State of the Environment Monitoring

River Water Quality State and Trends in Auckland 2005-2014

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State of the Environment Monitoring
River Water Quality State and Trends in Auckland 2005 - 2014

Laura E Buckthought
Martin W Neale

Research and Evaluation Unit
Auckland Council

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1 Executive summary

Auckland Council (AC) operates a long-term water quality monitoring programme in a network of rivers and streams throughout the region. The objectives of this programme include data collection for state of the environment reporting, identification of environmental issues and assessment of the efficacy and efficiency of current AC policy initiatives and strategies. This technical report provides detailed analyses of water quality state and trends at monitoring sites across the programme.

Monthly water quality data from 29 sites were summarised to determine the state across the Auckland region (annual medians) and analysed for long-term trends (Seasonal Kendall tests) for a range of water quality parameters. A 10-year trend analysis was carried out at 23 sites from the period 2005 to 2014 (inclusive) and a 6-year trend analysis was carried out at 6 sites for the period 2009-2014 (inclusive).

In the case of water quality state, there were many instances where site specific and even land use specific issues were hidden due to the large amount of data included in region-wide analysis. This has raised questions around the usefulness of this analysis and whether the annual state of the environment river water quality data reports fill the requirement for an overall 'snapshot' of water quality in the Auckland region. In general, water quality in the Auckland region is excellent in undisturbed native forest catchments, good in most rural catchments and poor in urban catchments (Holland and Buckthought, 2015).

There were improving trends on a regional scale for total lead, total copper, soluble copper, total zinc, soluble zinc, total phosphorus, soluble phosphorus, and total suspended solids. In a general sense, this indicates improving water quality in the Auckland region.

There was an apparent deteriorating trend in total oxidised nitrogen, however, upon further investigation, this was the result of the addition of a particular site to the programme in 2009. This stream has very high total oxidised nitrogen concentrations, which gave the impression of an increasing regional trend when in fact there was no such trend on a regional scale.

While these results are positive in that they indicate improving water quality in a range of parameters, the trends do not take into account the actual background concentrations of these parameters, they only indicate the magnitude of change each year. While some parameters showed decreasing trends, many of these are decreasing from a very high (poor) baseline. So while some water quality indicators are improving, there is still a lot more room for improvement, particularly in the highly impacted urban environments.

The poorest quality streams tend to be those dominated by urban land use (Holland and Buckthought, 2015), suggesting that the management of land-water interactions in urban streams should be a focus for Auckland's water quality monitoring programmes and investigations. However, poor quality streams are also observed in some rural catchments where high nutrient concentrations are a concern.

2 Introduction

The Auckland region encompasses a land area of 4900km^2 extending from Wellsford in the north to Franklin in the south, including the islands of the Hauraki Gulf.

Auckland has an estimated 16,500km of permanently flowing rivers, increasing to 28,240km when intermittent and ephemeral rivers are included (Storey and Wadhwa, 2009). As no mainland location in the region is greater than 20km from the coast, the catchment areas of each river are relatively small. Most of Auckland's rivers are small first and second order rivers, with many reaching the sea before they merge to form larger rivers.

The relatively low elevation of the Auckland region and the underlying geology have a large influence on the nature of the rivers, resulting in many slow flowing, low gradient rivers with soft substrate beds. Fast flowing, high gradient rivers with hard stony substrates are mostly restricted to catchments that drain the Waitakere and Hunua Ranges.

The water quality of a river is indicative of its suitability for supporting animal and plant life and for use by humans. River water quality is a function of many physical and chemical variables in the water (e.g. temperature, nutrient loads, oxygen content and sediment); the catchment characteristics (e.g. climate, topography, geology and soil type); and human influences within the catchment (e.g. land use, land management and waste discharge).

The majority (63%) of rivers within the Auckland region drain non-forested rural catchments (pastoral farming, horticulture and rural residential), followed by native forest catchments (21%), with exotic forest and urban catchments accounting for eight per cent each.

2.1 Auckland Council monitoring programme

The Auckland Council river water quality programme monitors the physical, chemical and microbiological properties of rivers at 36 sites across the Auckland region. The results enable us to assess the life-supporting capacity of the rivers (for plants and animals) and their suitability for human use. The monitoring programme is regionally representative in that a range of river types and sizes are monitored at different points within their catchments, across a variety of land uses in the Auckland region.

The river water quality programme has been running continuously since 1986. The programme was last reviewed in 2008 and subsequent changes were described in the 2009 Annual Report (Neale, 2010). Between 2009 and 2011, 31 sites were monitored, and three new sites were added to the network at the beginning of 2012, and a further two in February of 2013, bringing the current total to 36 sites. It should be noted that there are two sites in the Auckland region (the Hoteo and Rangitopuni Rivers) that are monitored by the National Institute for Water and Atmospheric Research (NIWA) as part of the National River Water Quality Network (NRWQN). These sites are not reported in this state and trends report, but are reported on as part of the NRWQN.

2.2 Purpose and report scope

The purpose of this report is to assess the current state of river water quality across the Auckland region and to report on trends and indicate whether water quality has improved, remained the same or deteriorated over the reporting period.

Trend analysis was conducted on all sites that had at least five years of monthly data (Ballantine, 2012). There are 6 sites with 6 years of accumulated data and 23 sites with at least 10 years of data.

- This report provides a summary of the data (the “state”) across all sites included in the analysis and, where appropriate, compared to relevant guidelines and standards.
- This report also provides a trend analysis for each parameter at a regional level, a land use level and an individual site level.

Since the inception of the River Water Quality Programme, 22 reports have been produced on the state of river water quality in the Auckland region. All of these reports can be obtained from the publications area of the Auckland Council website (www.aucklandcouncil.govt.nz/publications).

The last technical report on state and trends of water quality in the Auckland region was prepared by Scarsbrook (2006) which included an analysis of state and trends from 27 sites from 1986 to 2007. In future, such reports will be published every five years.

3 Methods

3.1 Sample sites

There are 29 sites with the required minimum five years monthly monitoring data for this state and trend analysis. These sites are detailed below in Table 1 and the location of each site is illustrated in Figure 1.

Table 1: River monitoring sites, with location details, catchment land cover and record start dates.

Site name	NZTM X	NZTM Y	Dominant Land cover	Monitoring start date	Trend analysis (Years)
Cascades Stream	1735628	5916378	Native forest	1978	10
Kaukapakapa River	1735833	5944978	Rural	2009	6
Kumeu River	1739252	5928781	Rural	1993	10
Lucas Creek	1751468	5934510	Urban	1993	10
Mahurangi River (Forestry HQ)	1747750	5965035	Exotic forest	1993	10
Mahurangi River (Water supply)	1748864	5970457	Rural	1993	10
Makarau River	1736150	5953126	Rural	2009	6
Matakana River	1753500	5976481	Rural	1986	10
Ngakaroa Stream	1775164	5881624	Rural	1993	10
Oakley Creek	1751963	5917636	Urban	1994	10
Okura Creek	1751405	5938716	Rural	2003	10
Omaru Creek	1766268	5916749	Urban	1985	10
Opanuku Stream	1742086	5915581	Rural	1978	10
Otaki Creek	1764306	5907216	Urban	1985	10
Otara Creek (East Tamaki)	1767422	5907535	Urban	1986	10
Otara Creek (Kennell Hill)	1768335	5908376	Urban	1992	10
Oteha Stream	1751325	5933519	Urban	1986	10
Pakuranga Creek (Botany Rd)	1769973	5913013	Urban	1985	10
Pakuranga Creek (Greenmount Drive)	1769473	5910813	Urban	1985	10
Papakura Stream	1771240	5900290	Rural	1993	10
Puhinui Stream	1766440	5904295	Urban	1994	10
Riverhead Forest Stream	1737125	5933216	Exotic forest	2009	6
Vaughan Stream	1755414	5938729	Rural	2001	10
Wairoa River	1782682	5901720	Rural	1978	10
Wairoa Tributary	1784426	5898982	Native forest	2009	6
Waitangi River	1754343	5878534	Rural	2009	6
Waiwera River	1748628	5953665	Rural	1986	10
West Hoe Stream	1748314	5950610	Native forest	2002	10
Whangamaire Stream	1763578	5884625	Rural	2009	6

Figure 1: Auckland Council river monitoring sites for state and trend analysis

3.2 Sample collection and analysis

Sample collection is carried out by Auckland Council staff. A variety of water quality parameters (Table 2) are routinely monitored. Some of these are measured in the field using a portable handheld multiparameter meter (YSI 556 MPS), and for the remainder, samples are collected, chilled and delivered to the laboratory for analysis within 24 hours.

All field and laboratory data generated by council are stored in the council's water quality archiving database (HYDSTRA).

