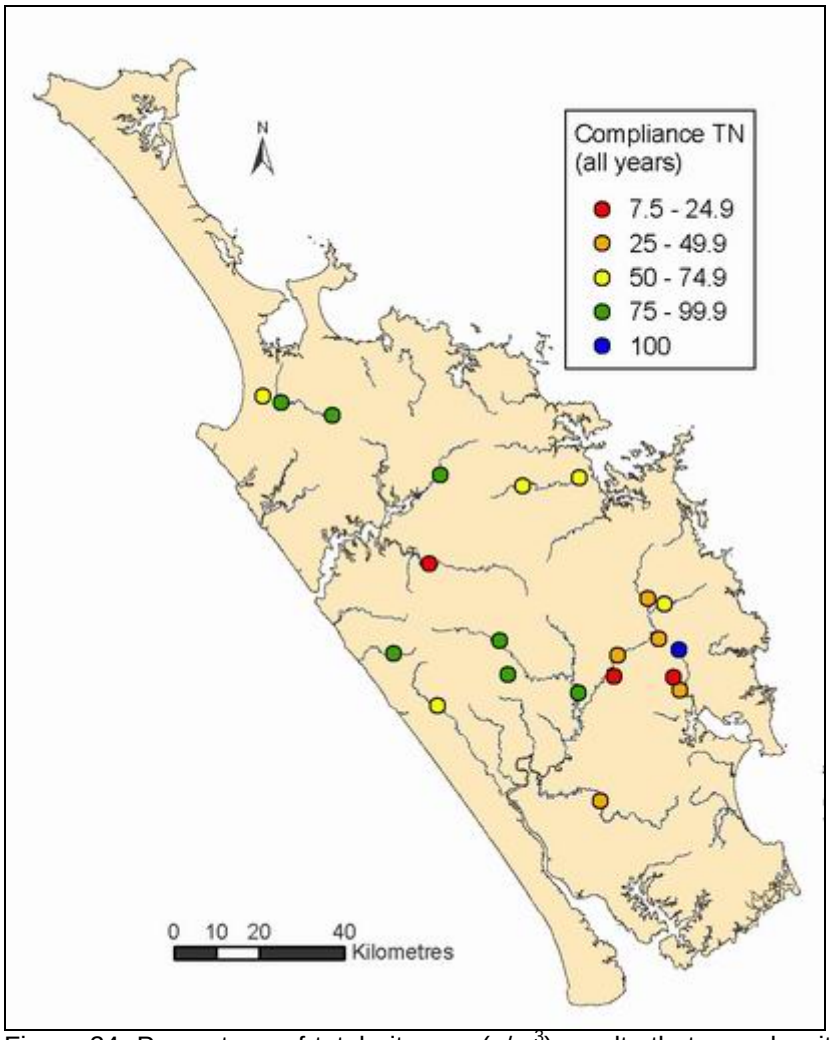

Figure 24: Percentage of total nitrogen (g/m^3) results that comply with the ANZECC guidelines for 21 RWQMN sites for all years sampled.

3.4.8 Dissolved reactive phosphorus

Mangahahuru Stream at Main Road was the only site that complied with the DRP guideline on all sampling occasions. There were 10 sites that exceeded the guideline on more than 75% of sampling occasions, of which for the following sites it was on more than 95% of occasions; Manganui, Mangere, Awanui at Waihue Channel and Wairua at Purua.

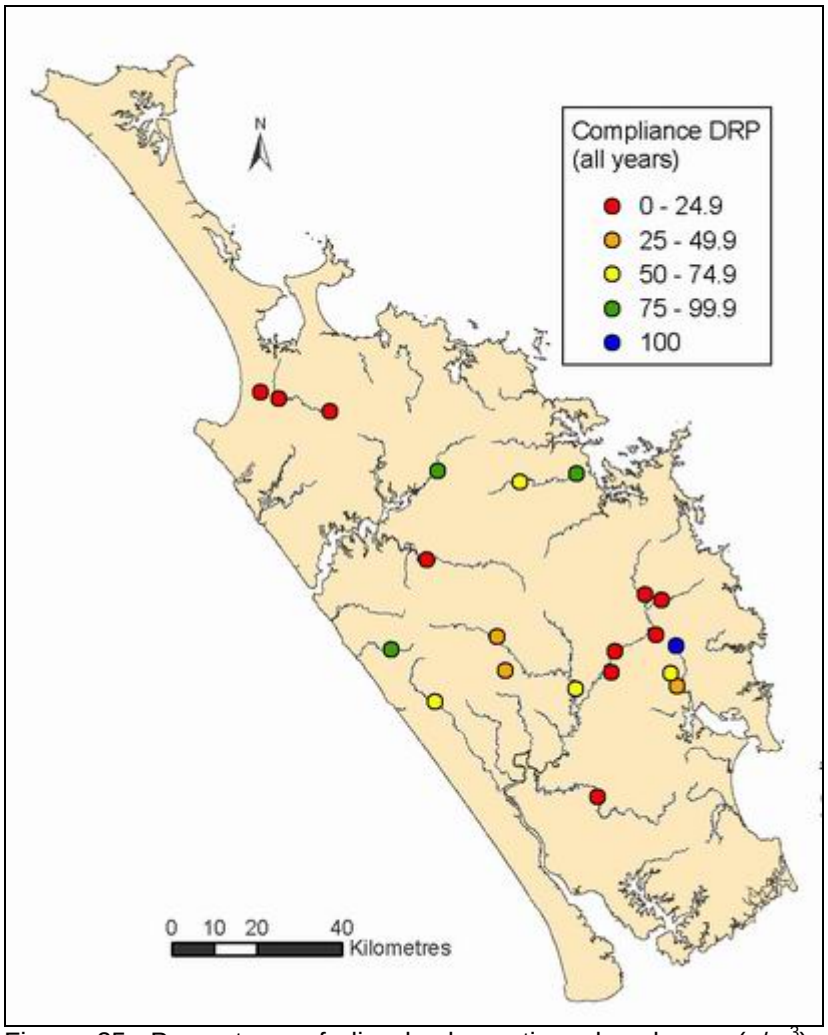

Figure 25: Percentage of dissolved reactive phosphorus (g/m^3) results that comply with the ANZECC guidelines for 21 RWQMN sites for all years sampled.

3.4.9 Total phosphorus

Eleven sites exceeded the guideline for TP on more than 75% of sampling occasions, of which the following sites exceeded the guideline on more than 95% of sampling occasions; Mangere, Awanui at Waihue Channel, Mangahahuru at Apotu Road, Waiarohia at Whau Valley and Wairua at Purua. Four sites complied with the guideline on more than 75% of sampling occasions.

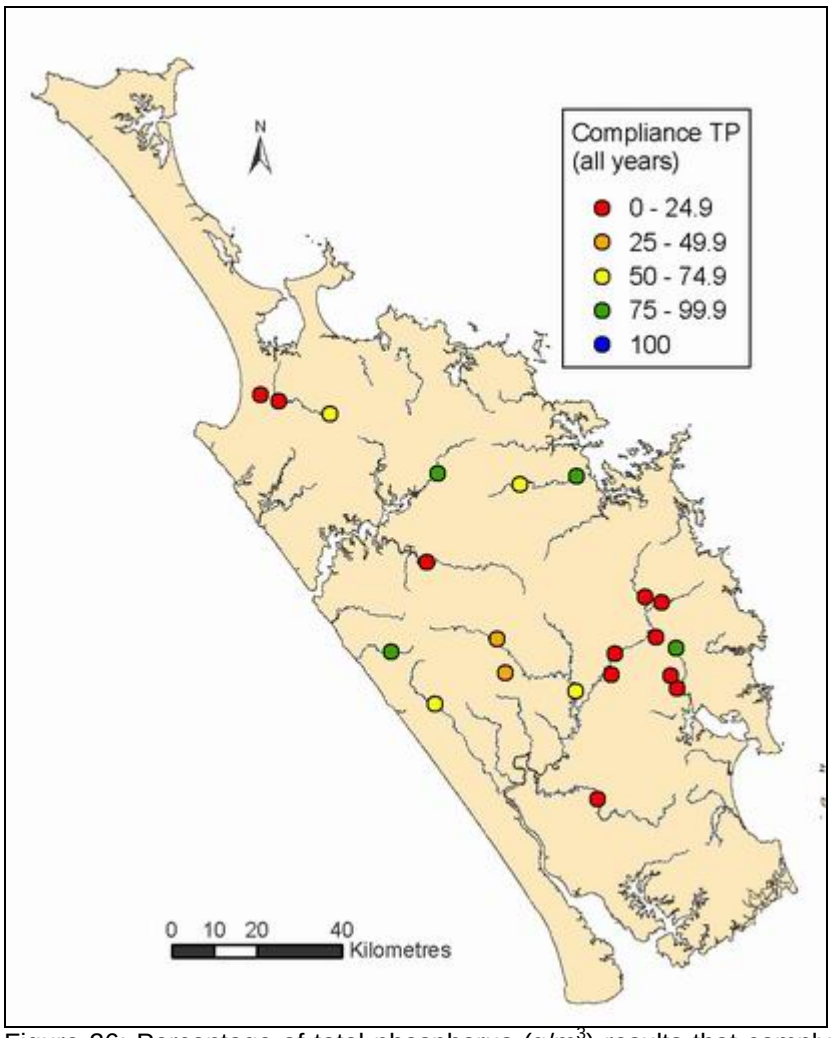

Figure 26: Percentage of total phosphorus (g/m^3) results that comply with the ANZECC guidelines for 21 RWQMN sites for all years sampled.

3.5 Compliance with recreational bathing guidelines

The site compliances with the recreational bathing guidelines for all years of data and for the 2006 data are in tables 7 and 8 in Appendix B. This includes both the guideline for *Escherichia coli* (bacteria) (MFE 2002) and water clarity from the RWSP (NRC 2007). For more information on the guidelines check out the methods (section 2).

The following maps (figures 27 and 28) show the percentage of samples for each site that comply with these guidelines for all years, following the same format as the maps above.

3.5.1 Escherichia coli (bacteria)

Compliance with the microbiological water quality guideline of 550 E. coli/100mL (MFE 2002) for all data available for each RWQMN site is shown in figure 27 (below). The following five sites comply with the recreational bathing guideline for E. coli on 85 to 95% of sampling occasions; Waipapa, Waipoua, Mangakahia at twin bridges, Opouteke and Mangahahuru at Main Road. Two sites only complied with the guideline on less than 50% of sampling occasions; Mangere Stream at Knights Road and Waiarohia at Whau Valley.

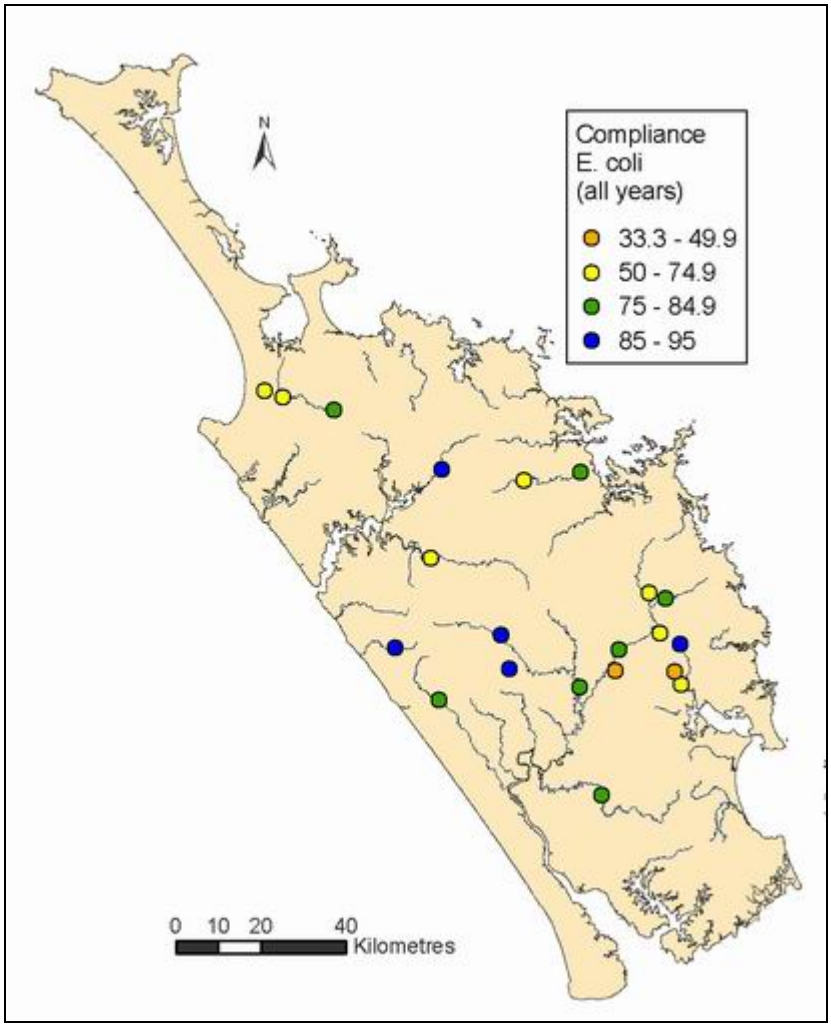

Figure 27: Percentage of E. coli (MPN/100mL) results that comply with the recreational bathing guideline for 21 RWQMN sites for all years sampled.

3.5.2 Water clarity

Compliance with the water clarity guideline for recreational purposes of 1.6 m for all data for each RWQMN site is shown in figure 28 (below).

Only two sites, both headwater sites, comply with this guideline on at least 75% of sampling occasions; Victoria and Waipoua River and only a further 3 sites comply with the guideline at least 50% of the time.

Seven sites comply with this guideline on less than 10% of sampling occasions. This means that for these seven rivers water clarity is likely to exceed the RWSP guideline of 1.6 m for at least 10 months of the year.

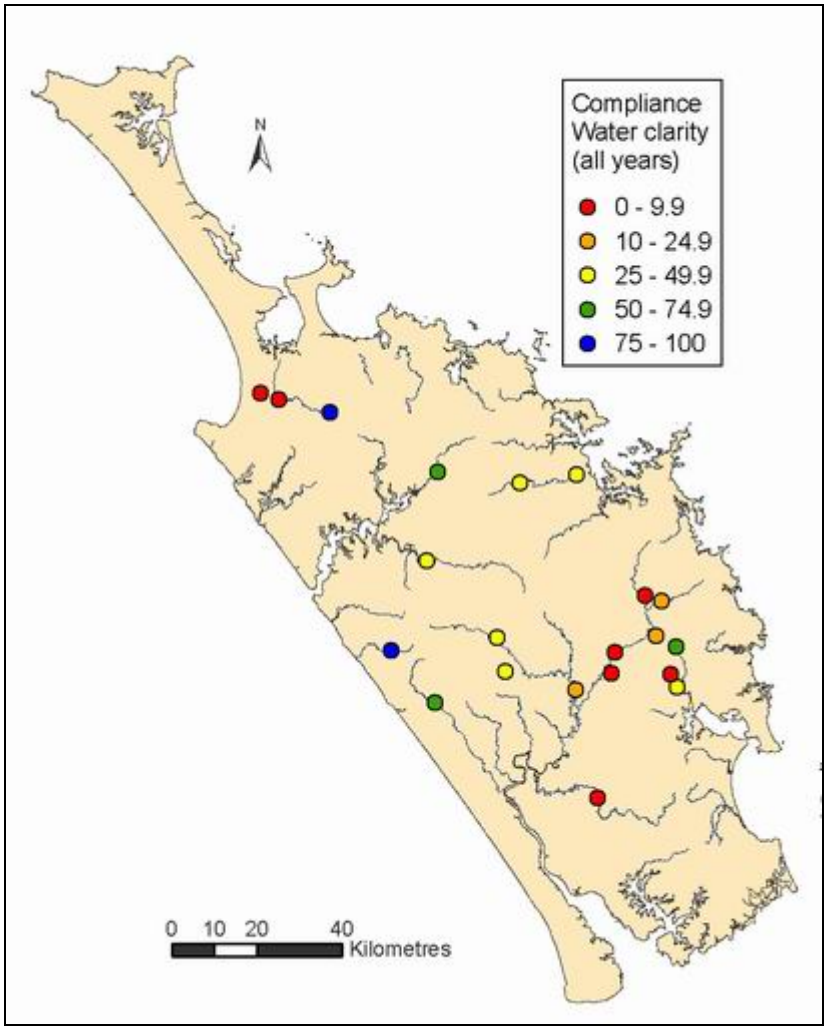

Figure 28 Percentage of water clarity (m) results that comply with the RWSP guideline for contact recreation waters for 21 RWQMN sites for all years sampled.

3.6 Compliance with drinking water standards

Some Northlanders in rural areas use untreated water from rivers and streams for their domestic supply, including human drinking water. Based on the *E. coli* results for the RWQMN sites in figure 27 (above) there are no rivers in Northland, including rivers in pristine native forested catchments, that would have microbiological water quality that meets the NZ drinking water standard of less than 1 *E. coli*/100mL (MoH 2005). Note this standard is the Maximum acceptable value for microbiological contamination for drinking water leaving a treatment plant. Therefore water taken directly from rivers and streams in Northland is not suitable for human drinking water without treatment.