A number of sites historically showed metal concentrations that were consistently below laboratory detection limits, and have no significant sources of heavy metals within their catchments. These sites are therefore not routinely monitored for metals and include the Cascades, Hoteo, Kaukapakapa, Ngakaroa, Opanuku, Rangitopuni, Wairoa tributary, Waitangi, West Hoe and Whangamaire streams. Tests are carried out on an intermittent basis at these sites to monitor any changes, and to determine whether routine monitoring should be re-initiated.

Quality control measures are undertaken in accordance with Auckland Council's internal standards which meet ISO 9001:2008. This covers procedures for the collection, transport and storage of samples, methods for data verification and quality assurance to ensure consistency and accuracy across the monitoring programmes.

Laboratory samples are analysed under contract by Watercare Laboratory Services Ltd. Analytical methods (for all analytes except metals) follow the "Standard Methods for the Examination of Water and Wastewater" 22nd Edition (APHA, 2005). Metal analytes are tested according to US EPA Method 200.8 for the "Determination of Trace Metals in Waters and Wastes by Inductively Coupled Plasma – Mass Spectrometry" Revision 5.4 (USEPA, 1994).

Table 2: Parameters tested in the river water quality programme and analysed for state and trends in this report (laboratory test methods refer to those tests carried out by Watercare Services Ltd under contract).

Parameters	Identifier	Units	Field/Laboratory
Dissolved oxygen	DO (sat)	% sat	Field
Temperature	Temperature	^{o}C	Field
Electrical conductivity (EC)	Conductivity	mS cm^{-1} @ 25 °C	Field
pH (lab)	pH	pH units	Laboratory
Total Suspended solids	Suspended solids	mg/L	Laboratory
Turbidity	Turbidity	NTU	Laboratory
Ammoniacal nitrogen	Ammoniacal N	mg/L	Laboratory
Nitrate/nitrite nitrogen	Oxidised N	mg/L	Laboratory
Total nitrogen	Total N	mg/L	Laboratory
Soluble reactive phosphorus	Soluble P	mg/L	Laboratory
Total phosphorus	Total P	mg/L	Laboratory
Soluble copper	Soluble copper	mg/L	Laboratory
Total copper	Total copper	mg/L	Laboratory
Soluble zinc	Soluble zinc	mg/L	Laboratory
Total zinc	Total zinc	mg/L	Laboratory
Soluble lead	Soluble lead	mg/L	Laboratory
Total Lead	Total lead	mg/L	Laboratory
Eschericia coli	*E. coli*	cfu/100mL	Laboratory

4 Water quality state

The purpose of the water quality state assessment is to provide a snapshot of the status of the water quality parameters at a regional level, including all sites in the river water quality monitoring programme over time, and where appropriate, comparisons to relevant standards and guidelines. In the following section, water quality state is represented for each parameter by box plots for each year from 2005-2014. The boxes represent the interquartile range (25^{th} to 75^{th} percentiles of the data) and the lower and upper bars represent the 5^{th} and 95^{th} percentiles, respectively. The median is the center line in each box. Where there are standards or guidelines for a parameter, this is indicated on the graph.

4.1 Relevant guideline comparisons

The relevant guidelines and standards to compare the water quality state include the National Objectives Framework (NOF) national bottom lines and the Australia New Zealand Environment Conservation Council guidelines (ANZECC). These guidelines are intended to provide context for the data in the box plots, where they are relevant:

- *National Objectives Framework (NOF) national bottom lines*

The National Policy Statement for Freshwater Management (NPSFM), 2014 provides a statutory context for the assessment of water quality in freshwater environments. The NPSFM includes two compulsory national values (ecosystem health and human health for recreation) and nine water quality attributes (parameters) that must be managed to meet these values. The National Objectives Framework (section CA of the NPSFM) provides the context for these nine water quality attributes, which are specified in Appendix 2 of the NPSFM. Each attribute has a series of both numeric and descriptive ‘states’: A, B, C and a National Bottom Line, D. The National Bottom Line is considered the minimum acceptable state for that attribute to meet the compulsory values.

Table 3: National Objectives Framework “national bottom line” values for rivers

NOF attribute and associated value	Attribute measure	Numeric Attribute State (Value)
Dissolved oxygen for ecological health	7-day mean minimum	5.0 mg/L
	1-day minimum	4.0 mg/L
Nitrate toxicity for ecological health	Annual 95th percentile	9.8 mg/L
	Annual median	6.9 mg/L
Ammonia toxicity for ecological health	Annual maximum	2.20 mg/L
	Annual median	1.30 mg/L
E. Coli for human health for recreation (secondary contact)	Annual median	>1000 cfu/100 mL
E. Coli for human health for recreation (primary contact, state “C”)	Annual median	>540 and ≤1000 cfu/100 mL

- *ANZECC Guidelines*

The Australia New Zealand Environment Conservation Council (ANZECC) Guidelines for Fresh and Marine Water Quality provides an authoritative guide for setting water quality objectives to maintain current and future environmental values for both natural and semi-natural water resources. The ANZECC guidelines present ‘trigger values’ for different levels of species protection (99, 95, 90 and 80%) based on toxicant-specific concentration-response data from a range of species. The data in this report has been compared to the ANZECC trigger values for copper, zinc and lead (Table 6). The trigger values can be applied to both total and soluble metals; however comparison with the soluble form of metals is more conservative in terms of stream ecological health.

Table 4 ANZECC trigger values for copper zinc and lead in freshwater.

Water Quality Parameter	Trigger Values for Freshwater (mg/L)			
	Level of Protection (% Species)			
	99%	95%	90%	80%
Copper	0.0010	0.0014	0.0018	0.0025
Zinc	0.0024	0.0080	0.0150	0.0310
Lead	0.0010	0.0034	0.0056	0.0094

4.2 Water quality state results

In many cases, site specific and even land use specific issues were hidden due to the large amount of data included in this analysis; therefore the usefulness of a region-wide state assessment in future is questionable. Furthermore, a more detailed understanding of water quality state across the region can be obtained each year from the state of the environment river water quality annual data reports (Holland and Buckthought, 2015).

Regionally, dissolved oxygen is generally above 80% saturation or 8 mg/L most of the time, however recordings of below 60% saturation and above 115% saturation do occur. Dissolved oxygen fluctuates diurnally, generally decreasing at night and increasing during the day. Because DO data is collected at each site at different times of the day, the results will be influenced by this diurnal fluctuation. For example a site sampled in the early morning would reflect lower night time DO concentrations, and a site sampled late in the afternoon would reflect higher day time DO concentrations. The installation of continuous DO sensors is one method of capturing this diurnal DO variability. The NOF national bottom line for DO relates only to sites below point sources, but has been used for comparison in this report for context only. There are no systematic exceedances of the 7 day or 1 day minimum national bottom line for DO (5.0 and 4.0 mg/L, respectively).

Water temperatures fluctuate between a low of 10°C in the winter and a high of 22°C in the summer and while temperature varies with the seasons, there is little variability across the years. Water pH is slightly alkaline ranging between 7.0 and 8.0, with the median pH between 7.4 and 7.5 each year. There is a period of missing pH data during 2009 and 2010 due to pH being measured on site rather than in the laboratory. For consistency in the results, only the pH from laboratory analysis is presented here. Electrical conductivity varies little over time (with the exception of a slightly higher conductivity in 2008) and ranges between 0.1 and 0.4 mS/cm at 25°C.

Total suspended solids and turbidity show similar patterns as they are both highly influenced by rainfall events. Grab samples are collected monthly so in any given year, some samples are representative of rainfall events and some are not, hence the large year to year variability in the total suspended solids and turbidity results.

Ammoniacal nitrogen concentrations are generally low, with the majority of data below 0.05 mg/L and even the 95th percentiles remaining below 0.15 mg/L. This is safely below the NOF national bottom line annual median of 1.30 mg ammonium-N/L.

The majority of total oxidised N (primarily nitrate nitrogen) data ranges between 0 and 2 mg/L and is well below the NOF national bottom line value of 6.9 mg nitrate-N/L however; the percentile statistics shown in Figure 2(i) for this parameter hide an important issue. There is one site (the Whangamaire Stream) where total oxidised N concentrations are all greater than the 95th percentile, and range between 5 and 18 mg/L. This is up to more than double the NOF national bottom line. This data is shown as outliers in Figure 2(j). The same occurs for total N which is shown without and with outliers in Figure 2(k) and Figure 2(l).

Soluble reactive phosphorus (P) generally ranges between 0 and 0.04 mg/L. There is a clear reduction in soluble reactive P between 2008 and 2009 and it should be noted that the laboratory detection limit was halved from 0.01 to 0.005 mg/L over this time. The same is observed for total P, where concentrations range between 0.01 and 0.1 mg/L, however the laboratory detection limit was reduced around the same time from 0.02 to 0.01 mg/L.