4 Trends

4.1 Annual median values

The following graphs are a descriptive way of showing changes in water quality through time (Scarsbrook 2006). Annual median was calculated using the monthly data for the 21 RWQMN sites for each parameter from 1997 to 2006, remembering that there was only 13 sites in 1997 and the number of sites has increased since. These annual site medians were then used to calculate 5th, 20th, 50th, 80th and 95th percentiles for all RWQMN sites. The 50th percentile shows us what is happening in a "middle of the road" river, while the 5th and 95th percentiles show us changes in the best and worst rivers. The 20th and 80th percentiles are shown because management decisions are often based on the 80:20 rule.

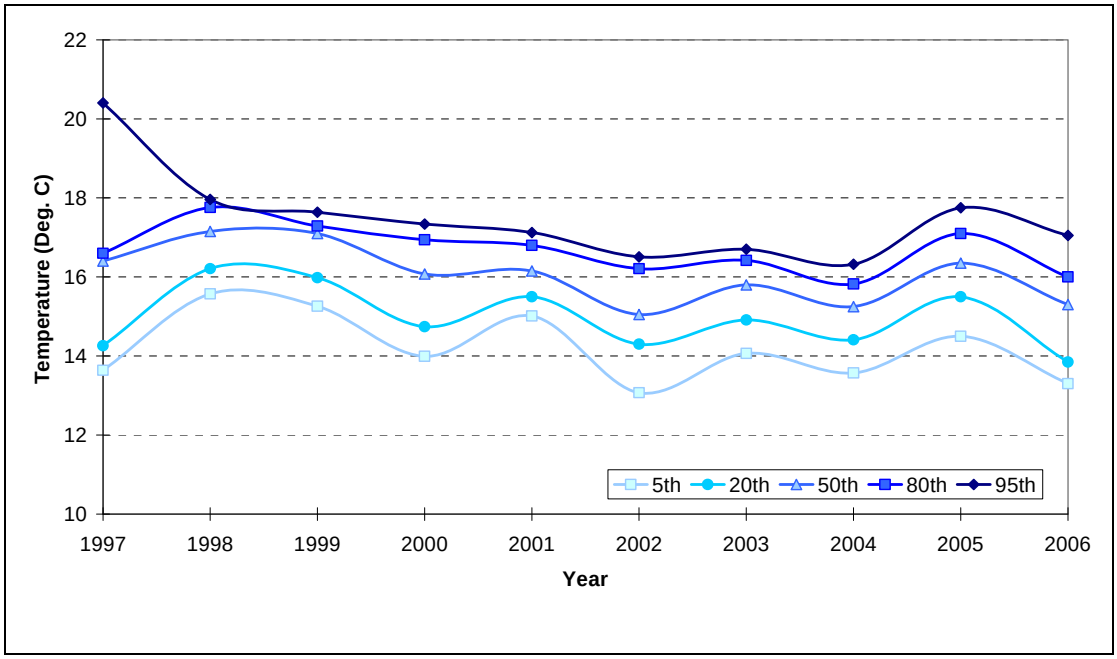

Figure 29: Percentiles based on annual median temperature for up to 21 RWQMN sites.

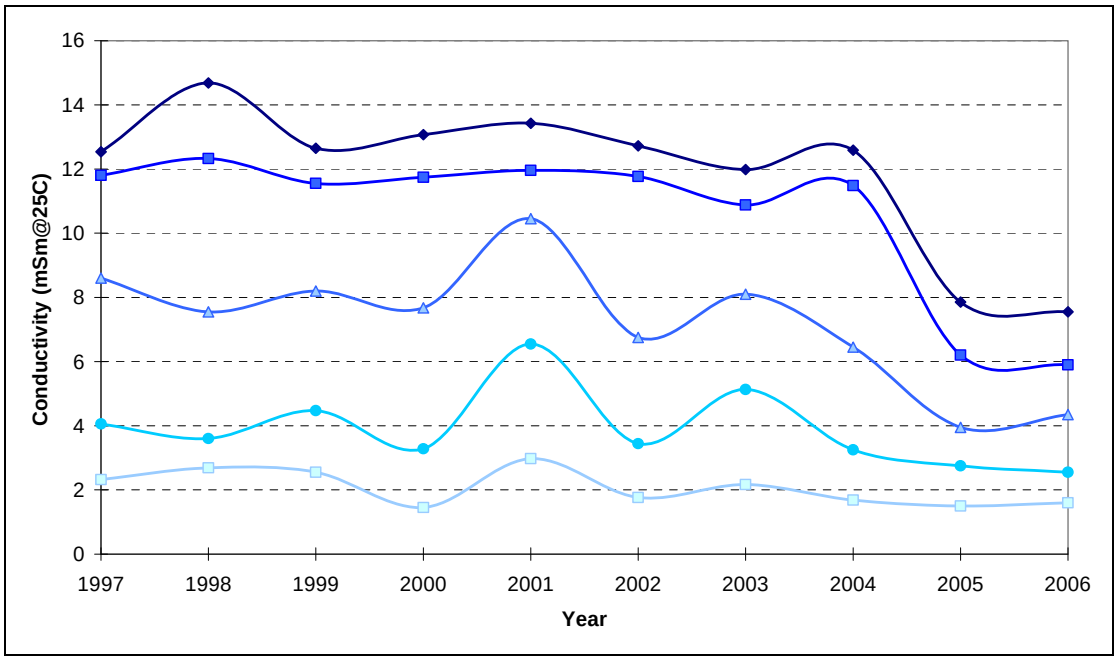

Figure 30: Percentiles based on annual median conductivity (mSm) for all RWQMN sites.

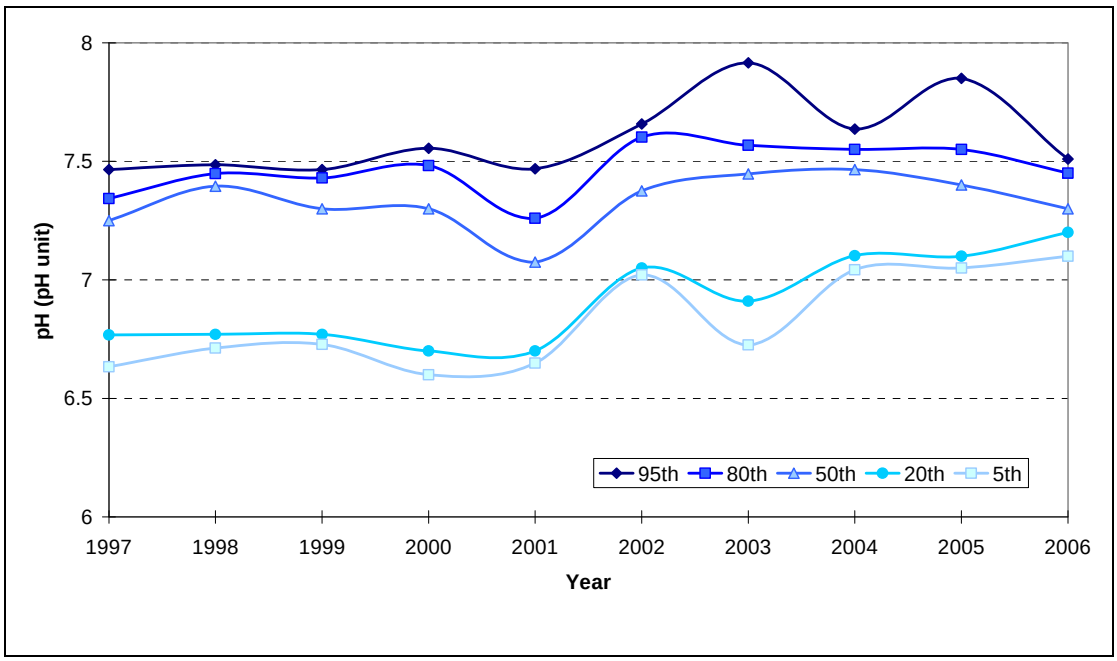

Figure 31: Percentiles based on annual median pH for up to 21 RWQMN sites.

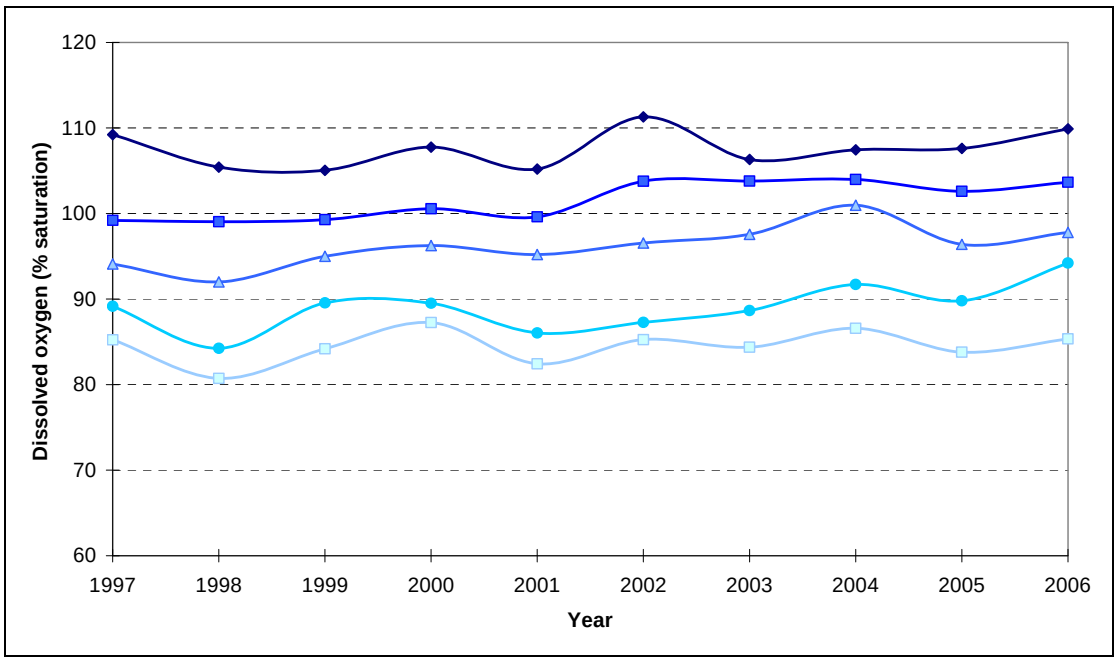

Figure 32: Percentiles based on annual median dissolved oxygen (% saturation) for up to 21 RWQMN sites.

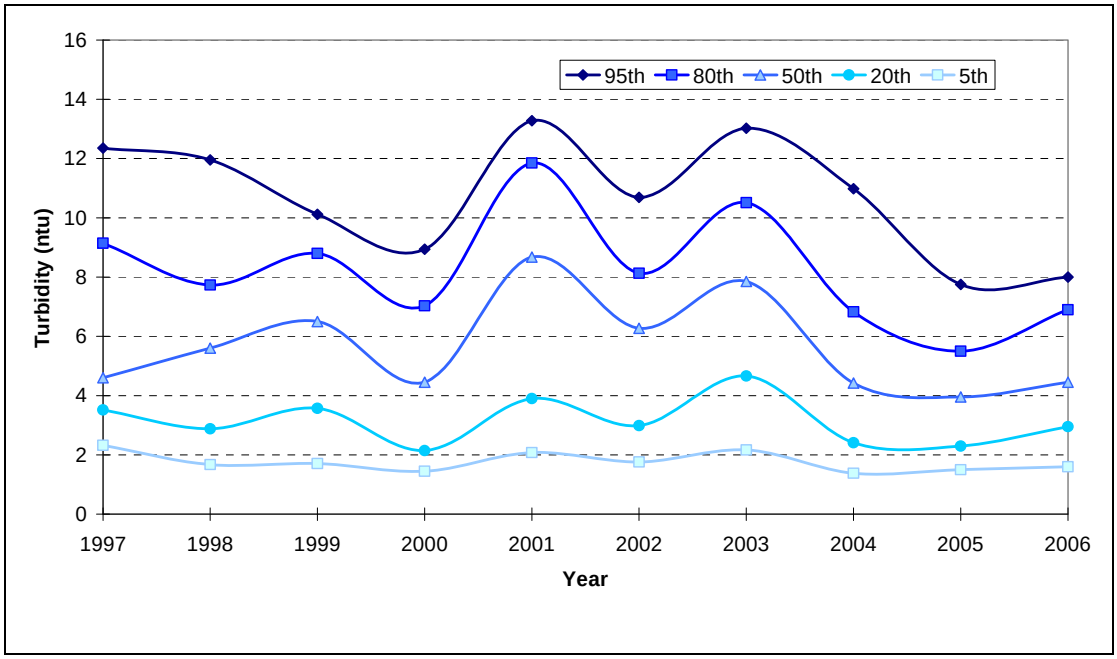

Figure 33: Percentiles based on annual median turbidity (ntu) for all RWQMN sites.

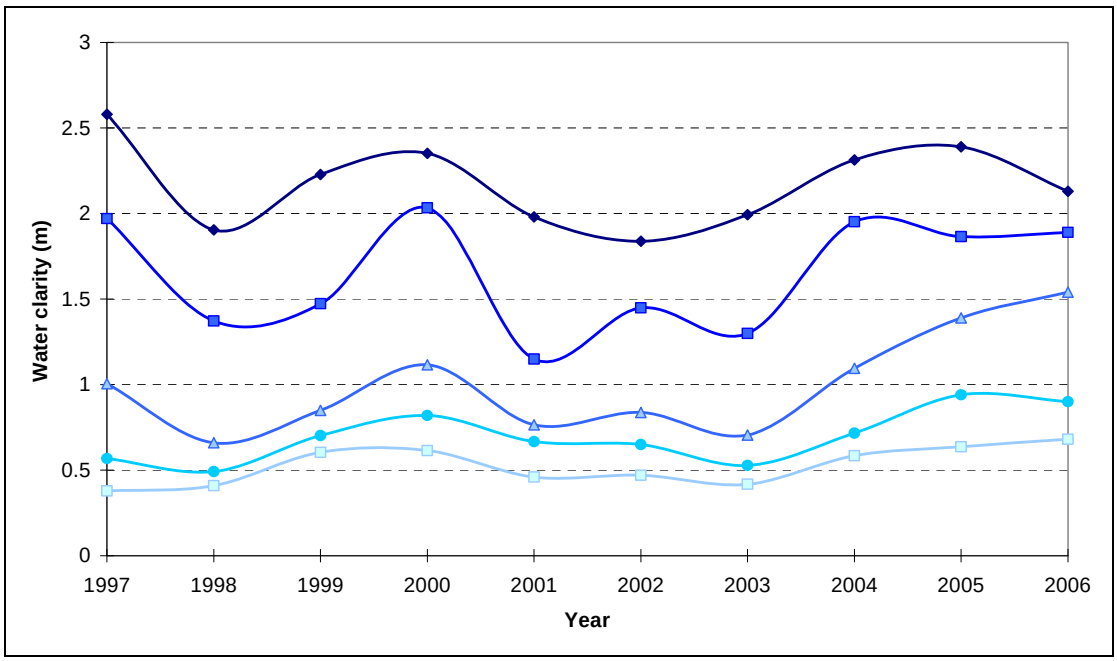

Figure 34: Percentiles based on annual median water clarity (m) for all RWQMN sites.

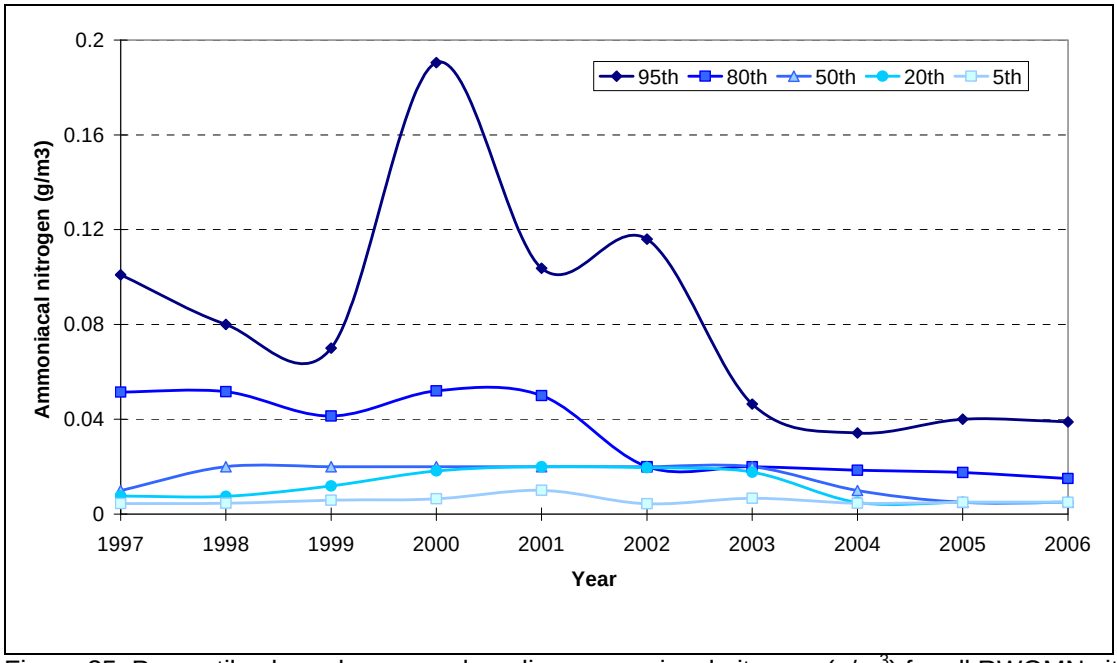

Figure 35: Percentiles based on annual median ammoniacal nitrogen (g/m^3) for all RWQMN sites.