Both total and soluble copper concentrations have little year to year variability and, with the exception of 2005, remain below 0.005 mg/L. These higher copper concentrations in 2005 could possibly be due to a reduction in the laboratory detection limit. At the higher end, copper concentrations exceed the ANZECC 80% species protection guideline. Both soluble and total copper concentrations appear to be decreasing over time.

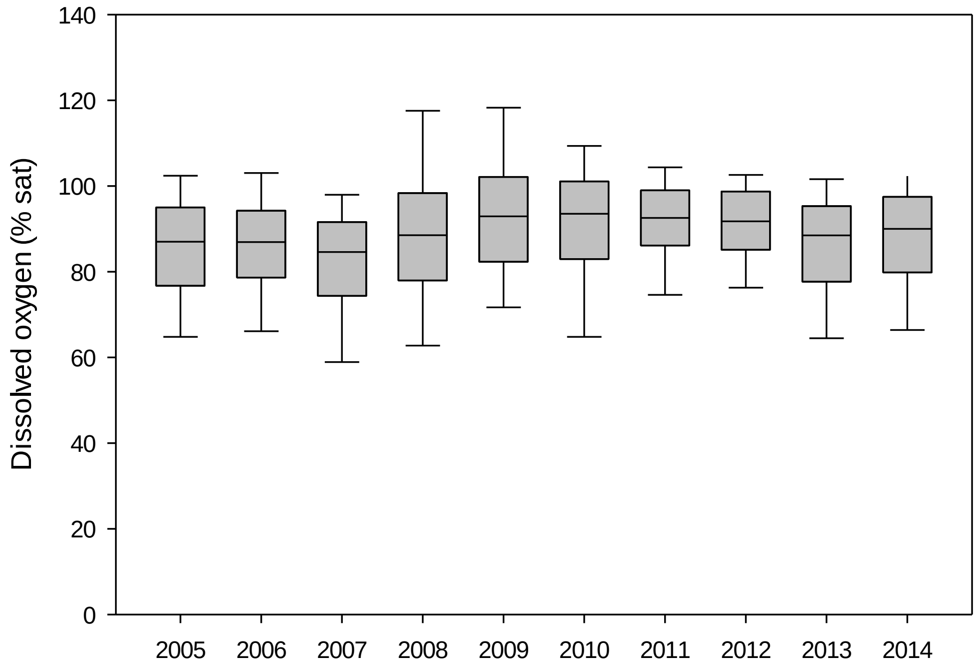
Soluble zinc concentrations range between 0 and 0.05 mg/L and total zinc concentrations range between 0 and 0.08 mg/L. Total and soluble zinc concentrations often exceed the most permissive (80% species protection) ANZECC guideline. Both total and soluble zinc concentrations also appear to be decreasing over time.

Concentrations of soluble lead have been very close to laboratory detection limits since 2005. Total lead concentrations are higher and have more year to year variability ranging between 0 and 0.0025 mg/L. These values are all below the ANZECC 80% species protection guideline. Total lead concentrations have also declined since 2005.

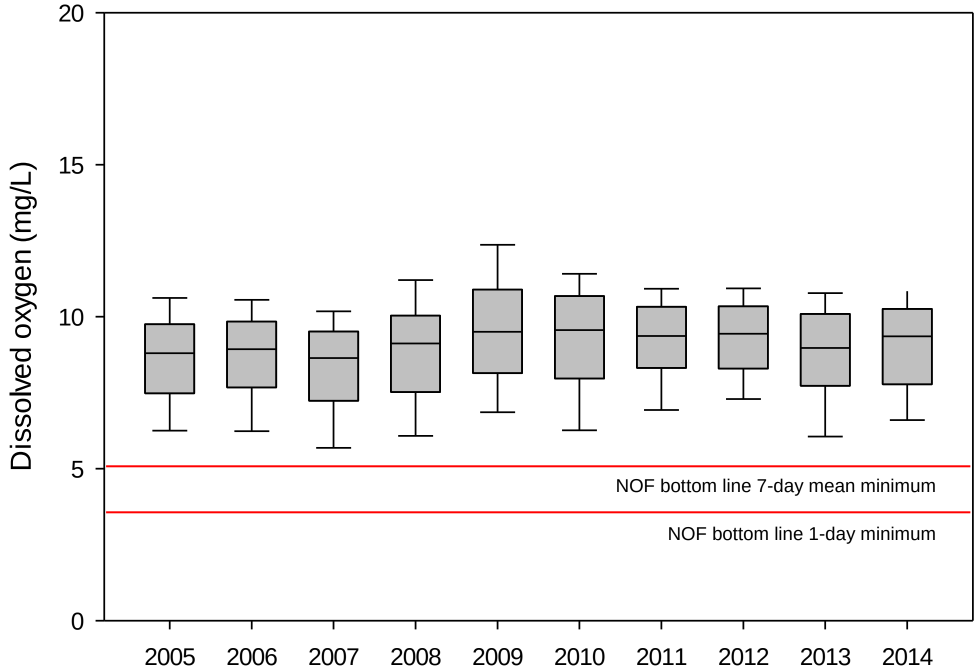
E.coli varies considerably year to year and over time and can range from small values to extremely large values of over 100000 cfu/100mL. The 5th and 95th percentiles range from <10 to 20000 cfu/100 mL. *E.coli* is also heavily influenced by rainfall events.

Figure 2 (a)–(u): Auckland regional water quality state for each parameter from 2005-2014

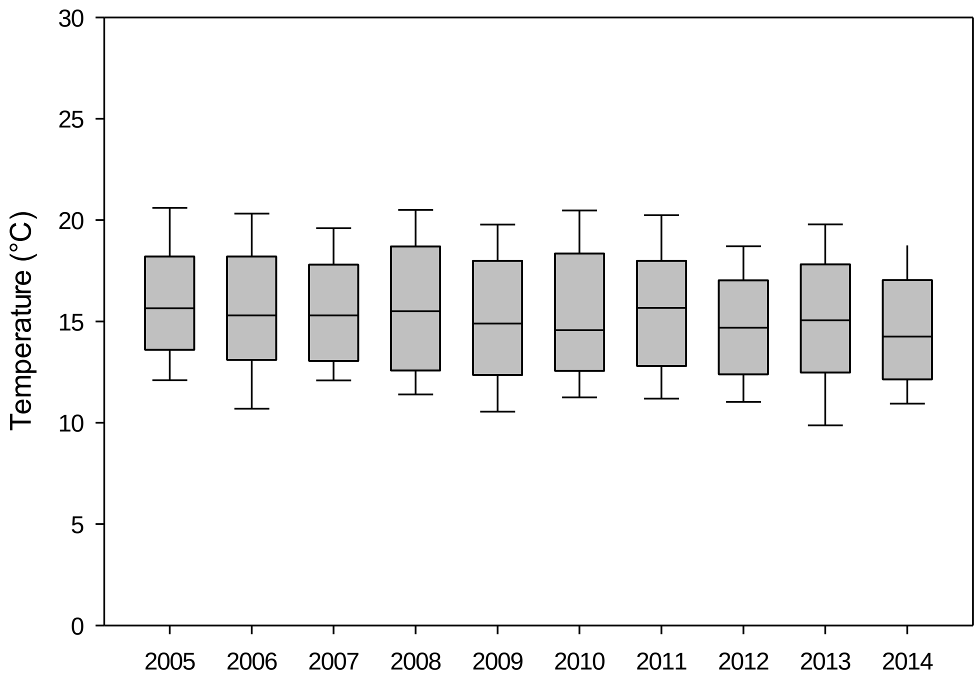
(a) Dissolved oxygen (percent saturation)