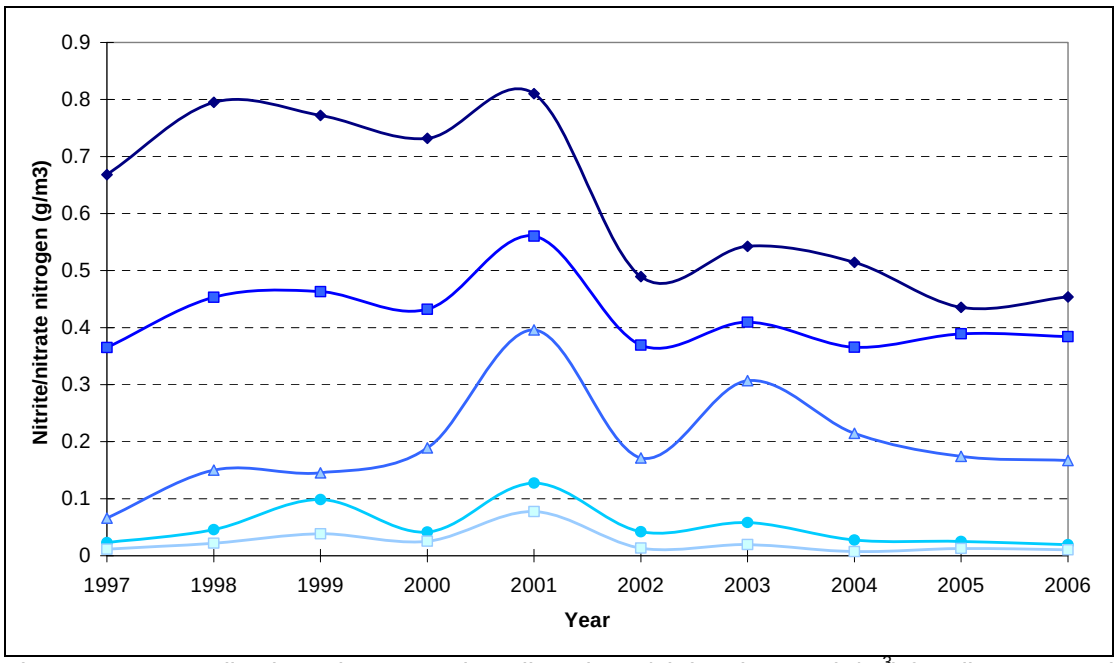

Figure 36: Percentiles based on annual median nitrate/nitrite nitrogen (g/m^3) for all RWQMN sites.

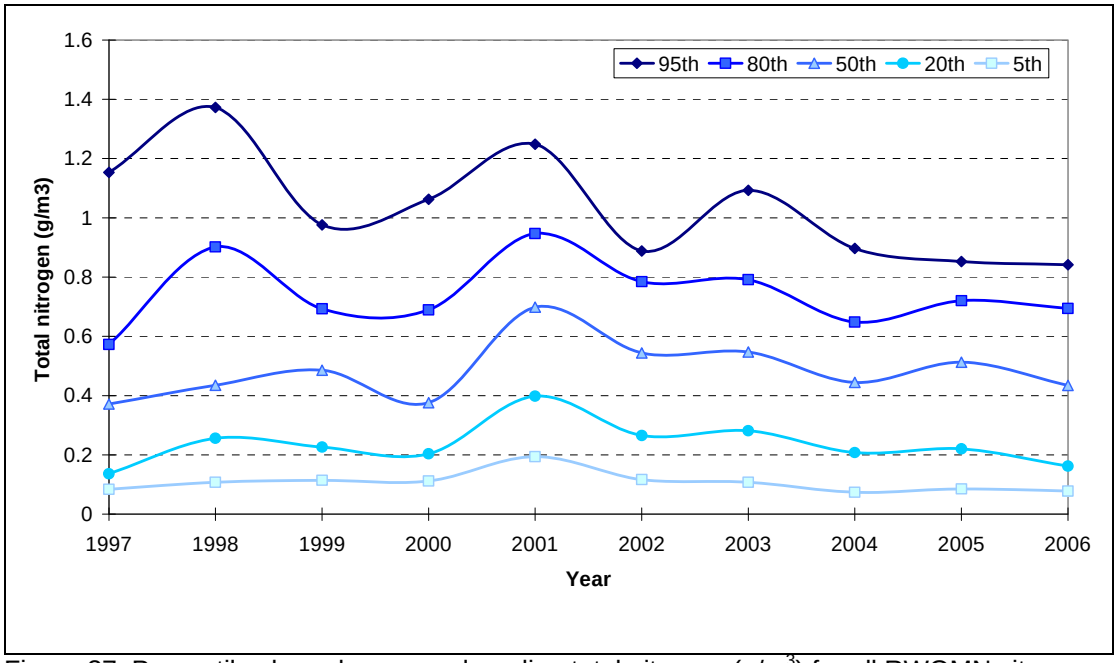

Figure 37: Percentiles based on annual median total nitrogen (g/m^3) for all RWQMN sites.

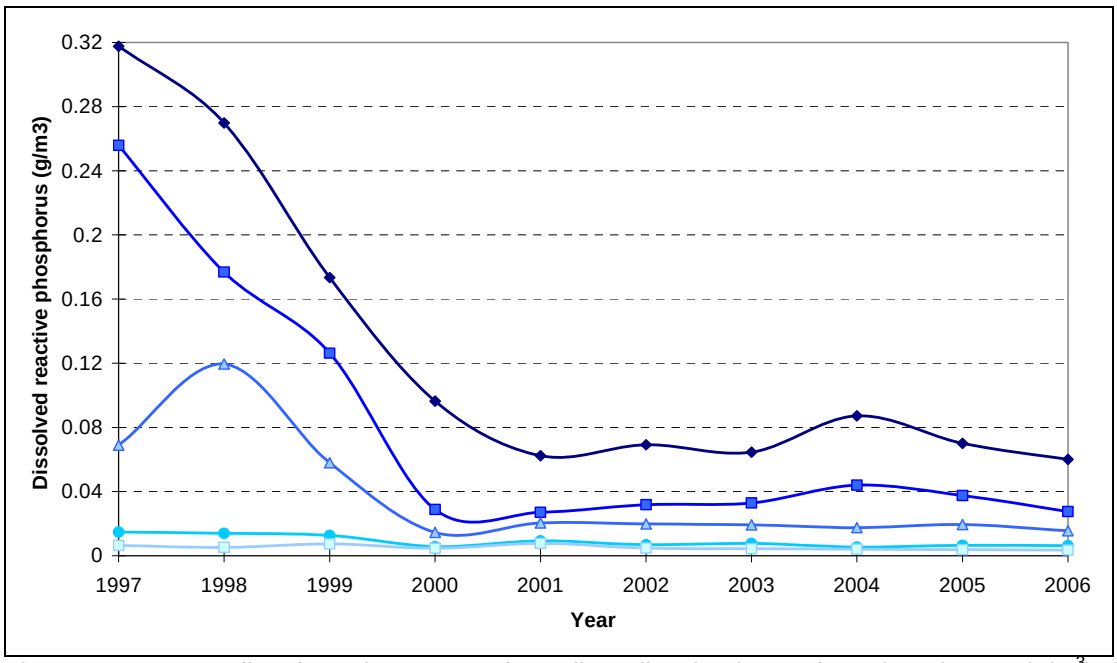

Figure 38: Percentiles based on annual median dissolved reactive phosphorus (g/m^3) for all RWQMN sites.

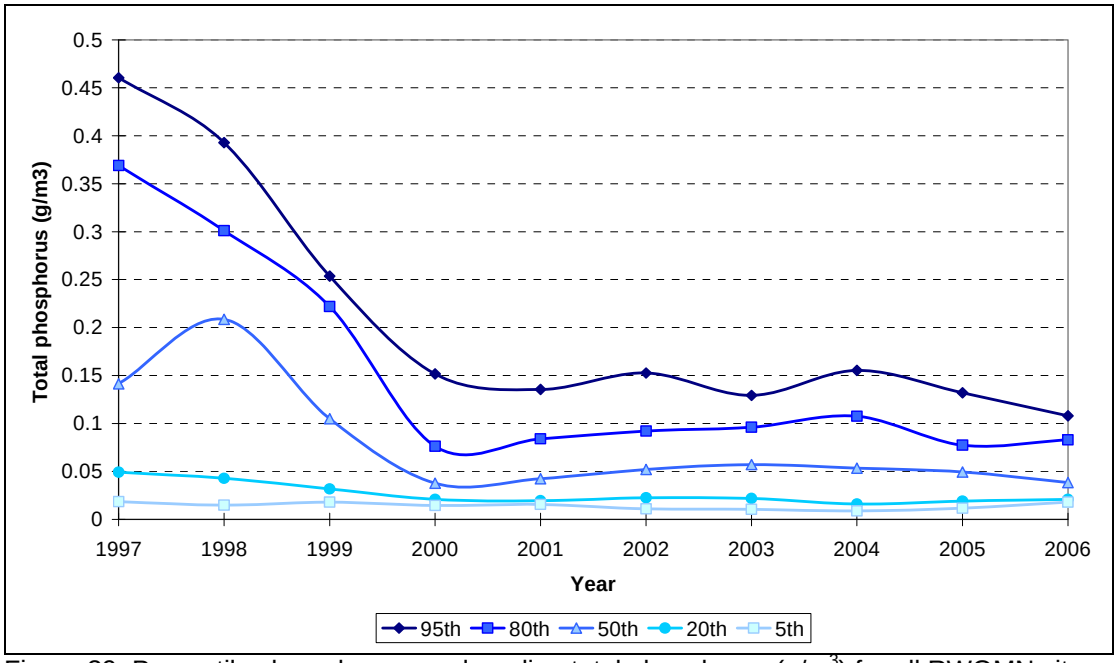

Figure 39: Percentiles based on annual median total phosphorus (g/m^3) for all RWQMN sites.

4.2 Formal trend analysis

All trends are based on flow adjusted data except for Waipoua River at SH12, as there is not yet any flow data available for this river. A flow recorder will be installed at this site in 2007.

WQstat plus ™ only reports *p*-values into four categories as follows:

- less than or equal to 5% (≤5)
- greater than 5% but less than or equal to 10% (≤10)
- greater than 10% but less than or equal to 20% (≤20)
- greater than 20%

How the *p*-value results are shown in table 4 (below) is above in brackets. Anything without a *p*-value in table 4 has a *p*-value greater then 20%. For this analysis any trends with a *p*-value of 5% or less are significant.

It should be noted that the number of samples for each site and parameter varies because sampling was started in different years for each site and there are some missing results. The trend analysis was done on data from January 1997 to December 2006 for all sites where this data was available (including the national network sites). However for sites that were added to the network later than January 1997, the trend analysis included data from when sampling began for these sites (see table 1). Table 10 in appendix D shows the number of samples for each of the trends in table 4.

Table 4: Trend slopes for water quality parameters for 18 RWQMN sites with *p*-values (%) shown in brackets, including the 4 sites in the National network from January 1997 to December 2007 or when records began (see table 1).

	Temperature (10^{-3} °C/yr)	Dissolved oxygen (10^{-3} % saturation/yr)	Dissolved oxygen (10^{-3} mgL^{-1}/yr)	Conductivity (10^{-3} mS/m@25°C/yr)	pH (10^{-3} /yr)	Turbidity (10^{-3} NTU/yr)	Visual clarity (10^{-3} m/yr)	Dissolved colour (10^{-3} G-abs@340nm/ cm/yr)	Dissolved colour (10^{-3} G-abs@440nm/ cm/yr)	*Escherichia coli* (CFU/100mL/yr)
Victoria	**-168 (≤5)**	290 (≤20)	50 (≤20)	17	10	-54 (≤10)	**-110 (≤5)**	45	8	-6
Awanui (FNDC take)	-398 (≤20)	-310	24	70	**-37 (≤5)**	-116	NA	336 (≤10)	-21	5
Awanui (Waihue)	**-169 (≤5)**	140	10	**129 (≤5)**	7	**-376 (≤5)**	18	231 (≤10)	**148 (≤5)**	19 (≤20)
Waitangi (Waimate)	-239 (≤20)	550 (≤10)	**124 (≤5)**	-5	**76 (≤5)**	-28	-12	149 (≤20)	49 (≤20)	25 (≤20)
Waitangi(Watea)	-154 (≤10)	-73	18	**-46 (≤5)**	5	2	-14	59	17	NA
Waipapa	-13	53	4	26 (≤20)	**16 (≤5)**	**-104 (≤5)**	**46 (≤5)**	-34	-7	NA
Punakitere	-253	-255	59	-39	39	-134	NA	788	172	17
Waiotu	-113	770 (≤10)	**129 (≤5)**	-19	**84 (≤5)**	-45	NA	179	16	-1
Whakapara	-43	**1060 (≤5)**	**180 (≤5)**	-26	**44 (≤5)**	-159 (≤20)	**48 (≤5)**	**310 (≤5)**	**70 (≤5)**	-3
Mangahahuru	-81 (≤10)	**1520 (≤5)**	**225 (≤5)**	**170 (≤5)**	**27 (≤5)**	**-300 (≤5)**	**69 (≤5)**	390 (≤10)	49	-9
Wairua	-42	**511 (≤5)**	**71 (≤5)**	-20	**22 (≤5)**	-89	4	158	13	NA
Mangakahia (Twin)	-117 (≤20)	56	NA	**123 (≤5)**	23 (≤10)	-81	-9	25	50	2
Mangakahia (Titoki)	15	63	5	-24	**9 (≤5)**	93	-11 (≤10)	77	6	NA
Opouteke	-92	**202 (≤5)**	NA	121 (≤10)	**32 (≤5)**	-50	-2	59	46	5 (≤20)
Mangere	-153 (≤10)	**741 (≤5)**	94	8	**50 (≤5)**	**-192 (≤5)**	**44 (≤5)**	229 (≤20)	109 (≤10)	**118 (≤5)**
Manganui	-21	357	12	230	53	-436	NA	245	-5	401
Kaihu	-49	295	-91	NA	-23	-571 (≤10)	NA	NA	NA	-3
Waipoua	-17	-1053	-182	NA	0	-150	NA	NA	NA	-9

Note: Apart from Waipoua River all parameters were flow adjusted. Trends shown in bold are significant ($p \leq 5\%$).

Table 4 cont: Trend slopes for water quality parameters for 18 RWQMN sites with *p*-values (%) shown in brackets, including the 4 sites in the National network from January 1997 to December 2007 or when records began (see table 1).

	Dissolved reactive phosphorus (10^{-3} gm^{-3}/yr)	Total Phosphorus (10^{-3} gm^{-3}/yr)	Nitrate/nitrite nitrogen or nitrate (10^{-3} gm^{-3}/yr)	Total nitrogen (10^{-3} gm^{-3}/yr)	Ammoniacal nitrogen (10^{-3} gm^{-3}/yr)	Total Kjedahl Nitrogen (10^{-3} gm^{-3}/yr)
Victoria	**-3.7 (≤5)**	**-5.0 (≤5)**	**-0.7 (≤5)**	-1.0	**-0.7 (≤5)**	NA
Awanui (FNDC take)	-0.2	-0.3	-1.1	3.2	**-4.5 (≤5)**	4.5
Awanui (Waihue)	**-16 (≤5)**	**-27 (≤5)**	0.3	6.0	**-0.7 (≤5)**	3.1
Waitangi (Waimate)	-0.3	**1.6 (≤5)**	**-13 (≤5)**	-0.2	**-1.9 (≤5)**	**15 (≤5)**
Waitangi(Watea)	**-0.2 (≤5)**	0.3	-0.2	2.4	0.0	**-5.0 (≤5)**
Waipapa	**-0.2 (≤5)**	-0.1	**-1.4 (≤5)**	-0.2	**-0.3 (≤5)**	1.7 (≤20)
Punakitere	-0.2	3.4 (≤20)	-10	-23	-1.5	-0.9
Waiotu	0.2	1.9	**-12 (≤5)**	-31 (≤20)	**-2.5 (≤5)**	-13.5
Whakapara	**-3.0 (≤5)**	**-5.0 (≤5)**	**-9.5 (≤5)**	-3.2	-0.4	6.4 (≤10)
Mangahahuru	**-5.0 (≤5)**	**-8.5 (≤5)**	-0.2	3.6	**-3.6 (≤5)**	2.4
Wairua	-0.8 (≤10)	**1.0 (≤5)**	-16 (≤20)	**-15 (≤5)**	**-1.1 (≤5)**	1.8
Mangakahia (Twin)	-0.9	-4.8 (≤20)	-0.4	-4.5	-0.2 (≤20)	0.9
Mangakahia (Titoki)	**-0.2 (≤5)**	0.0	**-4.7 (≤5)**	-5.5 (≤10)	**-0.5 (≤5)**	2.8 (≤10)
Opouteke	**-4.8 (≤5)**	**-13 (≤5)**	-1.8 (≤10)	0.1	-0.2 (≤20)	3.5
Mangere	**-5.8 (≤5)**	**-11 (≤5)**	**-47 (≤5)**	**-47 (≤5)**	**-4.7 (≤5)**	-3.5
Manganui	**3.8 (≤5)**	1.3	**-9.5 (≤5)**	**-45 (≤5)**	**-4.7 (≤5)**	-7
Kaihu	0.0	3.1	-23	-44 (≤10)	**-3.5 (≤5)**	**-25 (≤5)**
Waipoua	**2.0 (≤5)**	**2.0 (≤5)**	-0.5	**-6.0 (≤5)**	**-2.5 (≤5)**	NA

Note: Apart from Waipoua River all parameters were flow adjusted. Trends shown in bold are significant (*p* <5%).