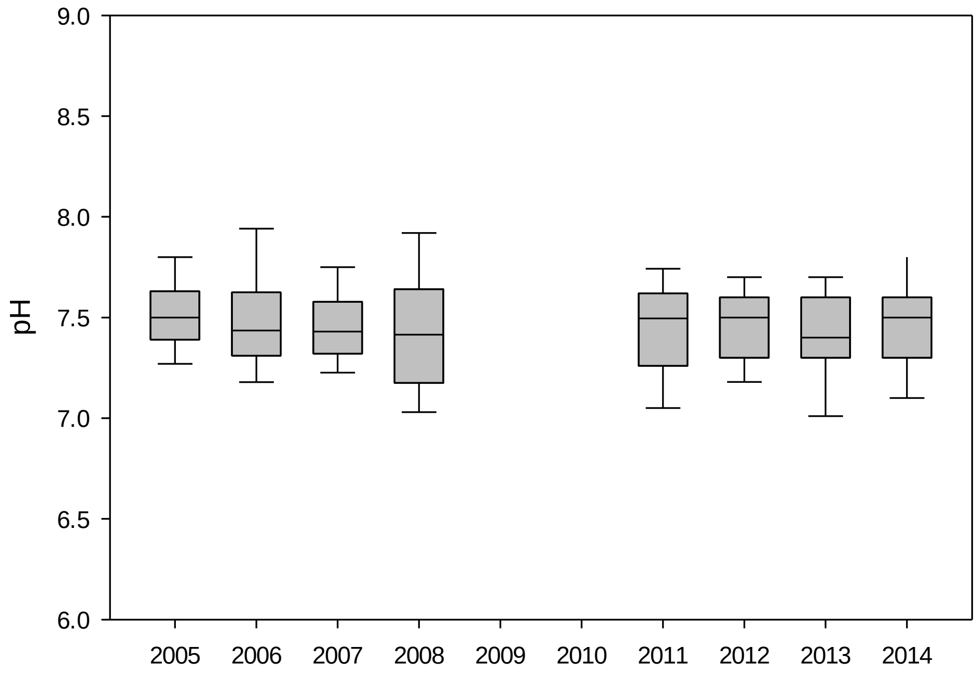
(b) Dissolved oxygen (mg/L)