4.3 Maps showing trends

The results from the formal trend analysis have been summarised into the maps below (Figures 40 to 53) in the following way:

- Insufficient data for this particular parameter at this site
- No significant change ($P > 0.05$)
- Significant increase or decrease ($P \leq 0.05$)
- Meaningful increase or decrease ($P \leq 0.05$) and the magnitude of the trend is greater than 1% per annum of the raw data medium (see table 11 in appendix E)

4.3.1 Temperature

There were only two significant trends for temperature, of which both were a meaningful decreasing trend. They were both located in the Victoria/Awanui River catchment in the Far North. The reason for this decrease is unknown at this stage but it is seen as an improvement.

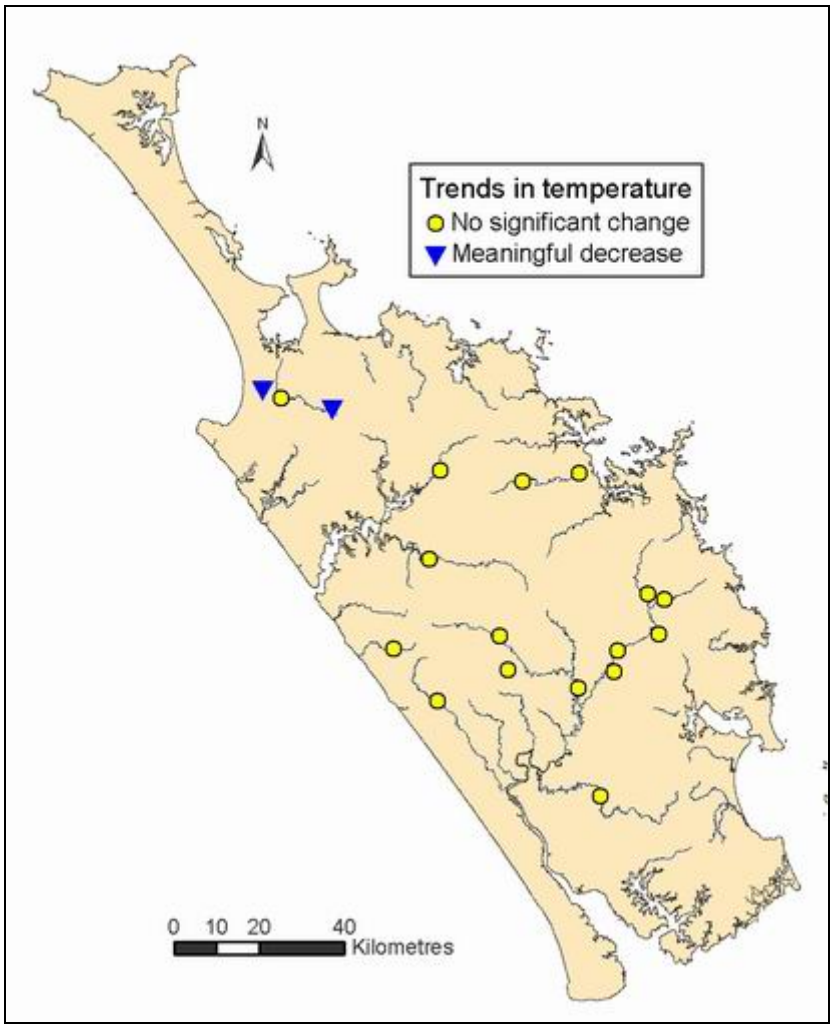

Figure 40: Trends in temperature (°C) at 18 RWQMN sites

4.3.2 Dissolved oxygen

There were five sites with significant trends for dissolved oxygen, all of which were increases in dissolved oxygen levels. Of these five sites, Mangahahuru Stream at Apotu Road and Whakapara River had meaningful increases in dissolved oxygen. It is likely that these are deteriorating trends, based on the results from the investigation into diurnal patterns in dissolved oxygen results (discussed in section 3.2 above).

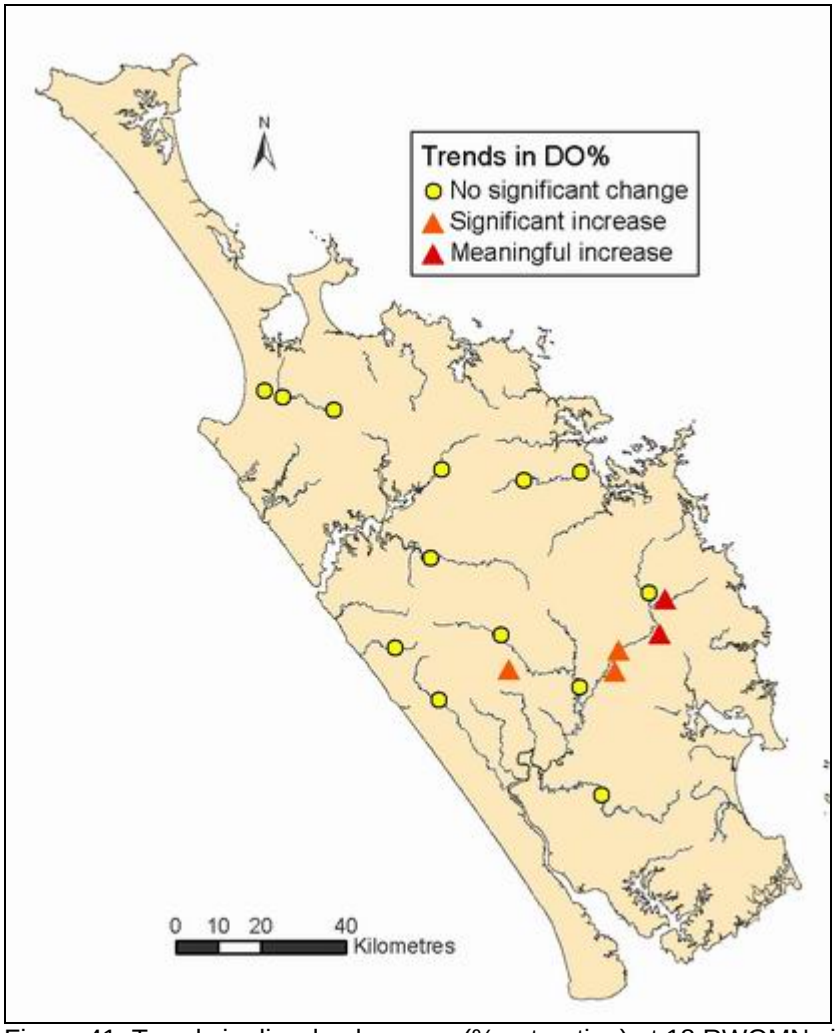

Figure 41: Trends in dissolved oxygen (% saturation) at 18 RWQMN sites

4.3.3 Conductivity

Four sites showed significant changes in conductivity, of which three were of a magnitude to be meaningful. The following sites showed a meaningful increasing trend in conductivity; Awanui at Waihue Channel, Mangakahia at Twin Bridges and Mangahahuru Stream at Apotu Road. This is likely to be deterioration in water quality at these sites.

Waitangi at Watea showed a significant decreasing trend in conductivity but the trend is not meaningful, at only 0.4% of the median conductivity for this site.

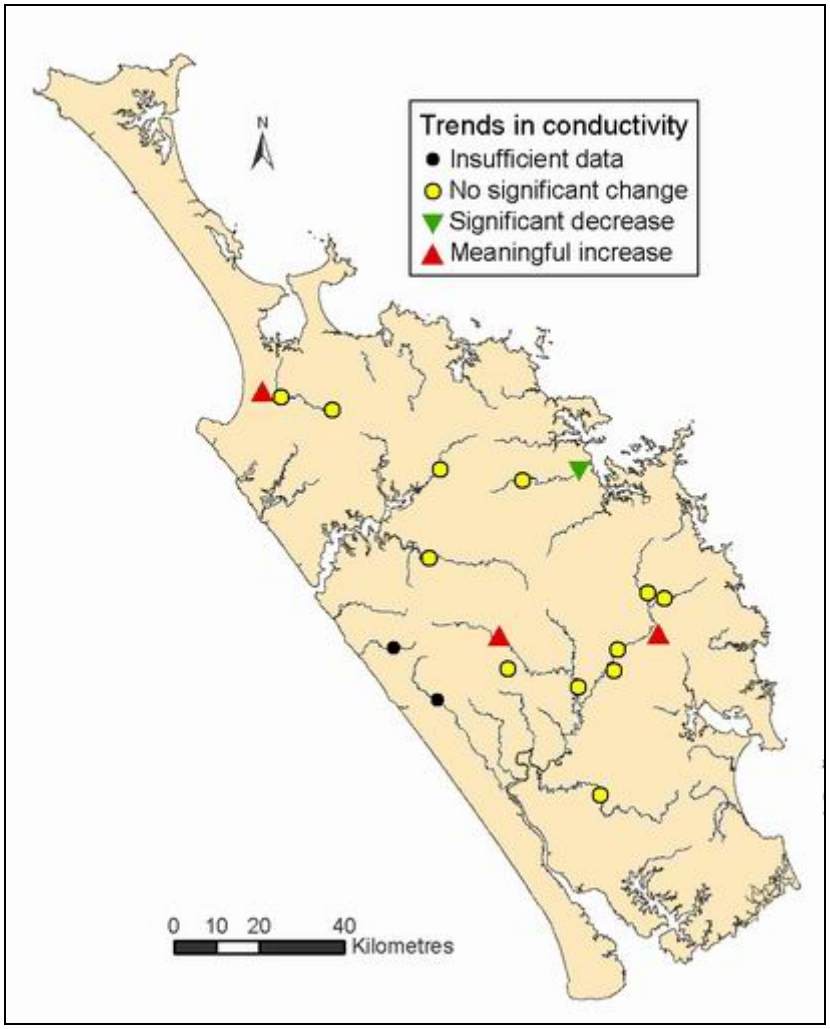

Figure 42: Trends in conductivity (mSm) at 18 RWQMN sites

4.3.4 pH

One site, Awanui River at the FNDC water take, shows a significant decreasing trend in pH (i.e. becoming more acidic), but not meaningful. Nine sites show significant increasing trends in pH (i.e. becoming more alkaline), of which two are meaningful trends for the Waitangi River at Waimate and Waiotu River sites. These sites both had an increasing pH of 0.08 per year. While this may seem small, it is important to highlight that pH varies with the base-10 logarithm of the hydrogen ion concentration. For example an increase in pH of 0.08 is equivalent to an increase in the hydrogen ion concentration by a factor of 1.2 mol/L per year.

As the median pH for both of these sites is almost neutral at 6.9, these increasing trends can be regarded as a deterioration. The cause of this increasing pH is unknown and is not consistent with elsewhere in New Zealand. Other NZ studies have typically found decreasing trends in pH (Scarsbrook et al 2003, Vant and Smith 2004, Scarsbrook 2006).

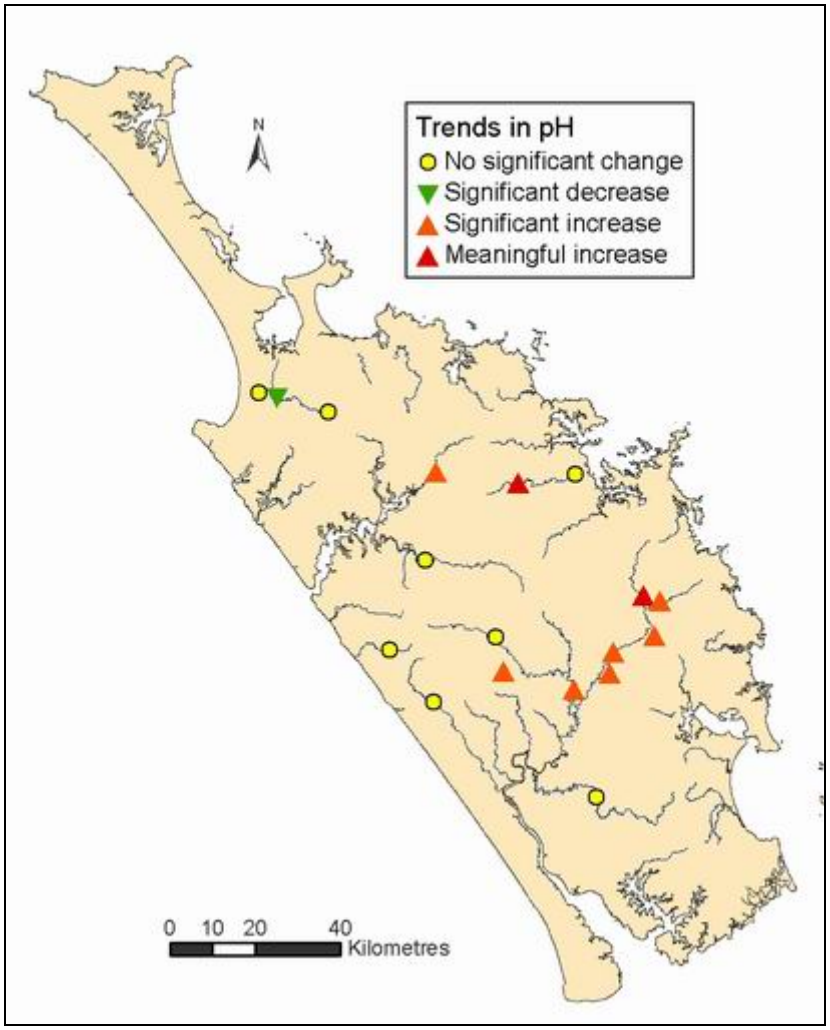

Figure 43: Trends in pH at 18 RWQMN sites

4.3.5 Turbidity

Four of the 18 sites show a significant and meaningful decreasing trend in turbidity; Awanui at Waihue Channel, Waipapa at Puketi forest, Mangahahuru Stream at Apotu Road and Mangere Stream at Knight Road.

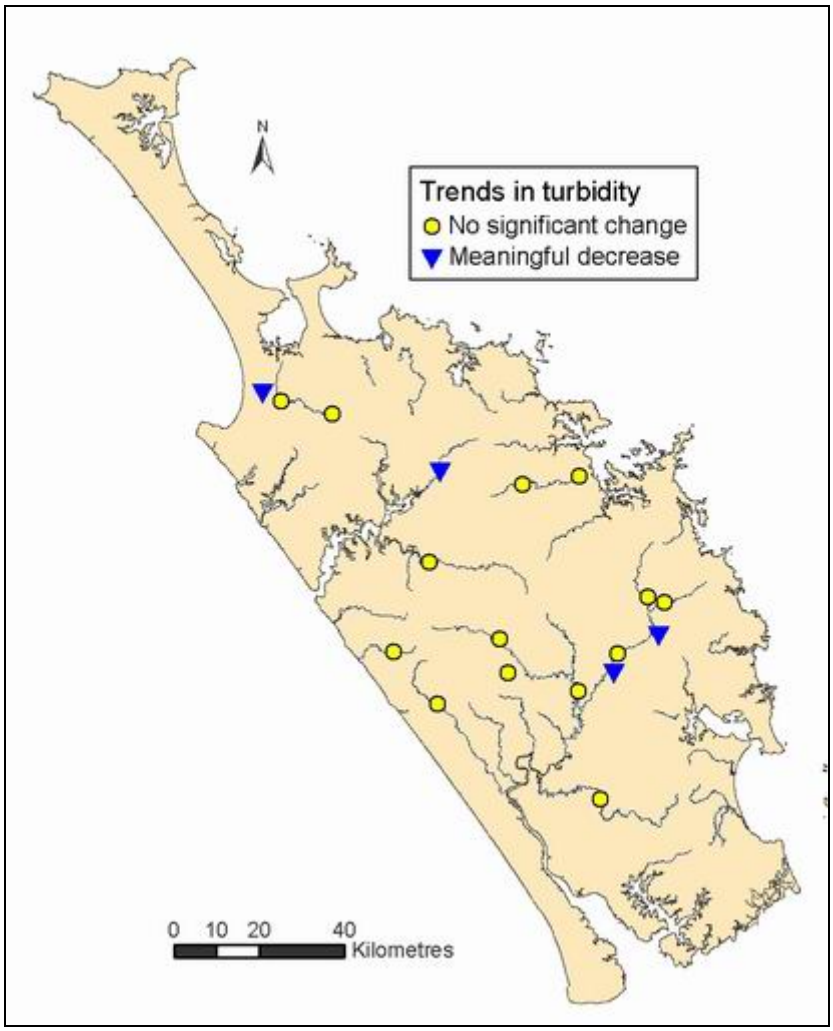

Figure 44: Trends in turbidity (ntu) at 18 RWQMN sites

4.3.6 Water clarity

Water clarity exhibited meaningful trends at five of the 18 sites. Only one site was decreasing, Victoria River, and the rest were increasing clarity; Waipapa at Puketi Forest, Whakapara River, Mangahahuru Stream and Mangere Stream.

Three of the above trends correspond with decreasing trends in turbidity. However, this is not the case for Victoria and Whakapara River sites. It is possible that the loss in water clarity at the Victoria River site is related to changes in sampling officer. This will be investigated further.

These results for the last 10 years of data (1997 to 2006) contradict the results of an analysis of 17 years data from 1989 to 2005 by Scarsbrook (2006). Scarsbrook detected decreasing trends in water clarity at the four Northland sites in the national network, while in this regional analysis three showed no significant trend and one in fact shows an increasing trend (Waipapa). This highlights the importance of taking into account the length of the dataset.