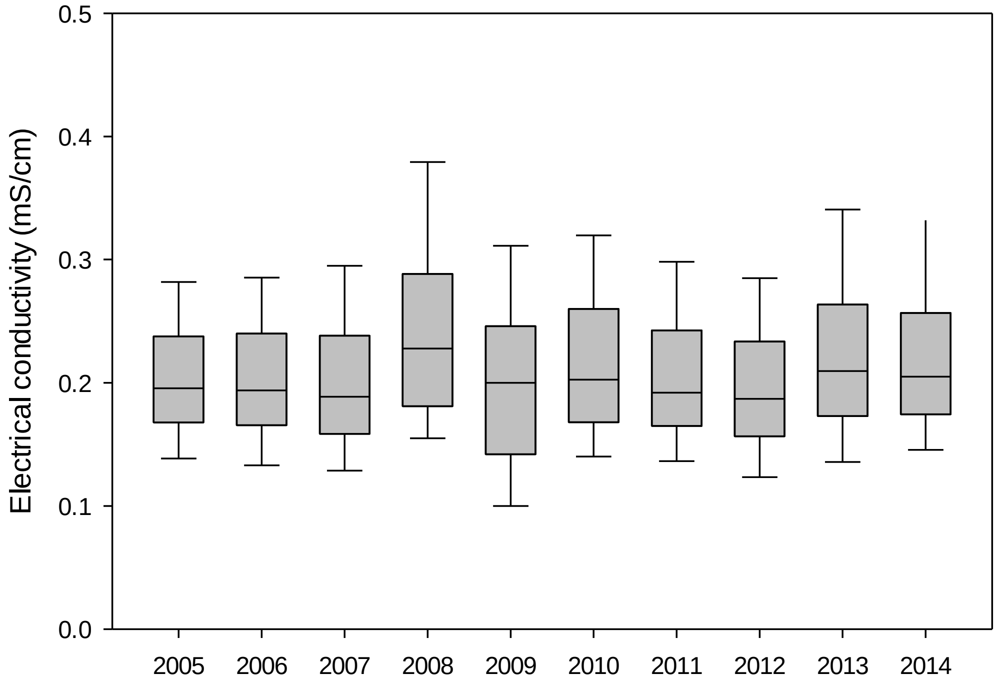
(c) Temperature



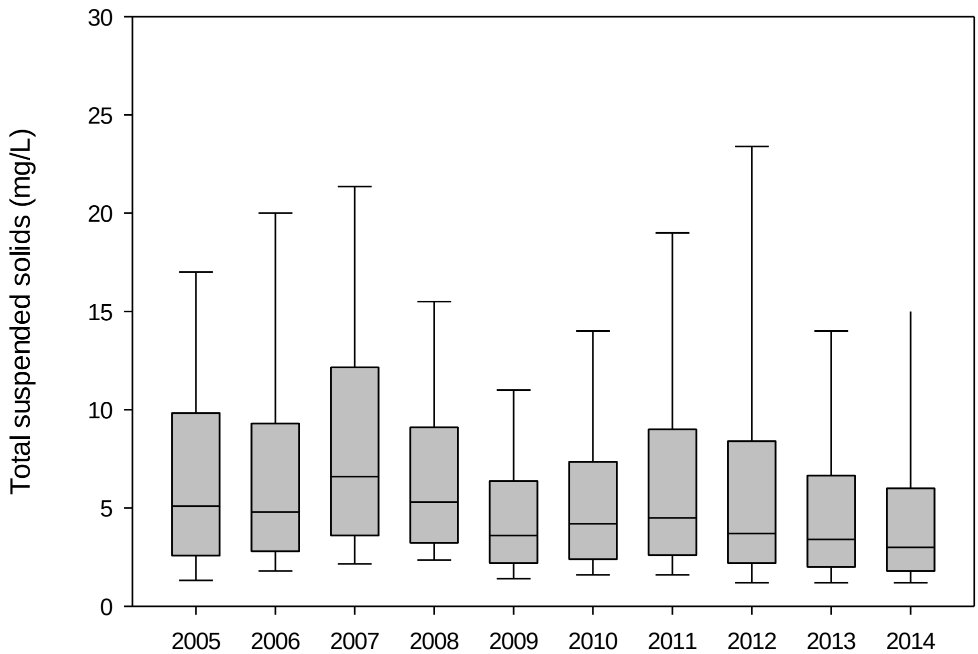
(d) pH



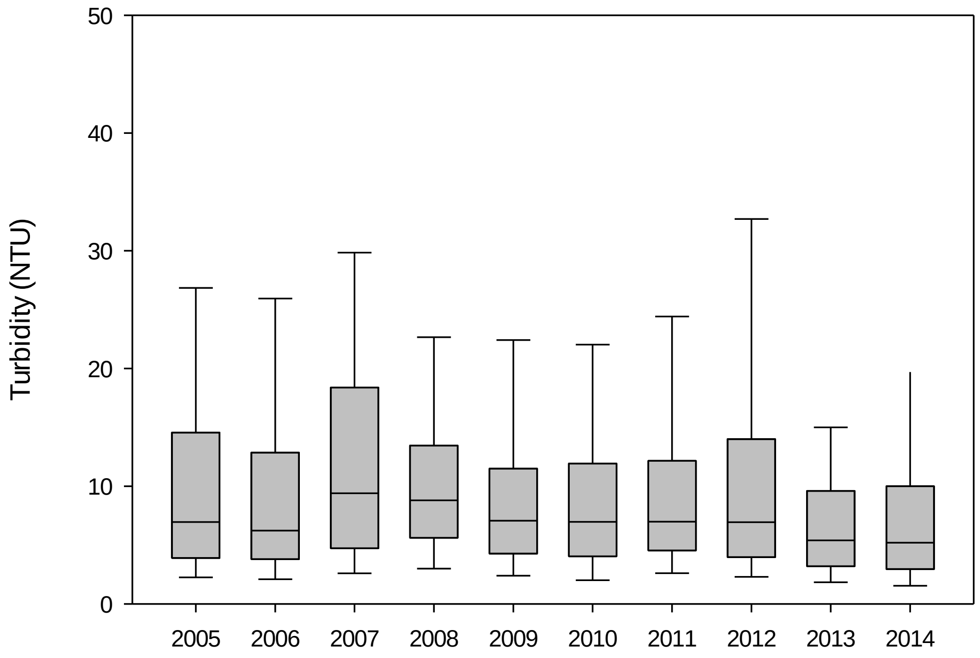
(e) Electrical conductivity



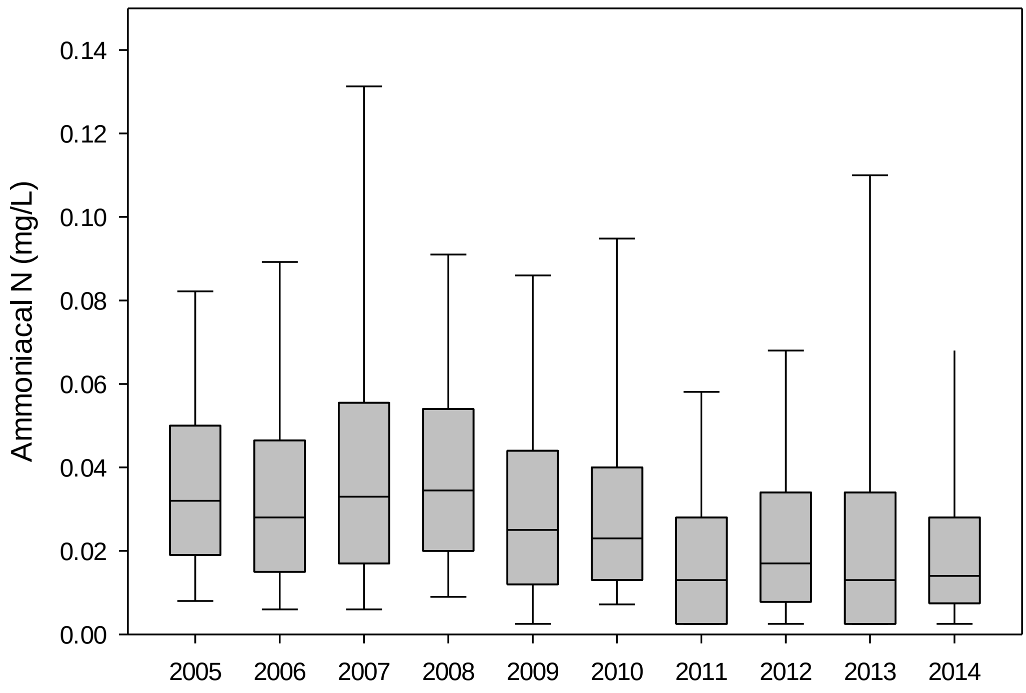
(f) Total suspended solids



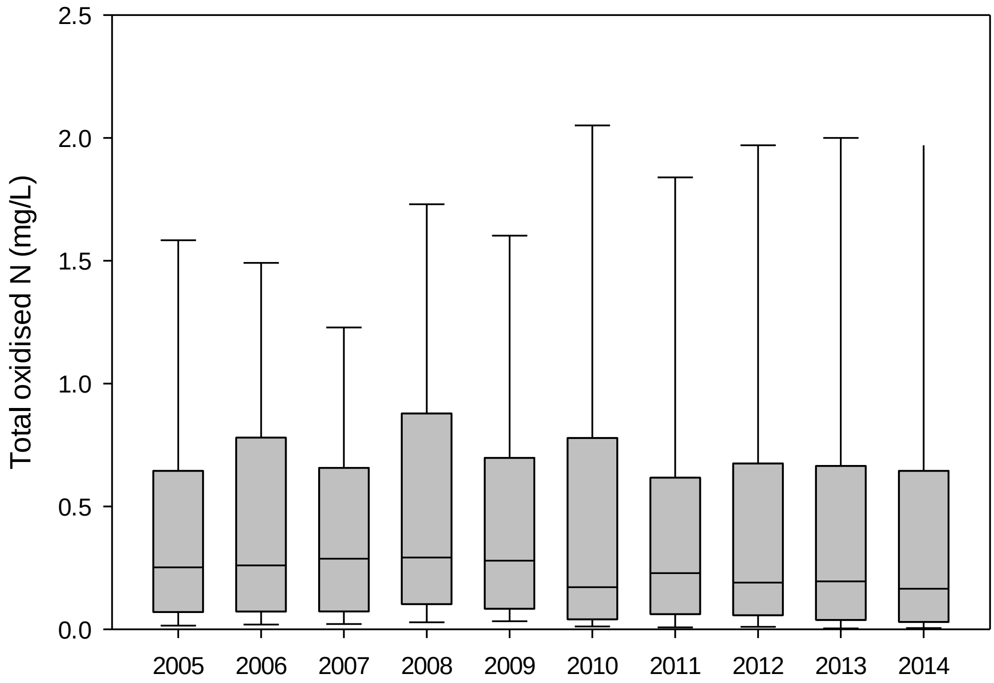
(g) Turbidity



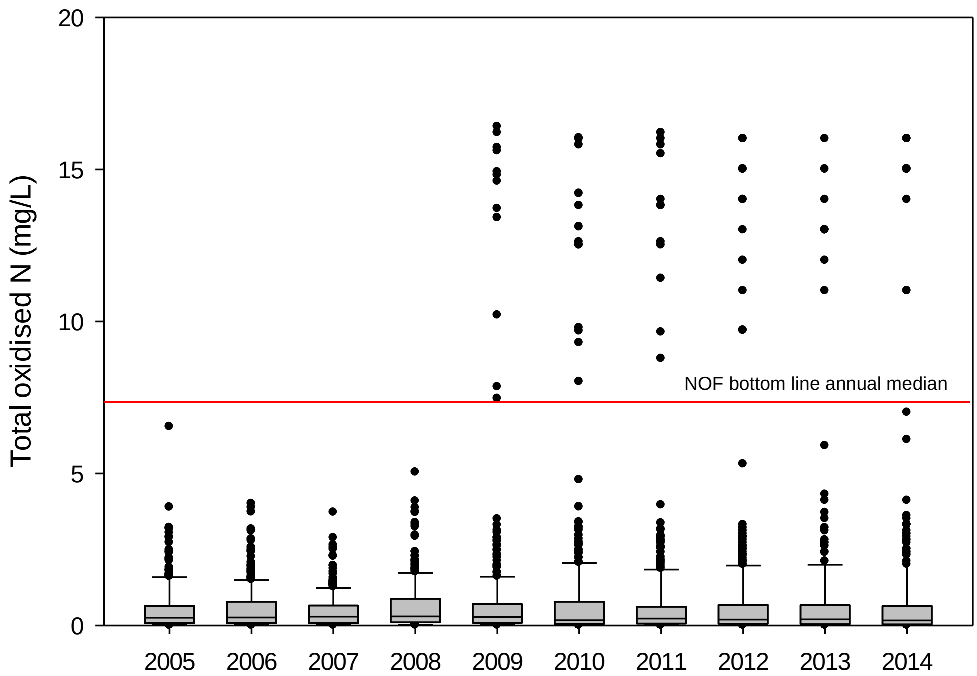