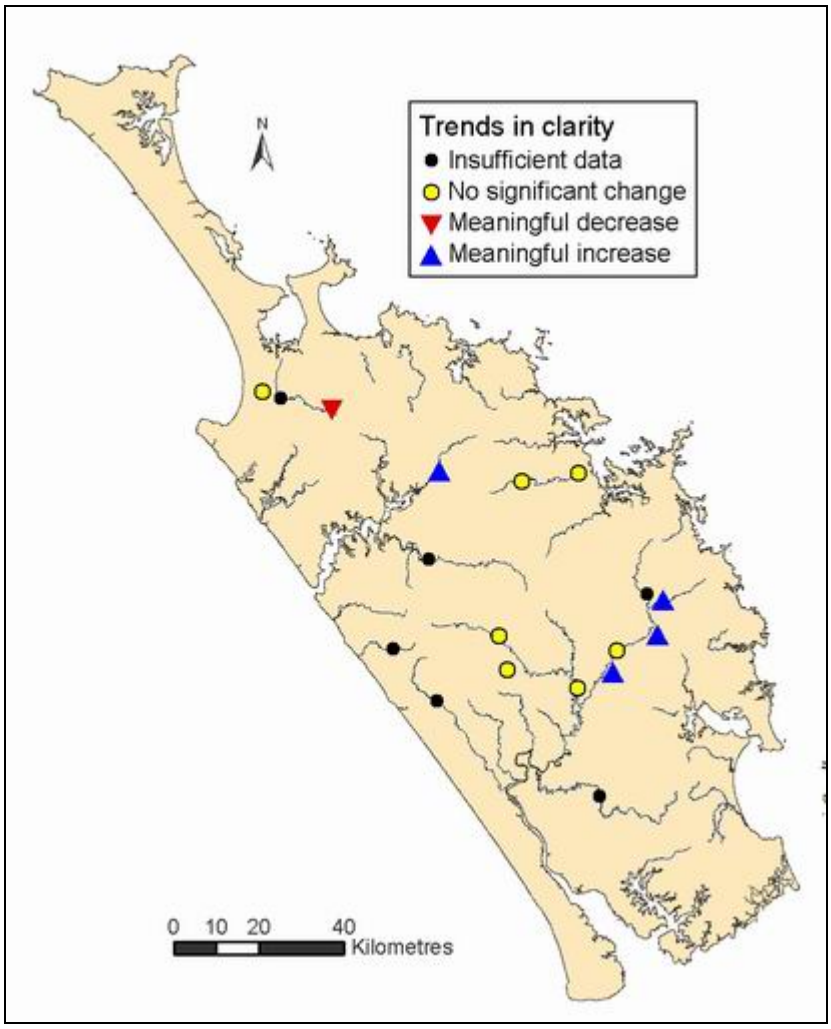

Figure 45: Trends in clarity (m) at 18 RWQMN sites

4.3.7 Dissolved colour

The only river to have a significant change in dissolved colour is Whakapara River and this was a meaningful increase. This is surprising considering that water clarity has improved at this site.

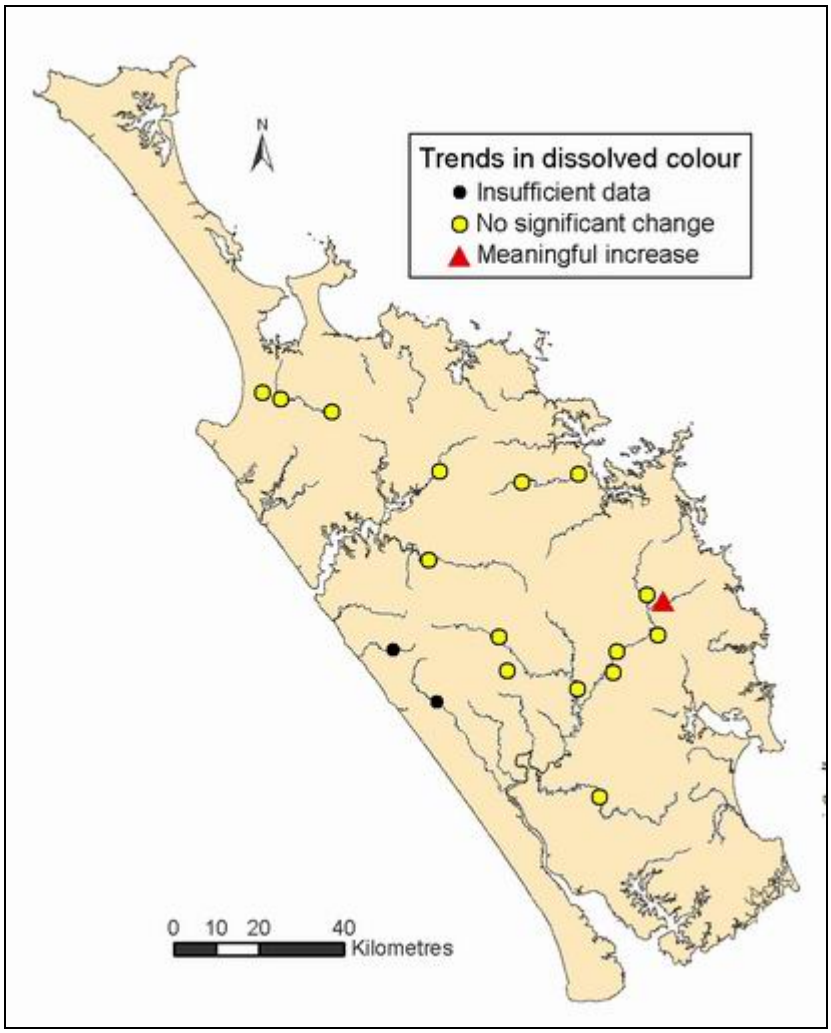

Figure 46: Trends in dissolved colour (340 nm) at 18 RWQMN sites

4.3.8 Escherichia coli (Bacteria)

E. coli analysis only started for the four NWQMN sites in 2005, so they do not have sufficient data yet to carry out trend analysis.

Of the other 14 sites, only Mangere stream shows a significant change in E. coli levels, with a meaningful increase of 118 MPN/100ml/year from 2000 to 2006. This is a large increase, at 21% of the site median. The cause of this increase is unknown at this stage but will be investigated further.

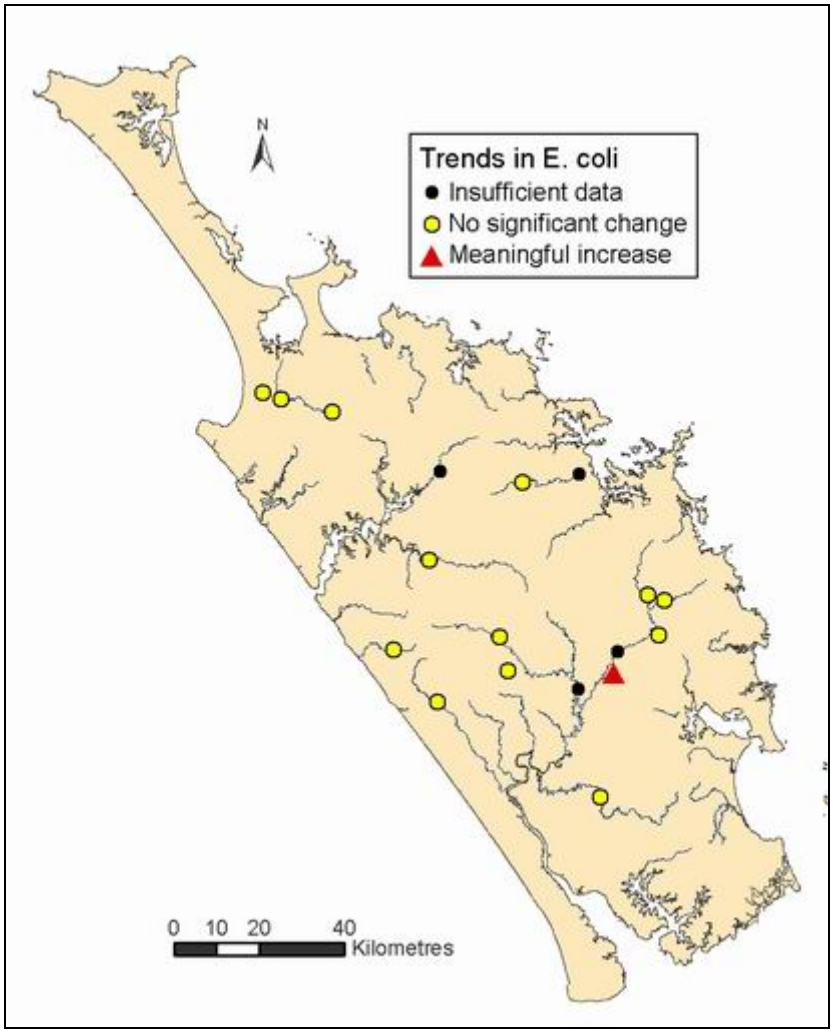

Figure 47: Trends in E. coli (MPN/100ml) at 18 RWQMN sites

4.3.9 Ammoniacal nitrogen

Thirteen sites showed meaningful decreases in ammoniacal nitrogen. However care should be taken interpreting these results as there has been two changes in detection limits for ammoniacal nitrogen (July 1999 and July 2003) and for many sites ammoniacal nitrogen is frequently below detection.

Of these 13 sites with decreasing trends only four have less than 15% (recommended in IDT 1998) of their ammoniacal nitrogen results above detection: Waipapa at Puketi Forest, Wairua at Purua, Mangakahia at Titoki and Mangere Stream, and therefore the decreasing trend detected is valid. However the other nine sites have more than 15% of their samples below detection and therefore the decreasing trend is probably as a result of the changes in detection limit rather than an actual decrease in ammoniacal nitrogen levels. The two exceptions to this are Awanui above Waihue Channel and Mangahahuru Stream at Apotu. The greatest proportion of the below detections for these two sites have occurred since 2003, so it is possible that there has been an actual decrease in ammoniacal nitrogen.

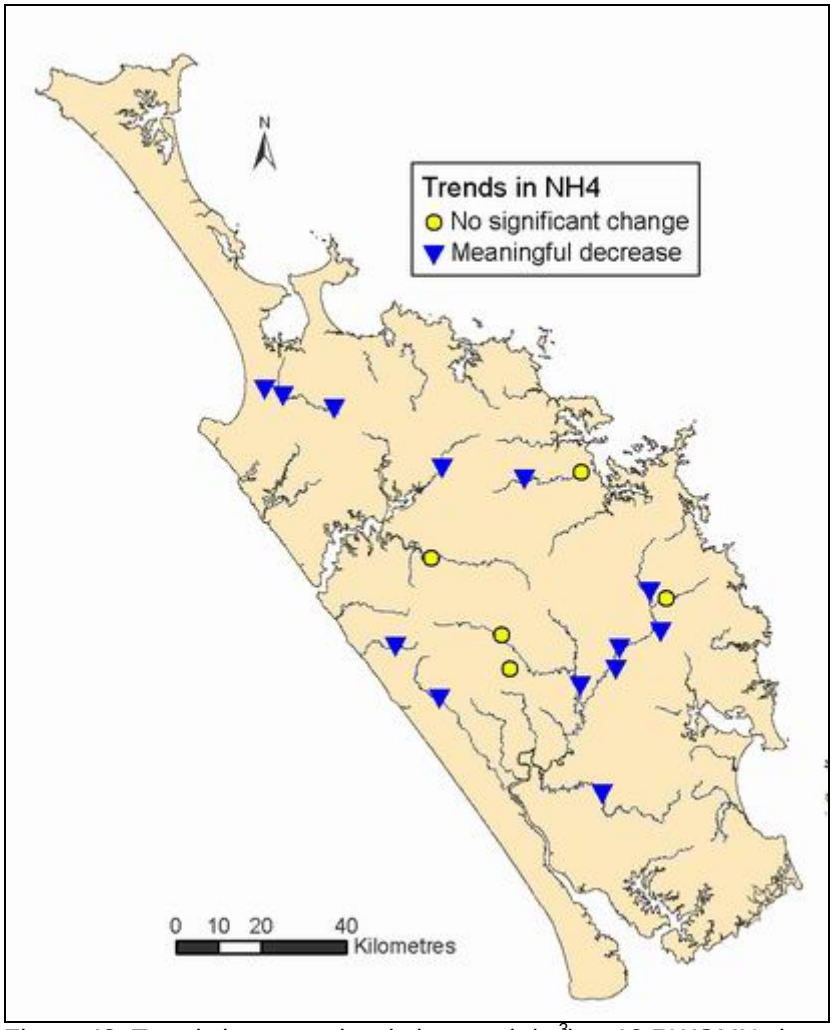

Figure 48: Trends in ammoniacal nitrogen (g/m^3) at 18 RWQMN sites

4.3.10 Nitrate/nitrite nitrogen

All sites are nitrate/nitrite nitrogen (NNN or NO_x), except the four national network sites, which are just nitrate (NO_3).

Eight sites spread throughout Northland showed a meaningful decrease in nitrate/nitrite nitrogen (NNN) levels. Similarly to the trend for ammoniacal nitrogen, the decreasing trend for NNN detected at Victoria River is likely to be an artefact of too many samples below detection limit and a change in detection limits, rather than an actual decreasing trend in NNN. However the trends at the other seven sites are valid, which again includes Mangere Stream, the site ranked as having the worst water quality of all the RWQMN sites (table 9 in appendix C).

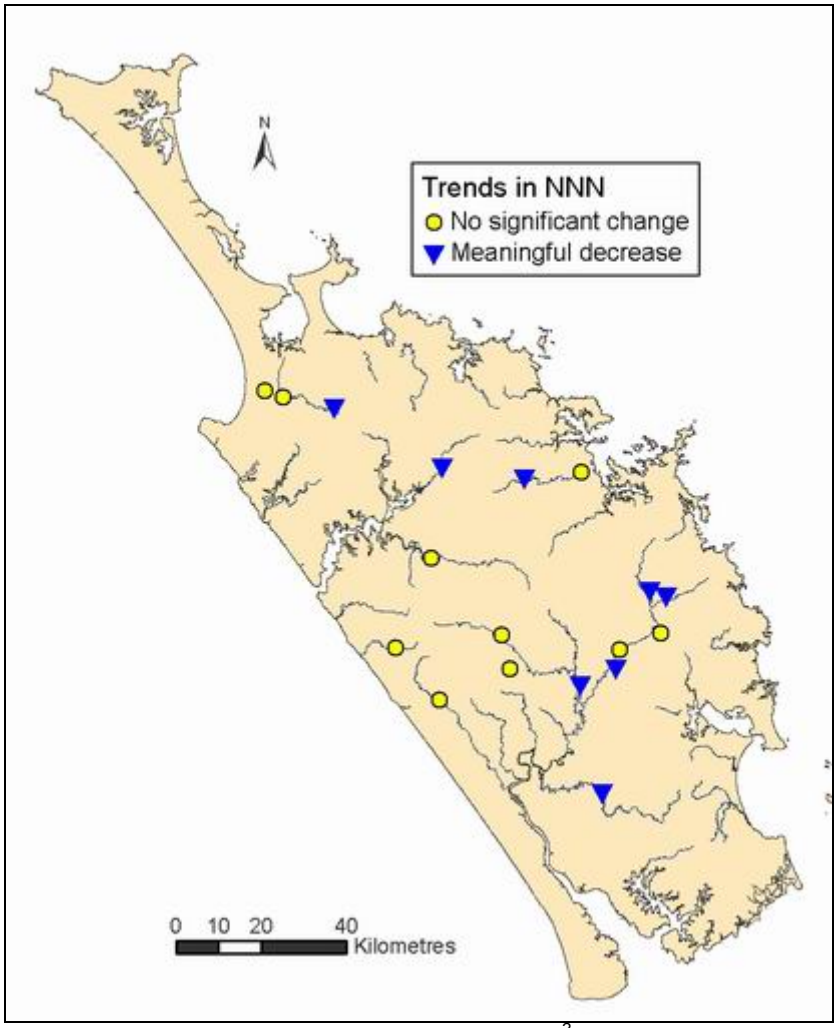

Figure 49: Trends in nitrate/nitrite nitrogen (g/m^3) at 18 RWQMN sites

4.3.11 Total Kjedahl nitrogen

The total kjedahl nitrogen (TKN) results presented below for the four NRWQN sites have been calculated by subtracting the concentration of nitrate from the concentration of total nitrogen (i.e. TN – NO_3 = TKN).

TKN exhibited meaningful decreasing trends at two sites (Waitangi at Watea and Kaihu) and meaningful increasing trend at one site (Waitangi at Waimate). It is interesting that two sites on the same catchment are showing opposite trends.