(h) Ammoniacal nitrogen



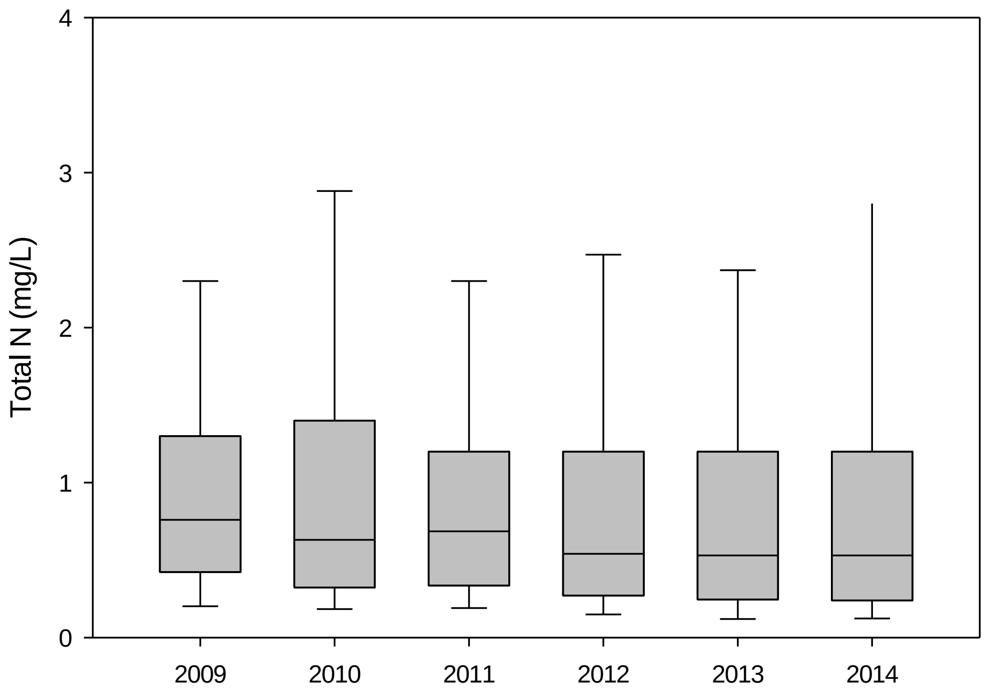
(i) Total oxidised nitrogen



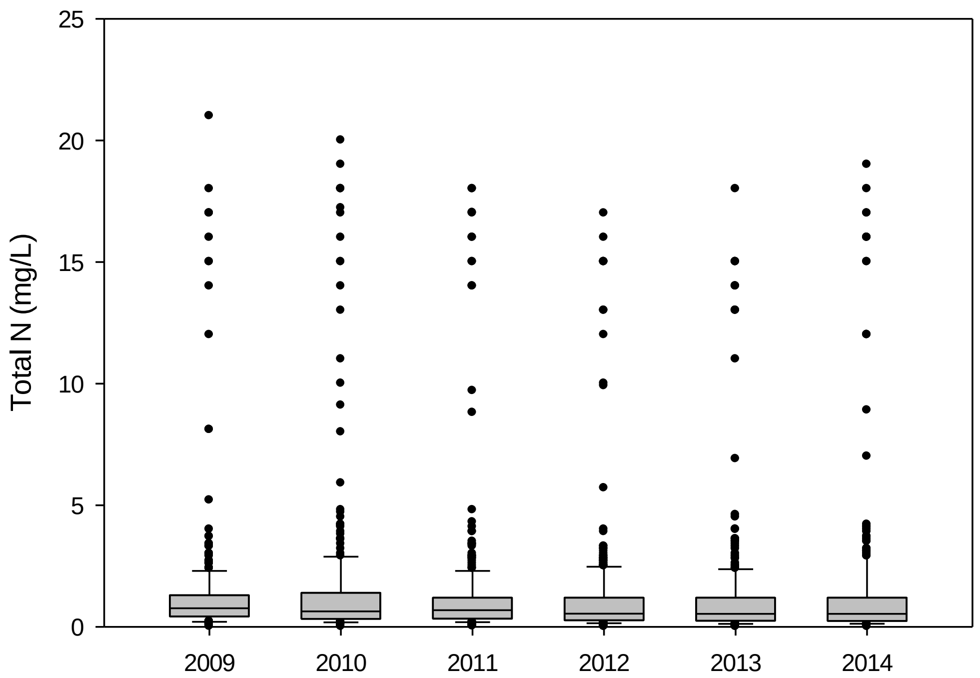
(j) Total oxidised nitrogen (with outliers)



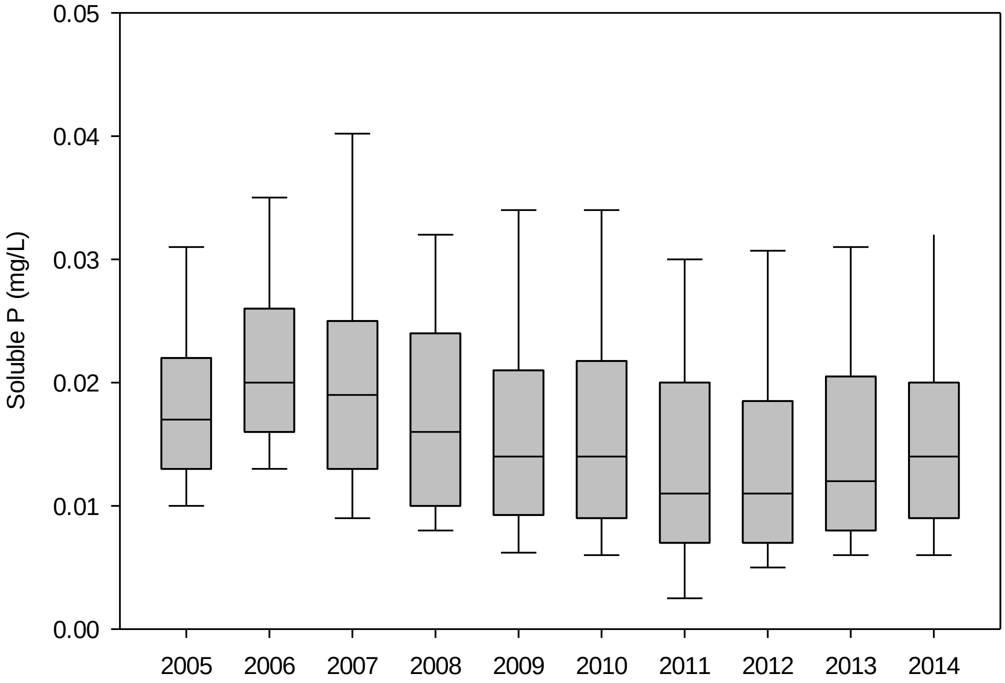
(k) Total nitrogen



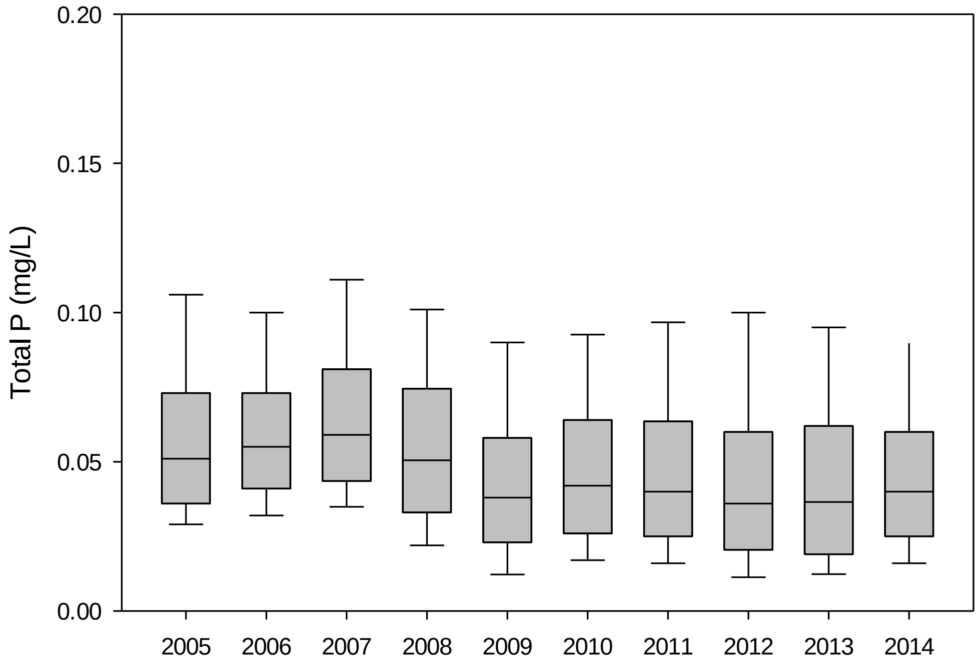
(l) Total nitrogen (with outliers)