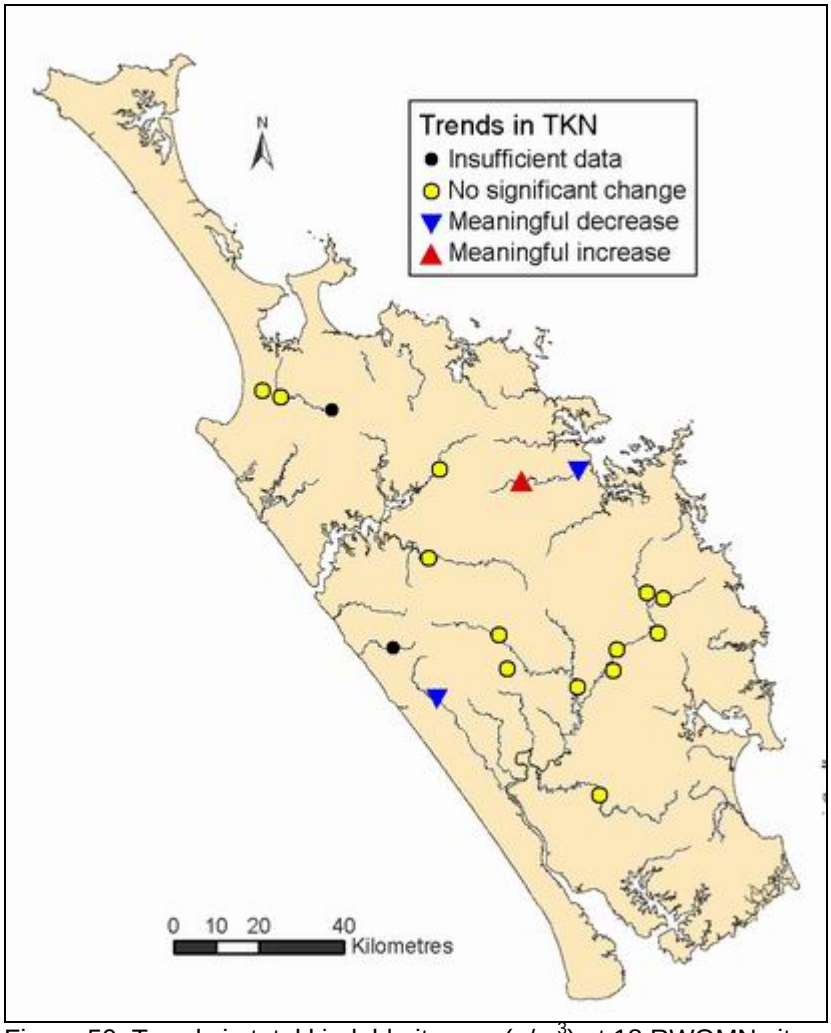

Figure 50: Trends in total kjedahl nitrogen (g/m^3) at 18 RWQMN sites

4.3.12 Total nitrogen

Four sites showed meaningful decreasing trends in total nitrogen. These were Waipoua, Manganui, Mangere and Wairua at Purua. Other than Waipoua River, these sites also have corresponding decreasing trends for either NNN, TKN or NH_4.

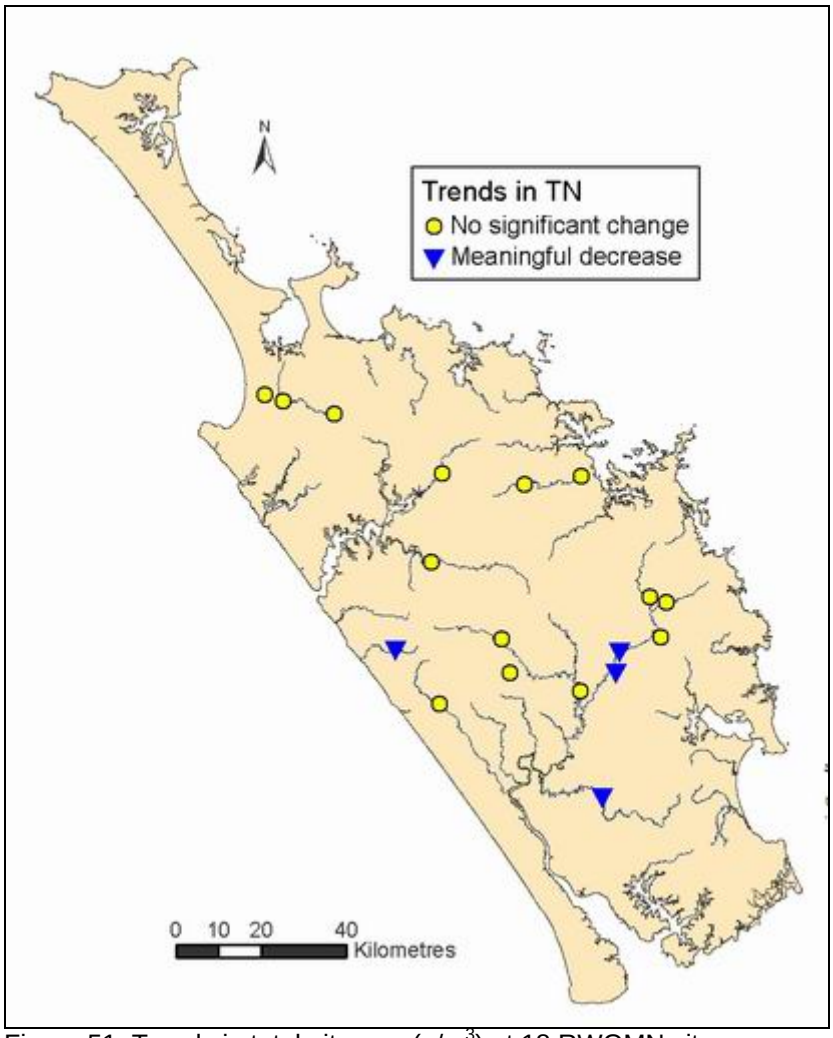

Figure 51: Trends in total nitrogen (g/m^3) at 18 RWQMN sites

4.3.13 Dissolved reactive phosphorus

Nine of the 18 sites showed meaningful decreasing trends in dissolved reactive phosphorus (DRP), one of which was Mangere Stream, while two sites showed meaningful increasing trends (Waipoua and Manganui Rivers). These increasing trends are a concern, particularly for Waipoua River at 0.002g/m^3/year, which is 40% of the median DRP.

With over 90% of the Waipoua River catchment being native forest, thus indicates DRP is likely to be natural as a result of catchment geology. This is consistent with findings at Whatawhata in Waikato region where high DRP concentrations from native forest streams indicate an unusual geological source that is masking any land-use influence (Quinn and Stroud 2002). However it is unknown why the DRP levels have increased in Waipoua River over the last five years. The trend could be influenced by the fact that there is no historical flow data for this site to be able to flow adjust the water quality data. However this will no longer be an influencing factor as a water level recorder station was installed at this site in 2007. This trend will be re-assessed every year and investigated if it persists.

The results for the 10 years of regional data from 1997 to 2006 contradict the trends reported nationally by Scarsbrook (2006) for 1989 to 2005 for the four Northland sites in the NRWQN. The 17 years of national data showed all four Northland sites as having meaningful increasing trends. In contrast the regional data for 1997 to 2006 for the same four sites showed three had decreasing trends and the other had no change.

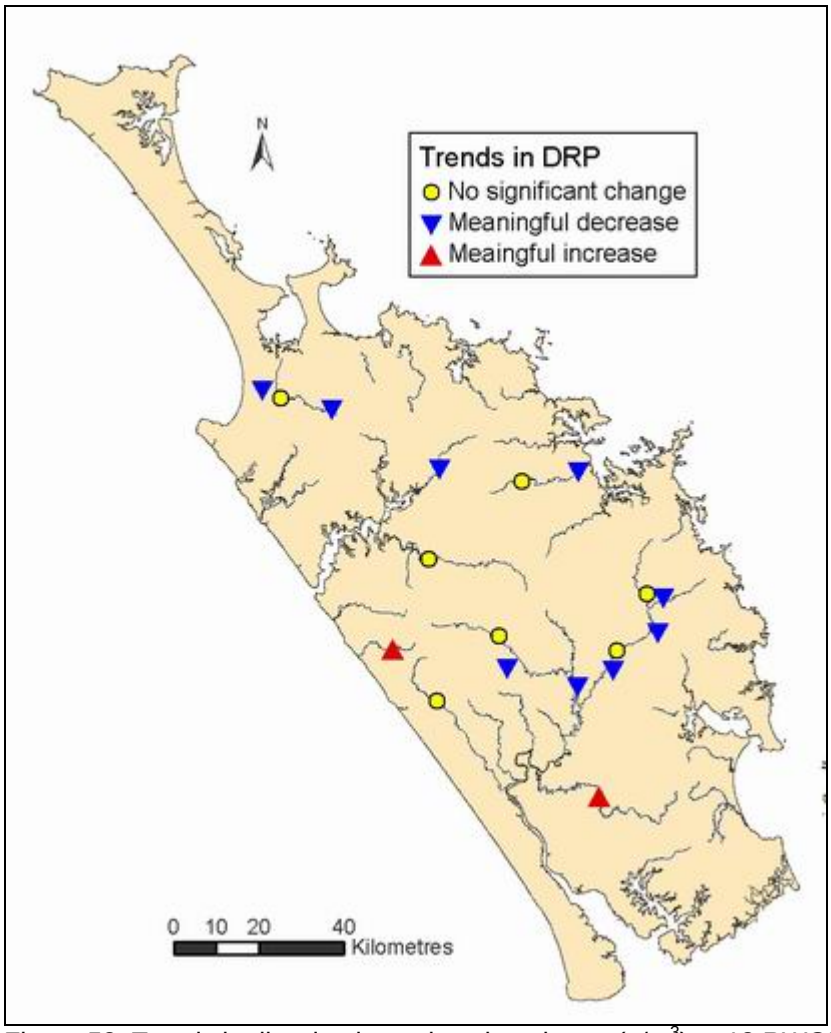

Figure 52: Trends in dissolved reactive phosphorus (g/m^3) at 18 RWQMN sites

4.3.14 Total phosphorus

Total phosphorus exhibited meaningful decreases at six sites, one of which was Mangere Stream and meaningful increases at three sites. Similarly to DRP, total phosphorus also shows an increasing trend for Waipoua River at 0.002g/m^3 per year, which is 25% of the median for this site.

Similarly to DRP, the total phosphorus trend results for the last 10 years (1997 to 2006) contradict the results for 1989 to 2005 for three of the four NRWQN sites. Scarsbrook (2006) found meaningful increasing trends at these three sites for the 17-year national analysis, while for the 10-year regional analysis only one site showed a meaningful increase and the other two showed no change.

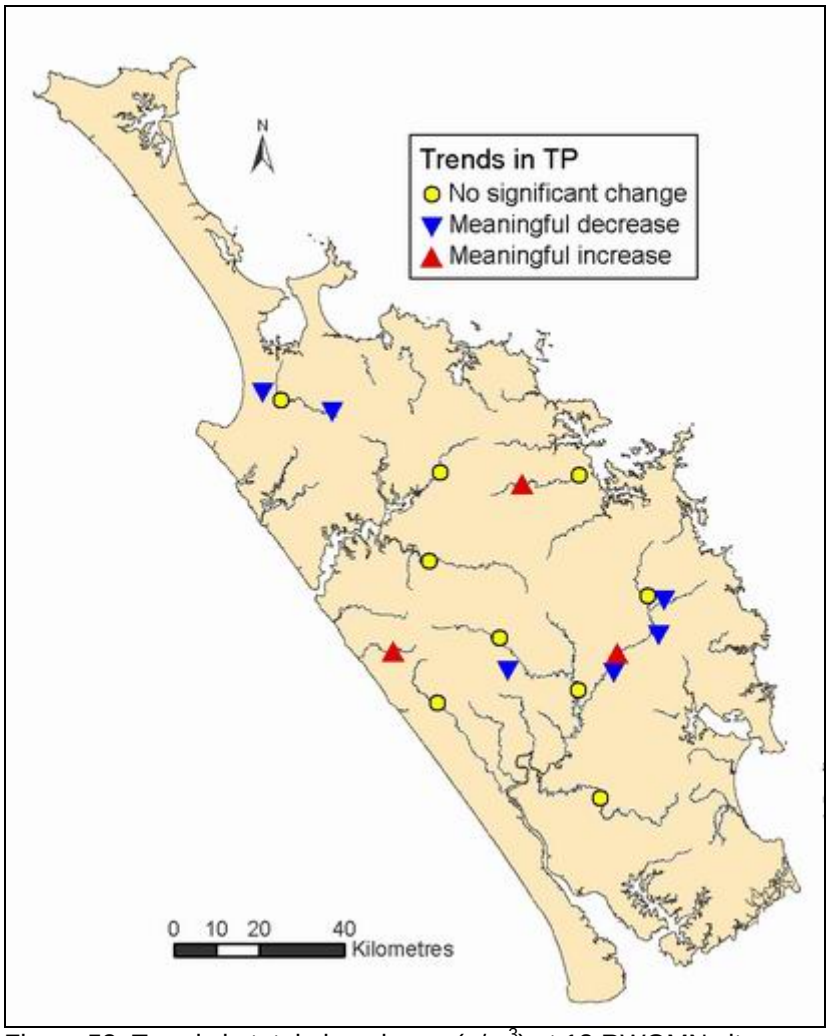

Figure 53: Trends in total phosphorus (g/m^3) at 18 RWQMN sites

5 Discussion

Overall the results show that many of Northland's rivers have poor water quality on occasion and some consistently have poor water quality. Water quality is related to surrounding land use. Sites in catchments dominated by native forest have the best water quality including the Waipoua, Waipapa and Victoria River sites, followed closely by those with catchments dominated by exotic forestry such as Mangahahuru Stream at Main Road. The worst water quality is at sites in intensive pastoral farming and urban environments. The worst being Mangere Stream, followed by Awanui upstream of Waihue Channel, Wairua at Purua and Mangahahuru at Apotu Road. These latter sites typically have low clarity and high nutrient and bacterial levels.

This relationship between water quality and land use is consistent with findings from other regions (Quinn et al. 1997, Quinn and Stroud 2002) and national results (Larned et al. 2004, Larned at al. 2005 and Scarsbrook 2006).

Many sites have dissolved oxygen levels outside the ideal range. This appears to be limited to a few areas of New Zealand. Scarsbrook (2006) in an analysis of data from 77 river sites throughout New Zealand found that sites in Northland, Auckland and on the lower Tarawera River had the lowest dissolved oxygen levels.

As it was noted in previous Annual Environmental Monitoring Reports (NRC 2005 and 2006) that the extreme high and low dissolved oxygen levels were of concern, further investigation was carried out in 2007. This showed large daily fluctuations in dissolved oxygen at unshaded sites with high plant biomass, with significant drops in DO at night while the plants respire. Large diurnal patterns for DO in unshaded streams with high plant biomass is consistent with the findings of Wilcock et al. (2006a and 2006b). This suggests that in some situations riparian fencing and planting will help with dissolved oxygen levels as well as reducing the inputs of faecal pathogens, where riparian vegetation creates enough shade over the stream to reduce photosynthetic respiration.

Overall the majority of sites occasionally had water quality outside the trigger values for the protection of aquatic ecosystems (ANZECC 2000) and exceeding the recreational bathing guidelines (MFE 2002). The exceptions are the relatively pristine sites in native or exotic forest catchments, which are often in compliance, including Waipoua River, Waipapa River in Puketi Forest and Mangahahuru Stream at Main Road. The following sites consistently had water quality outside the guidelines: Mangere Stream, Wairua River at Purua and Mangahahuru at Apotu Road.

Again this is consistent with the rest of New Zealand. Larned et al. (2005) in an analysis of all national and regional river water quality data for New Zealand found that most sites in natural land cover (e.g. native forest or tussock land) were within guideline values except for ammoniacal nitrogen. They found very few urban sites met the water quality guidelines, while over 50% of the pastoral sites failed to meet all the guidelines.

Overall there were several positive changes in water quality detected in the trend analysis for 1996 to 2006. There were decreasing trends for dissolved reactive and total phosphorus, oxides of nitrogen (NNN) and ammoniacal nitrogen at the Mangere Stream site. Several other sites exhibited decreasing trends in several nutrient parameters, including Victoria River, Awanui River above Waihue channel outflow, Waipapa River in Puketi Forest, Whakapara River near SH1, Mangahahuru Stream at Apotu Road, Mangakahia at Titoki and Manganui River.

The decreasing trends in ammoniacal nitrogen at several sites is a good indication of improvements in point source discharges, which is consistent with the national picture (Scarsbrook 2006) and research into the impacts of dairy farming (Wilcock et al. 2006).

There were positive trends in water clarity at three sites that had a corresponding positive trend for turbidity: Waipapa River, Mangahahuru at Apotu Road and Mangere Stream. Similarly to the positive trends for ammoniacal nitrogen, this suggests improvements in point source discharges upstream of these sites.

It is encouraging that overall many of these positive trends were found in the rivers ranked as having the worst water quality (table 9 in appendix C). However some of these rivers also showed negative trends in other parameters.

Overall there were much fewer negative trends detected in water quality. The most noteworthy are the increasing trends in: dissolved oxygen detected at five sites, conductivity at three sites, pH at nine sites, E. coli levels in Mangere Stream and dissolved reactive and total phosphorus in Waipoua River. The large magnitude of the increasing trend in E. coli, DRP and TP is of particular concern. All of these negative trends will be investigated further.

In conclusion, many of Northland's rivers have severely deteriorated water quality, particularly in pastoral farming catchments, while in contrast water quality is best in native forest catchments. These findings are consistent with elsewhere in New Zealand. However many of these degraded Northland Rivers have shown some improvements in water quality in the last 10 years. These improvements are most likely as a result of improvements in point source discharges. As a region the focus now needs to shift to reducing the impacts of diffuse surface runoff on water quality.

6 Acknowledgements

A huge thank you to all NIWA and NRC staff that have contributed to the Northland RWQMN programme over the last ten years, including water quality monitoring, laboratory, hydrology and administrative support staff.