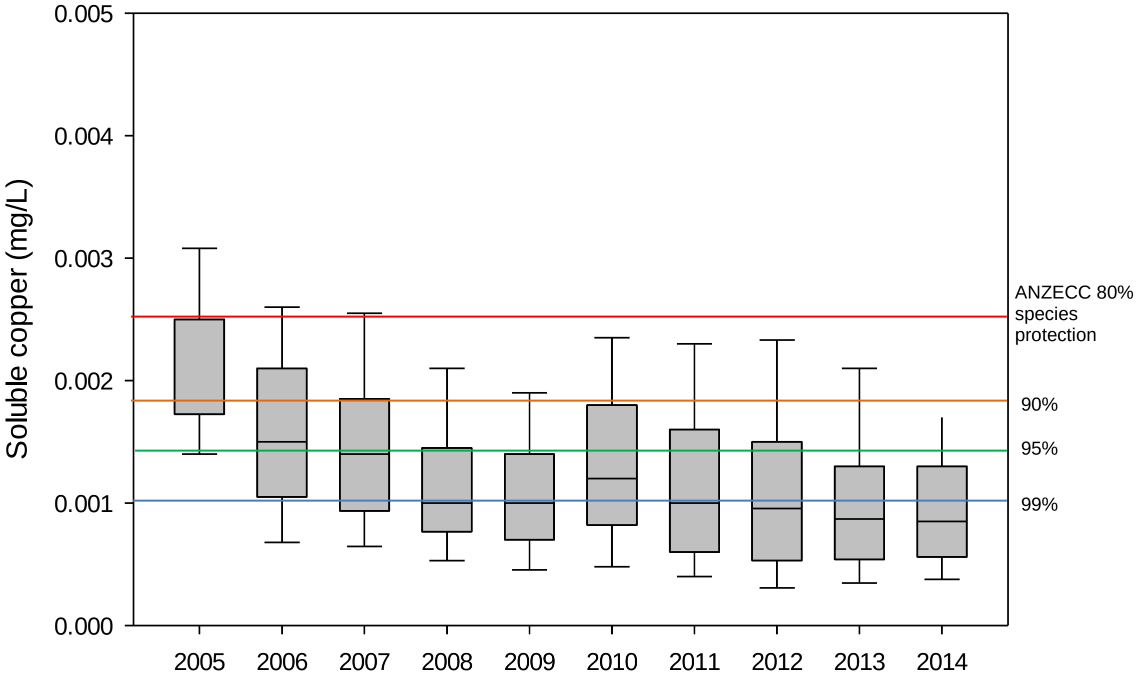
(m) Soluble reactive phosphorus



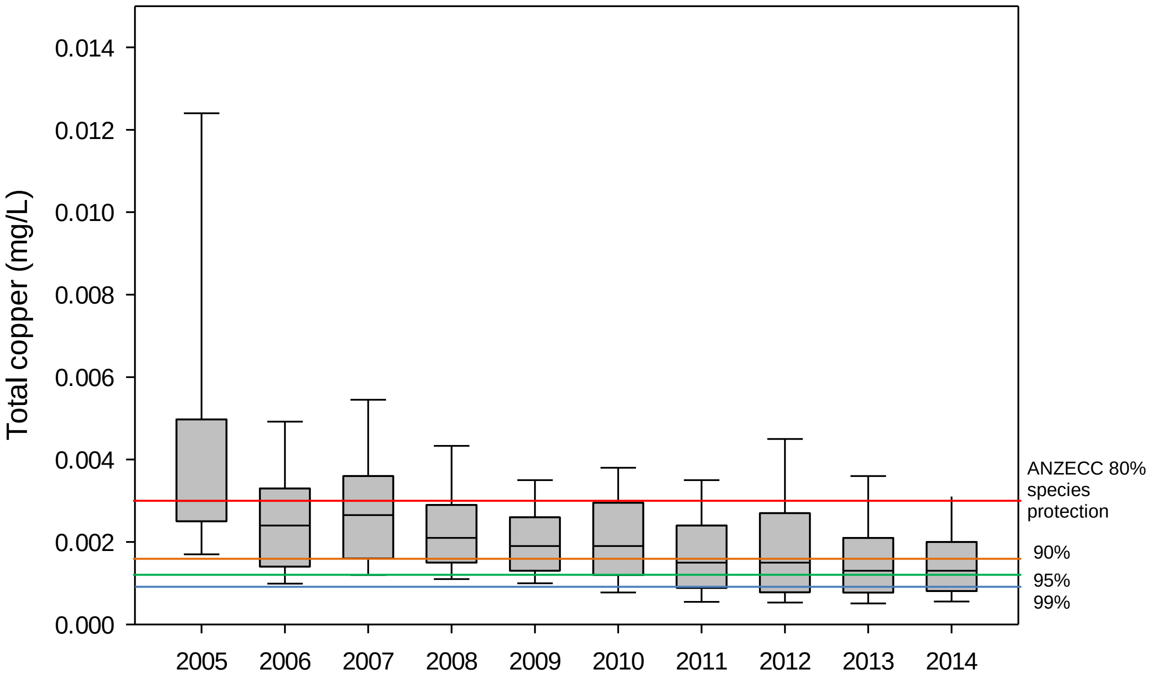
(n) Total phosphorus



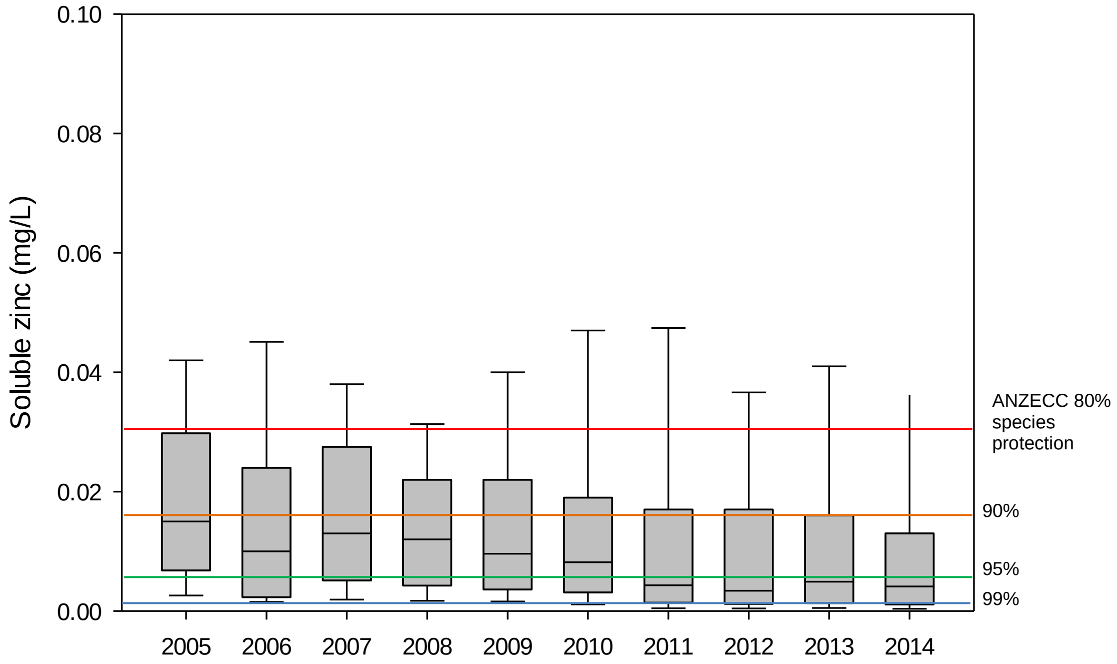
(o) Soluble copper



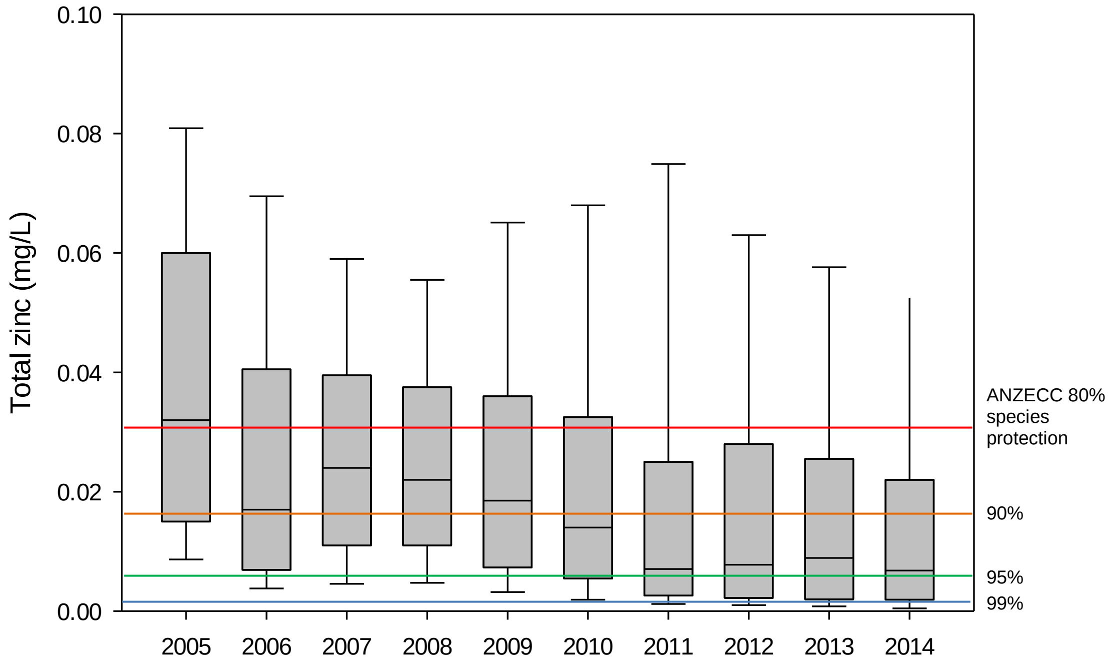
(p) Total copper



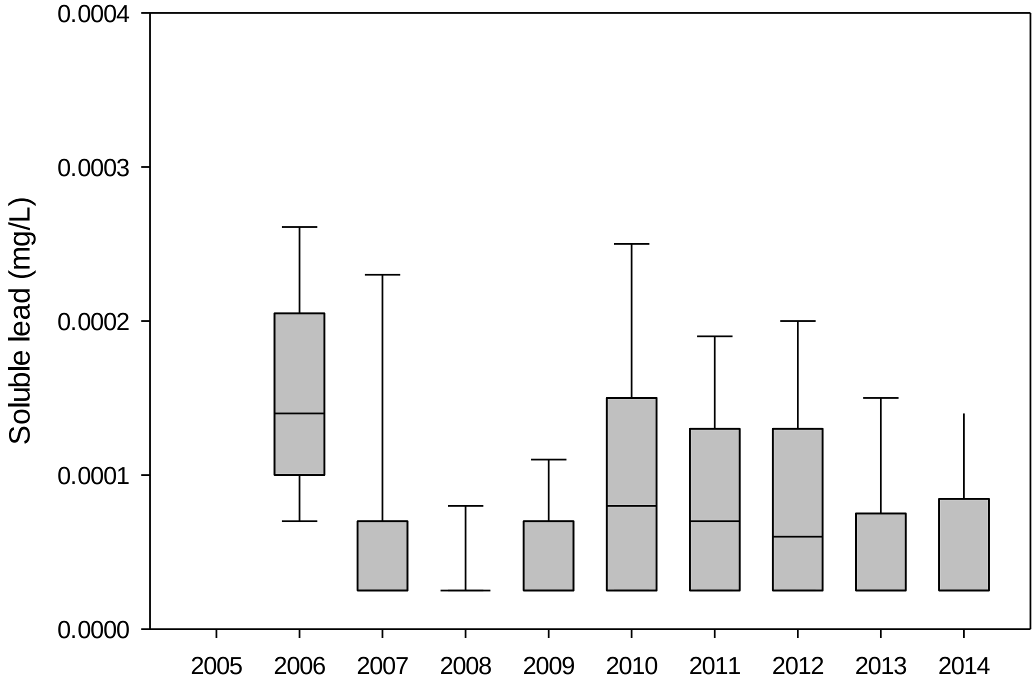
(q) Soluble zinc



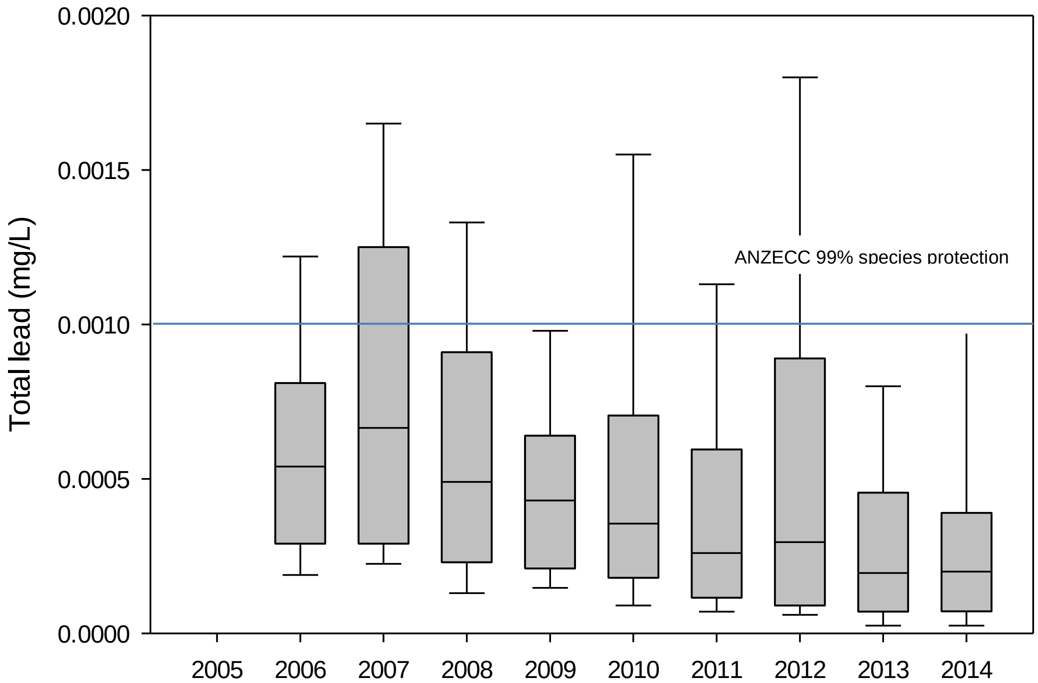
(r) Total zinc



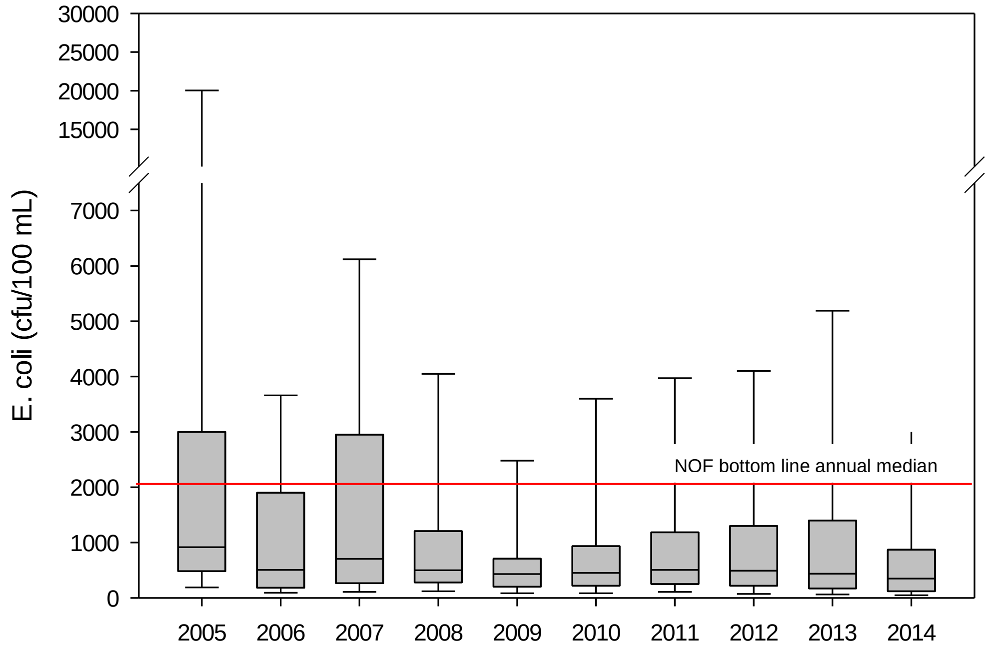
(s) Soluble lead



(t) Total lead



(u) Escherichia coli (E. coli)



5 Water quality trends

Trend analysis was carried out using the R stats package (R Core Team, 2013). The Wq (water quality) package within R was used to undertake a Seasonal Kendall test, a seasonally adjusted non-parametric method which is based on two key measures (Helsel and Hirsch, 1992; Ballantine, 2012):

a) The Sen Slope: this represents the magnitude and direction of trends in the data. Sen Slope values are standardised by dividing by the median value of the raw data, and expressing it as a percent annual change. This standardisation allows direct comparison of rates of change between different sites; however care should be taken when comparing the results between different parameters because the magnitude of a standardised slope depends on the typical values of the parameter in question (e.g. a rate of change can be large where typical parameter concentrations are low, and small where typical concentrations are high). Caution should also be used in interpreting Sen Slope values where there are large amounts of censored data (i.e. below laboratory detection limits) as the median value can become skewed.

b) The Seasonal Kendall trend test: this determines the significance of the trend, at the 95% confidence level. A *P*-value is calculated based on the total number of increasing slopes compared with the total number of decreasing slopes. If the net result is close to zero, the *P*-value will be large and thus 'not significant' and conversely a large difference between the occurrence of increasing and decreasing slopes produces a low *P*-value. Caution should be used in interpreting *P* values as the larger a data set, the more likely a 'significant' *P*-value ($P < 0.05$) will be calculated. Therefore, it is prudent to assess the raw data to ensure 'significant' *P*-values represent real trends.