Also thank you to the following organisations/people, who have been instrumental in the completion of this report: NIWA and Graeme Bryers for supplying the National River Water Quality Network data for Northland, Mike Scarsbrook, Graham McBride and Bill Vant for their advice on the statistical analysis and from NRC; Stephanie Kane for assisting with data preparation; Riaan Elliot, Treena Davidson and Stuart Savill for peer reviewing and Lesley Webb for proof reading this report.

7 References

ANZECC (2000). *Australian and New Zealand guidelines for fresh and marine water quality*, Vol 1. The Guidelines. Prepared by Australian and New Zealand Environment and Conservation Council (ANZECC) and Agriculture and Resource Management Council of Australia and New Zealand. Available on the Ministry for the Environment website at the following link:

http://www.mfe.govt.nz/publications/water/anzecc-water-quality-guide-02/index.html

APHA (1998). *Standard methods for the Examination of Water and Wastewater*, 20th edition. American Public Health Association: 1015 15th Street NW, Washington, DC 20005-2605.

Gilbert, R.O. (1987). *Statistical methods for Environmental Pollution Monitoring.* Van Nostrand Reinhold.

IDT. (1998). *WQstat plus user's guide.* Intelligent Decision Technologies Ltd: Longmont.

Larned, S. C., Scarsbrook, M.R., Snelder, T.H., Norton, N.J. and Biggs, B.J.F. (2004). *Water quality in low-elevation streams and rivers of New Zealand: recent state and trends in contrasting land cover classes.* New Zealand Journal of Marine and Freshwater Research, 38, 347-366.

Larned, S. C., Scarsbrook, M.R., Snelder, T.H. and Norton, N.J. (2005). *Nationwide and regional state and trends in river water quality 1996-2002.* Report produced by the National Institute of Water and Atmospheric Research for Ministry for the Environment. Christchurch: New Zealand.

MFE. (2003) *Microbiological Water Quality Guidelines for Marine and Freshwater Recreational Areas.* Published by the Ministry for the Environment, Wellington. Available on Ministry for the Environment's website at the following link:

http://www.mfe.govt.nz/publications/water/microbiological-quality-jun03/

MFE. (1994). Water Quality Guidelines No. 2: Colour and Clarity. Report produced by the Ministry for the Environment. Wellington: New Zealand.

MoH 2005*. Drinking water standards for New Zealand 2005.* Published by the Ministry of Health. Wellington: New Zealand. Available on the Ministry for the Environment's website at the following link:

http://www.mfe.govt.nz/publications/water/nz-drinking-water-standards-00.html

NRC (2007) *Regional Water and Soil Plan for Northland.* Northland Regional Council: Whangarei, New Zealand. Section 7.8(a), p 53. Available on the Regional Council website at the following link:

http://www.nrc.govt.nz/Resource-Library-Summary/Plans-and-Policies/Regional-plans/Regional-Water-and-Soil-Plan/

NRC 2005 and 2006. Annual Environmental Monitoring Reports. Reports available on the Regional Council website at the following link:

http://www.nrc.govt.nz/Resource-Library-Summary/Environmental-Monitoring/

NRC. (1997) *Quality procedures manual for water quality, air and sediment sampling.* Northland Regional Council.

Quinn, J.M. and Stroud, M.J. (2002). *Water quality and sediment and nutrient export from New Zealand hill-land catchments of contrasting land use.* New Zealand Journal of Marine and Freshwater Research, 36, 409-429.

Quinn, J.M., Copper, A.B. Davies-Colley, R.J., Rutherford, J.C. and Williamson, R.B. (1997). *Land use effects on habitat, water quality, periphyton, and benthic invertebrates in Waikato, New Zealand, hill country streams.* New Zealand Journal of Marine and Freshwater Research, 31, 579- 597.

Scarsbrook 2006. *State and Trends in the National River Water Quality Network (1989-2005).* Report produced by the National Institute of Water and Atmospheric Research for the Ministry for the Environment. Wellington: New Zealand. Available on the Ministry for the Environment's website at the following link:

http://www.mfe.govt.nz/publications/ser/water-quality-network-nov06/index.html

Scarsbrook, M.R., McBride, C.G., McBride, G.B. and Bryers, G.G. (2003). *Effects of climate variability on river: consequences for long term water quality analysis*. Journal of the American Water Resources Association 39.

Vant, B. and Smith, P. (2004). *Trends in water quality in the Waikato Region, 1987 – 2002.* Report published by Environment Waikato Regional Council. Hamilton: New Zealand. Available on the Environment Waikato's website at the following link:

http://www.ew.govt.nz/publications/technicalreports/tr0402.htm

Wilcock, R.J., Monaghan, R.M., Quinn, J.M., Campbell, A.M., Thorrold, B.S., Duncan, M.J. McGowan, A.W. and Betteridge, K. (2006a). *Land-use impacts and water quality targets in the intensive dairying catchment of the Toenepi Stream, New Zealand.* New Zealand Journal of Marine and Freshwater Research, 40, 123 – 140.

Wilcock, R.J., Monaghan, R.M., Thorrold, B.S., Meredith, A.S., Duncan, M.J. and Betteridge, K. (2006b). *Dairy farming and sustainability: a review of water quality monitoring in five contrasting regions of New Zealand.* In: Proceedings of the Water2006 conference, 2-4 August 2006, Auckland.

Appendix A: Medians for RWQMN sites

Table 5: Medians for each parameter for 21 RWQMN sites for all years

Site	Temp. (deg. C)	DO (% sat.)	DO (mg/L)	Cond. (mSm/cm)	pH	Turb. (ntu)	Water clarity (m)	Dissolved colour (340 nm/cm)	Dissolved colour (440 nm/cm)	DRP (g/m3)	TP (g/m3)	NNN/ NO3 (g/m3)	NH4 (g/m3)	TKN (g/m3)	TN (g/m3)	Ecoli (n/100ml)
Awanui at FNDC take	16.5	86.0	8.6	7.1	7.4	7.1	0.82	12.92	2.90	0.020	0.046	0.044	0.020	0.2	0.299	306
Awanui u/s of Waihue	17.1	89.2	8.7	9.4	7.5	9.4	0.55	13.67	3.18	0.167	0.150	0.073	0.040	0.5	0.583	410
Kaihu	14.4	104.6	10.8	3.5	7.5	3.5	1.70	8.90	2.11	0.008	0.020	0.275	0.005	0.2	0.435	146
Mangahahuru at Apotu Rd	16.1	95.6	9.8	7.5	6.8	7.5	0.75	14.89	3.43	0.040	0.098	0.426	0.040	0.3	0.730	494
Mangahahuru at Main Rd	13.9	97.6	10.1	3.5	7.2	3.5	2.10	12.27	2.94	0.005	0.018	0.037	0.005	0.1	0.137	181
Mangakahia at Titoki	17.1	96.6	9.4	13.5	7.4	6.8	0.65	9.69	1.90	0.008	0.028	0.106[1]	0.015	0.2	0.320	182
Mangakahia at Twin Bridges	16.8	106.5	NA	3.6	7.4	3.6	1.38	8.09	1.99	0.044	0.072	0.064	0.010	0.1	0.261	180
Manganui River	15.8	85.3	8.2	8.6	7.2	8.6	0.73	18.54	4.01	0.035	0.092	0.250	0.020	0.5	0.712	122
Mangere River	15.3	83.2	8.5	7.2	6.9	7.2	0.81	17.72	4.05	0.110	0.175	0.720	0.100	0.5	1.341	561
Opouteke River	16.8	106.9	NA	2.6	7.5	2.6	1.58	5.96	1.56	0.036	0.078	0.043	0.020	0.1	0.215	121
Punakitere River	15.5	98.3	9.9	6.2	7.4	6.2	0.95	16.03	3.70	0.027	0.058	0.466	0.020	0.3	0.866	388
Victoria River	14.9	96.8	9.9	1.3	7.4	1.3	2.03	2.95	0.61	0.019	0.022	0.008	0.020	0.1	0.087	166
Waiarohia at Second Ave	16.4	111.2	10.9	3.0	7.4	3.0	1.49	8.51	2.09	0.022	0.051	0.397	0.005	0.2	0.643	465
Waiarohia at Whau Valley	15.8	97.5	9.6	7.3	7.2	7.3	0.90	12.03	2.95	0.007	0.076	0.235	0.005	0.5	0.784	726
Waiotu River at SH1	15.5	92.3	9.3	8.9	6.9	5.4	0.82	15.22	3.81	0.015	0.068	0.344	0.020	0.3	0.667	323
Waipapa at Puketi Forest	14.7	97.0	9.8	11.6	7.5	2.2	1.85	6.55	1.28	0.005	0.010	0.020[1]	0.003	0.1	0.107	71
Waipoua River	12.9	103.4	10.9	2.1	7.5	2.1	2.34	6.98	1.69	0.005	0.008	0.016	0.005	0.1	0.088	63
Wairua River at Purua	17.0	89.4	8.7	11.9	6.8	8.8	0.56	17.13	3.22	0.023	0.075	0.470[1]	0.041	0.3	0.828	111
Waitangi at Waimate	14.9	97.3	10.0	3.8	6.9	3.8	1.07	8.79	1.93	0.007	0.027	0.364	0.020	0.2	0.570	488
Waitangi at watea	16.7	100.7	9.8	11.2	7.5	3.7	1.16	9.82	1.86	0.006	0.022	0.294[1]	0.008	0.2	0.504	164
Whakapara River	15.9	96.5	9.8	6.0	6.9	6.0	1.01	13.27	3.06	0.025	0.057	0.308	0.020	0.2	0.504	177

1. For the four National sites compliance with NNN is using the NO_3 results as there is no NNN results for these sites.

Table 6: Medians for each parameter for 21 RWQMN sites for 2006

Site	Temp. (deg. C)	DO (% sat.)	DO (mg/L)	Cond. (mSm/cm)	pH	Turb. (ntu)	Water clarity (m)	Dissolved colour (340 nm/cm)	Dissolved colour (440 nm/cm)	DRP (g/m3)	TP (g/m3)	NNN/ NO3 (g/m3)	NH4 (g/m3)	TKN (g/m3)	TN (g/m3)	Ecoli (n/100ml)
Awanui at FNDC take	15.55	85.4	8.8	4.5	7.3	4.5	0.75	13.04	2.56	0.016	0.039	0.028	0.005	0.3	0.260	276
Awanui u/s of Waihue	16.80	85.0	8.7	7.0	7.4	5.0	0.55	13.53	3.34	0.060	0.107	0.073	0.005	0.5	0.573	323
Kaihu	14.20	105.3	10.7	3.0	7.3	3.4	1.76	7.76	2.43	0.011	0.027	0.265	0.005	0.1	0.435	128
Mangahahuru at Apotu Rd	15.20	103.7	10.5	4.5	7.2	4.7	1.55	14.64	3.36	0.038	0.086	0.386	0.030	0.2	0.694	419
Mangahahuru at Main Rd	13.75	97.6	10.2	3.4	7.2	3.5	2.13	11.41	2.68	0.005	0.018	0.028	0.005	0.1	0.124	161
Mangakahia at Titoki	16.40	96.6	9.6	5.9	7.4	6.9	0.68	9.91	1.92	0.007	0.029	0.209[1]	0.012	0.2	0.282	120
Mangakahia at Twin Bridges	15.80	108.5	NA	2.7	7.5	3.0	1.54	7.90	1.90	0.015	0.027	0.017	0.005	0.1	0.167	148
Manganui River	15.85	85.6	8.7	6.8	7.1	8.6	0.96	20.05	3.66	0.056	0.108	0.167	0.005	0.5	0.590	91
Mangere River	14.75	86.2	8.8	5.3	7.2	5.5	1.20	16.83	3.77	0.110	0.163	0.591	0.050	0.5	1.083	821
Opouteke River	15.85	109.9	NA	3.3	7.5	3.7	1.25	7.90	2.02	0.009	0.021	0.012	0.005	0.1	0.162	179
Punakitere River	14.70	97.4	10.2	5.0	7.3	4.6	1.67	16.51	3.55	0.028	0.057	0.420	0.020	0.3	0.842	389
Victoria River	13.85	97.7	10.5	1.1	7.3	1.1	1.95	3.17	0.55	0.014	0.021	0.004	0.005	0.1	0.055	179
Waiarohia at Second Ave	17.05	111.2	11.1	2.6	7.5	3.5	1.50	8.51	1.87	0.022	0.048	0.397	0.008	0.2	0.628	453
Waiarohia at Whau Valley	16.00	97.9	9.9	7.6	7.2	8.0	0.90	12.29	2.84	0.004	0.083	0.162	0.005	0.6	0.741	812
Waiotu River at SH1	14.85	94.2	10.2	5.4	7.3	7.3	1.40	15.31	3.48	0.018	0.051	0.263	0.015	0.2	0.430	251
Waipapa at Puketi Forest	13.30	97.8	10.5	1.6	7.6	1.6	2.05	7.30	1.53	0.005	0.010	0.024[1]	0.003	0.1	0.121	78
Waipoua River	13.15	102.0	10.9	2.0	7.4	2.1	2.13	7.22	1.78	0.021	0.029	0.016	0.005	0.1	0.078	20
Wairua River at Purua	17.10	94.2	9.7	7.6	7.1	7.6	0.76	15.63	2.99	0.024	0.062	0.532[1]	0.039	0.4	0.759	78
Waitangi at Waimate	13.85	97.8	10.7	2.6	7.2	2.8	1.89	8.74	1.92	0.002	0.019	0.379	0.010	0.2	0.560	386
Waitangi at watea	15.30	99.7	10.3	2.6	7.5	4.0	1.69	8.71	1.69	0.006	0.023	0.357[1]	0.006	0.2	0.479	167
Whakapara River	15.35	102.5	10.4	4.4	7.3	4.5	1.72	12.10	2.83	0.027	0.044	0.215	0.015	0.2	0.309	135

1. For the four National sites compliance with NNN is using the NO_3 results as there is no NNN results for these sites.

Appendix B: Compliance of RWQMN sites

Table 7: Compliance for all years data for the RWQMN sites with the ANZECC trigger values for DO%, pH, turbidity, water clarity, TP, NNN, NH_4, TN and DRP (ANZECC 2000), the recreational bathing guideline for *E. coli* (MfE 2002) and the guideline from the RWSP for water clarity of 1.6 m (NRC 2007)[2].

Site	DO (% sat.)	pH	Turbidity (ntu)	Water clarity (m)	TP (g/m3)	NNN/ NO3 (g/m3)	NH4 (g/m3)	TN (g/m3)	DRP (g/m3)	E. coli (n/100ml)	Clarity with 1.6 m
Awanui at FNDC take	0.0	77.5	46.2	67.5	24.6	100.0	80.7	92.3	9.3	73.8	6.0
Awanui u/s of Waihue	12.1	74.8	25.4	46.0	0.9	97.4	41.2	54.3	0.9	63.9	1.1
Kaihu	44.4	72.2	75.5	91.5	74.1	85.2	87.0	72.2	70.4	81.5	59.6
Mangahahuru at Apotu Rd	21.1	14.2	34.2	67.4	3.4	53.8	36.1	32.8	5.0	53.6	13.0
Mangahahuru at Main Rd	44.4	55.6	83.3	100.0	94.4	94.4	100.0	100.0	100.0	94.4	62.5
Mangakahia at Titoki	26.1	71.4	41.2	50.4	64.4	97.4[1]	74.4	89.8	74.4	77.3	10.9
Mangakahia at Twin Bridges	33.6	53.4	68.6	78.5	32.2	99.2	94.0	93.2	26.5	85.4	43.0
Manganui River	3.1	47.7	32.8	73.2	6.2	86.2	75.4	40.0	0.0	80.3	1.8
Mangere River	2.6	26.4	33.6	68.0	3.3	15.0	13.2	7.5	2.5	49.4	3.1
Opouteke River	38.4	53.0	75.2	82.1	33.6	100.0	94.9	93.9	27.8	91.4	49.1
Punakitere River	40.3	70.8	44.6	77.4	15.4	47.7	78.5	24.6	7.7	69.2	28.3
Victoria River	29.7	71.7	89.1	94.3	66.9	100.0	92.4	97.4	8.5	84.5	75.5
Waiarohia at Second Ave	16.7	77.8	83.3	94.1	11.1	61.1	94.4	38.9	38.9	61.1	41.2
Waiarohia at Whau Valley	27.8	61.1	22.2	88.2	0.0	77.8	100.0	16.7	72.2	33.3	0.0
Waiotu River at SH1	10.1	25.9	18.2	75.8	7.5	72.5	58.8	39.2	7.5	66.7	9.7
Waipapa at Puketi Forest	25.2	99.2	84.0	88.2	96.6	100.0[1]	100.0	99.2	98.3	86.4	62.2
Waipoua River	33.3	81.5	86.8	93.6	81.5	100.0	74.1	90.7	75.9	90.7	85.1
Wairua River at Purua	14.3	18.5	19.3	46.2	3.4	44.4[1]	34.2	25.6	3.4	77.3	5.0
Waitangi at Waimate	27.8	20.2	65.8	81.3	60.0	73.3	90.8	60.5	62.5	54.8	29.2
Waitangi at watea	71.4	89.9	67.2	70.6	79.3	75.2[1]	85.5	67.8	80.9	81.8	38.7
Whakapara River	21.7	25.0	47.1	82.7	10.8	80.8	74.2	66.1	14.2	83.3	22.2

1. For the four National sites compliance with NNN is using the NO_3 results as there is no NNN results for these sites.

2. For more information on the guidelines check out the methods (section 2).

Table 8: Compliance for the 2006 data for the RWQMN sites with the ANZECC trigger values for DO%, pH, turbidity, water clarity, TP, NNN, NH_4, TN and DRP (ANZECC 2000), the recreational bathing guideline for *E. coli* (MfE 2002) and the guideline from the RWSP for water clarity of 1.6 m (NRC 2007)[2].

Site	DO (% sat.)	pH	Turbidity (ntu)	Water clarity (m)	TP (g/m3)	NNN/ NO3 (g/m3)	NH4 (g/m3)	TN (g/m3)	Ecoli (n/100ml)	DRP (g/m3)	clarity with 1.6m
Awanui at FNDC take	0.0	75.0	58.3	70.0	41.7	100.0	100.0	91.7	83.3	8.3	10.0
Awanui u/s of Waihue	18.2	81.8	45.5	33.3	0.0	100.0	90.9	72.7	72.7	0.0	11.1
Kaihu	41.7	66.7	75.0	100.0	66.7	83.3	100.0	75.0	91.7	50.0	54.5
Mangahahuru at Apotu Rd	33.3	50.0	66.7	100.0	0.0	66.7	41.7	41.7	66.7	0.0	45.5
Mangahahuru at Main Rd	50.0	66.7	91.7	100.0	91.7	100.0	100.0	100.0	100.0	100.0	72.7
Mangakahia at Titoki	36.4	63.6	45.5	63.6	70.0	100.0[1]	88.9	100.0	81.8	88.9	0.0
Mangakahia at Twin Bridges	25.0	50.0	83.3	100.0	58.3	100.0	100.0	100.0	91.7	41.7	36.4
Manganui River	16.7	33.3	50.0	81.8	0.0	100.0	75.0	50.0	83.3	0.0	0.0
Mangere River	0.0	50.0	66.7	81.8	0.0	33.3	16.7	25.0	16.7	0.0	18.2
Opouteke River	36.4	58.3	75.0	90.9	58.3	100.0	91.7	100.0	91.7	58.3	36.4
Punakitere River	50.0	83.3	50.0	90.9	8.3	50.0	66.7	41.7	83.3	16.7	54.5
Victoria River	33.3	66.7	91.7	100.0	91.7	100.0	100.0	100.0	83.3	33.3	80.0
Waiarohia at Second Ave	16.7	75.0	91.7	100.0	0.0	58.3	91.7	41.7	58.3	33.3	45.5
Waiarohia at Whau Valley	33.3	58.3	16.7	90.9	0.0	83.3	100.0	16.7	33.3	75.0	0.0
Waiotu River at SH1	8.3	66.7	50.0	100.0	0.0	83.3	66.7	66.7	91.7	0.0	36.4
Waipapa at Puketi Forest	45.5	100.0	81.8	90.9	100.0	100.0[1]	100.0	100.0	100.0	100.0	81.8
Waipoua River	58.3	83.3	91.7	100.0	50.0	100.0	91.7	100.0	100.0	33.3	81.8
Wairua River at Purua	9.1	27.3	27.3	54.5	0.0	55.6[1]	33.3	30.0	90.9	0.0	0.0
Waitangi at Waimate	33.3	50.0	83.3	100.0	100.0	58.3	100.0	75.0	75.0	100.0	72.7
Waitangi at watea	45.5	100.0	81.8	81.8	80.0	66.7[1]	77.8	70.0	81.8	77.8	54.5
Whakapara River	41.7	66.7	75.0	100.0	8.3	83.3	66.7	83.3	91.7	0.0	72.7

1. For the four National sites compliance with NNN is using the NO_3 results as there is no NNN results for these sites, shown with asterisks.

2. For more information on the guidelines check out the methods (section 2).

Appendix C: Site ranking based on medians and sample compliance

Table 9: Ranking of sites[1] based on their medians as shown in green and bold below and % of compliance[2] as shown in italics and pink below. (Note: one is the best and 21 is the worst).

Site	Med temp.	Med cond.	Med turb.	Med clarity	Med diss. colour	Med DRP	Med TP	Med NNN NO3	Med NH4	Med TKN	Med TN	Med E. coli	**Overall med rank**	Total complying %	*Overall complying rank*
Awanui at FNDC take	15	11	15	14	13	11	9	6	17	13	7	13	**11**	572	*12*
Awanui u/s of Waihue	20	17	21	21	15	21	20	8	19	21	13	16	**20**	417	*17*
Kaihu	3	6	7	5	8	7	4	12	6	13	9	6	**5**	754	*5*
Mangahahuru at Apotu Rd	13	14	18	17	16	18	19	18	19	16	17	19	**18**	321	*19*
Mangahahuru at Main Rd	2	5	6	2	12	2	3	4	6	6	4	11	**4**	867	*2*
Mangakahia at Titoki	21	21	14	19	9	8	8	9	9	7	8	12	**12**	667	*8*
Mangakahia at Twin Bridges	18	7	8	8	5	19	14	7	8	6	6	10	**7**	665	*9*
Manganui River	11	15	19	18	21	16	18	11	17	21	16	5	**17**	445	*16*
Mangere River	7	12	16	16	20	20	21	21	21	21	21	20	**21**	222	*21*
Opouteke River	17	3	4	6	2	17	17	5	17	6	5	4	**6**	690	*7*
Punakitere River	9	10	13	12	18	15	12	19	17	16	20	15	**16**	476	*15*
Victoria River	6	1	1	3	1	10	5	1	17	2	1	8	**3**	735	*6*
Waiarohia at Second Ave	14	4	5	7	6	12	10	17	6	13	14	17	**9**	577	*11*
Waiarohia at Whau Valley	11	13	17	13	11	6	16	10	6	21	18	21	**14**	499	*14*
Waiotu River at SH1	8	16	11	15	17	9	13	15	17	16	15	14	**15**	382	*18*
Waipapa at Puketi Forest	4	19	3	4	3	3	2	3	1	3	3	2	**2**	877	*1*
Waipoua River	1	2	2	1	4	2	1	2	6	2	2	1	**1**	808	*3*
Wairua River at Purua	19	20	20	20	19	13	15	20	20	17	19	3	**19**	287	*20*
Waitangi at Waimate	6	8	10	10	7	6	7	16	17	13	12	18	**10**	597	*10*
Waitangi at watea	16	18	9	9	10	4	6	13	7	8	11	7	**8**	770	*4*
Whakapara River	12	9	12	11	14	14	11	14	17	13	10	9	**13**	506	*13*

1. Ranking of sites based on their median values for all years for each of temperature, conductivity, turbidity, clarity, dissolved colour, DRP, TP, NNN (or NO_3), NH_4, TKN, TN and E. coli were summed, giving an overall rank for the medians (green and bold).
2. Ranking of sites based on their total percentage of samples for all years that comply with all relevant guidelines, including dissolved oxygen, water clarity, turbidity, DRP, TP, NNN, NH_4, TN, pH and E. coli and therefore a possible maximum total compliance percentage of 1000 (pink and italics).

Appendix D: Number of samples for each RWQMN site

Table 10: Number of samples for each site and parameter for the calculation of medians and trend analysis.

	Temperature	Dissolved oxygen % saturation	Dissolved oxygen (mg/L)	Conductivity	pH	Turbidity	Visual clarity	Dissolved colour @ 340 nm	Dissolved colour @440nm	*Escherichia coli*	Dissolved reactive phosphorus	Total Phosphorus	Nitrate/Nitrite nitrogen or Nitrate	Total nitrogen	Ammoniacal nitrogen	Total Kjedahl Nitrogen
Victoria	119	118	95	119	120	119	106	114	114	84	118	118	118	117	119	NA
Awanui (FNDC take)	58	58	58	58	58	57	NA	57	57	58	57	57	57	57	58	58
Awanui (Waihue)	117	115	103	114	118	117	86	115	115	83	116	116	116	115	119	115
Waitangi (Waimate)	87	85	75	88	88	88	75	86	86	85	88	88	88	87	88	87
Waitangi(Watea)	119	119	119	119	119	119	119	119	119	NA	115	118	117	118	117	106
Waipapa	119	119	119	119	119	119	119	119	119	NA	117	119	117	118	117	117
Punakitere	63	65	63	65	65	65	NA	64	64	65	65	65	65	65	65	65
Waiotu	73	72	73	74	74	71	NA	69	69	74	73	73	73	72	73	72
Whakapara	118	115	77	120	120	119	81	117	117	86	120	120	120	118	120	118
Mangahahuru	116	112	76	118	118	118	90	115	115	85	117	117	117	117	117	117
Wairua	118	118	118	118	118	118	118	118	118	NA	116	117	116	116	116	115
Mangakahia (Twin)	113	113	NA	116	118	118	107	114	114	83	117	118	118	117	117	117
Mangakahia (Titoki)	118	118	118	118	118	118	118	118	118	NA	116	117	115	117	116	116
Opouteke	112	112	NA	115	117	117	106	111	111	82	115	116	116	115	117	116
Mangere	119	115	77	120	121	119	97	116	116	87	120	120	120	120	121	120
Manganui	65	64	65	63	65	64	NA	63	63	61	65	65	65	65	65	65
Kaihu	54	54	54	NA	64	53	NA	NA	NA	54	54	54	54	54	54	54
Waipoua	54	54	54	NA	54	54	NA	NA	NA	54	54	54	54	54	54	NA

Appendix E: Significant trends with their percentage of the median for each site

Table 11: Trends with their significance levels (*p-values*)[1] shown in brackets.

Site	Temperature	% of med	Dissolved oxygen	% of med	Dissolved oxygen	% of med	Conductivity	% of med	pH	% of med	Turbidity	% of med	Visual clarity	% of med	Dissolved colour	% of med
	10^{-3} ºC/yr		10^{-3} % saturation/yr		10^{-3} mgL^{-1}/yr		10^{-3} mS/m@25ºC/yr		10^{-3} /yr		(10^{-3} NTU/yr)		(10^{-3} m/yr)		(10^{-3} G-abs@340nm/cm/yr)	
Victoria	**-168 (≤5)**	**1.1**	290 (≤20)		50 (≤20)		17		10		-54 (≤10)		**-110 (≤5)**	**5.4**	45	
Awanui (FNDC take)	-398 (≤20)		-310		24		70		**-37 (≤5)**	**0.5**	-116		NA		336 (≤10)	
Awanui (Waihue)	**-169 (≤5)**	**1.0**	140		10		**129 (≤5)**	**1.4**	7		**-376 (≤5)**	**4**	18		231 (≤10)	
Waitangi (Waimate)	-239 (≤20)		550 (≤10)		**124 (≤5)**	**1.2**	-5		**76 (≤5)**	**1.1**	-28		-12		149 (≤20)	
Waitangi (Watea)	-154 (≤10)		-73		18		**-46 (≤5)**	**0.4**	5		2		-14		59	
Waipapa	-13		53		4		26 (≤20)		**16 (≤5)**	**0.2**	**-104 (≤5)**	**4.7**	**46 (≤5)**	**2.5**	-34	
Punakitere	-253		-255		59		-39		39		-134		NA		788	
Waiotu	-113		770 (≤10)		**129 (≤5)**	**1.4**	-19		**84 (≤5)**	**1.2**	-45		NA		179	
Whakapara	-43		**1060 (≤5)**	**1.1**	**180 (≤5)**	**1.8**	-26		**44 (≤5)**	**0.6**	-159 (≤20)		**48 (≤5)**	**4.8**	**310 (≤5)**	**2.3**
Mangahahuru	-81 (≤10)		**1520 (≤5)**	**1.6**	**225 (≤5)**	**2.3**	**170 (≤5)**	**2.3**	**27 (≤5)**	**0.4**	**-300 (≤5)**	**4**	**69 (≤5)**	**9.3**	390 (≤10)	
Wairua	-42		**511 (≤5)**	**0.6**	**71 (≤5)**	**0.8**	-20		**22 (≤5)**	**0.3**	-89		4		158	
Mangakahia (Twin)	-117 (≤20)		56		NA		**123 (≤5)**	**3.4**	23 (≤10)		-81		-9		25	
Mangakahia (Titoki)	15		63		5		-24		**9 (≤5)**	**0.1**	93		-11 (≤10)		77	
Opouteke	-92		**202 (≤5)**	**0.2**	NA		121 (≤10)		**32 (≤5)**	**0.4**	-50		-2		59	
Mangere	-153 (≤10)		**741 (≤5)**	**0.9**	94		8		**50 (≤5)**	**0.7**	**-192 (≤5)**	**2.7**	**44 (≤5)**	**5.4**	229 (≤20)	
Manganui	-21		357		12		230		53		-436		NA		245	
Kaihu	-49		295		-91		NA		-23		-571 (≤10)		NA		NA	
Waipoua	-17		-1053		-182		NA		0		-150		NA		NA	

1. Results shown in bold are significant at a 95% confidence level, i.e. the *p value* ≤ 5. Where the trend is significant at *p* ≤5, the magnitude of the trend as a percentage of the median has been calculated. Significant trends have been interpreted as meaningful where the magnitude of the trend is 1% of the median or greater.

Table 11 cont: Trends with their significance levels (*p-values*)[1] shown in brackets.

Site	Dissolved colour	% of med	*E. coli*	% of med	Dissolved reactive phosphorus	% of med	Total phosphorus	% of med	NNN or Nitrate	% of med	Total nitrogen	% of med	Ammoniacal nitrogen	% of med	Total Kjedahl Nitrogen	% of med
	10^{-3} G-abs@440nm/cm/yr		CFU/100mL/yr		10^{-3} gm^{-3}/yr		10^{-3} gm^{-3}/yr		10^{-3} gm^{-3}/yr		(10^{-3} gm^{-3}/yr)		(10^{-3} gm^{-3}/yr)		(10^{-3} gm^{-3}/yr)	
Victoria	8		-6		**-3.7 (≤5)**	**19.5**	**-5.0 (≤5)**	**22.7**	**-0.7 (≤5)**	**9.3**	-1		**-0.7 (≤5)**	**3.5**	NA	
Awanui (FNDC take)	-21		5		-0.2		-0.3		-1.1		3.2		**-4.5 (≤5)**	**22.5**	4.5	
Awanui (Waihue)	**148 (≤5)**	**4.7**	19 (≤20)		**-16 (≤5)**	**9.6**	**-27 (≤5)**	**18**	0.3		6		**-0.7 (≤5)**	**1.75**	3.1	
Waitangi (Waimate)	49 (≤20)		25 (≤20)		-0.3		**1.6 (≤5)**	**6**	**-13 (≤5)**	**4.6**	-0.2		**-1.9 (≤5)**	**9.5**	**15 (≤5)**	**7.5**
Waitangi (Watea)	17		NA		**-0.2 (≤5)**	**3.2**	0.3		-0.2		2.4		0		**-5.0 (≤5)**	**2.6**
Waipapa	-7		NA		**-0.2 (≤5)**	**3.8**	-0.1		**-1.4 (≤5)**	**7.1**	-0.2		**-0.3 (≤5)**	**10**	1.7 (≤20)	
Punakitere	172		17		-0.2		3.4 (≤20)		-10		-23		-1.5		-0.9	
Waiotu	16		-1		0.2		1.9		**-12 (≤5)**	**3.5**	-31 (≤20)		**-2.5 (≤5)**	**12.5**	-13.5	
Whakapara	**70 (≤5)**	**2.3**	-3		**-3.0 (≤5)**	**12**	**-5.0 (≤5)**	**8.8**	**-9.5 (≤5)**	**3.1**	-3.2		-0.4		6.4 (≤10)	
Mangahahuru	49		-9		**-5.0 (≤5)**	**12.5**	**-8.5 (≤5)**	**8.7**	-0.2		3.6		**-3.6 (≤5)**	**9**	2.4	
Wairua	13		NA		-0.8 (≤10)		**1.0 (≤5)**	**1.3**	-16 (≤20)		**-15 (≤5)**	**1.8**	**-1.1 (≤5)**	**2.7**	1.8	
Mangakahia (Twin)	50		2		-0.9		-4.8 (≤20)		-0.4		-4.5		-0.2 (≤20)		0.9	
Mangakahia (Titoki)	6		NA		**-0.2 (≤5)**	**2.5**	0		**-4.7 (≤5)**	**4.4**	-5.5 (≤10)		**-0.5 (≤5)**	**3.4**	2.8 (≤10)	
Opouteke	46		5 (≤20)		**-4.8 (≤5)**	**13.3**	**-13 (≤5)**	**16.7**	-1.8 (≤10)		0.1		-0.2 (≤20)		3.5	
Mangere	109 (≤10)		**118 (≤5)**	**21**	**-5.8 (≤5)**	**5.3**	**-11 (≤5)**	**6.3**	**-47 (≤5)**	**6.5**	**-47 (≤5)**	**3.5**	**-4.7 (≤5)**	**4.7**	-3.5	
Manganui	-5		401		**3.8 (≤5)**	**10.9**	1.3		**-9.5 (≤5)**	**3.8**	**-45 (≤5)**	**6.3**	**-4.7 (≤5)**	**23.5**	-7	
Kaihu	NA		-3		0		3.1		-23		-44 (≤10)		**-3.5 (≤5)**	**70**	**-25 (≤5)**	**12.5**
Waipoua	NA		-9		**2.0 (≤5)**	**40**	**2.0 (≤5)**	**25**	-0.5		**-6.0 (≤5)**	**6.9**	**-2.5 (≤5)**	**50**	NA	

1. Results shown in bold are significant at a 95% confidence level, i.e. the *p value* ≤5. Where the trend is significant at *p* ≤5, the magnitude of the trend as a percentage of the median has been calculated. Significant trends have been interpreted as meaningful where the magnitude of the trend is 1% of the median or greater.