Seasonality is a major source of variability in water quality data. The Seasonal Kendall test only compares water quality values that were collected during the same month of each year. Individual tests are performed for individual seasons (months) of the year, and then combined into a single test to determine if there is a trend over time.

A statistically significant trend does not necessarily indicate an 'environmentally meaningful' trend (that is likely to be relevant in a management sense), and as such, the trends in this report are categorised as recommended by Scarsbrook (2006) and Ballantine (2012). An environmentally meaningful trend occurs when the percent annual change is statistically significant and has an absolute magnitude greater than1% per year. This value is used because a 1% change per annum corresponds to a 10% change per decade, which is likely to be noticeable to public water users within a human lifespan (Ballantine and Davies-Colley, 2009).

The following Seasonal Kendall trend analyses were carried out on the data using the R stats package (R Core Team, 2013):

(a) Regional trend analysis for each parameter (across all sites, not flow adjusted)

(b) Land use trend analysis for each parameter (urban, rural, exotic forest and native forest, not flow adjusted)

(c) Individual trend analysis at each site for each parameter (not flow adjusted).

Trend analysis was carried out from 2005-2014 (inclusive) at sites where there was at least 10 years of data available, and also at sites where there was greater than 5 years data (but less than 10). There were 23 sites with at least 10 years of data and 6 sites with 6 years of data. The sites and their corresponding data records for trend analysis are shown in Table 1.

The following points and assumptions were made in the analysis of the water quality data:

- Data that were reported as below the laboratory detection limit were replaced by a value of half the detection limit value (Chapman, 1996). For example, a value reported as less than a 1 mg/L limit of detection would be included in the data analysis as 0.5 mg/L.
- More than 50% of the soluble lead data was censored (i.e. below laboratory detection limit and given a 'less than' value) therefore the reliability of any trends would be questionable. For this reason, trend analysis was not performed on soluble lead.
- For the majority of sites there was a complete data set (120 data points i.e. 12 sampling occasions per year from 2005-2014). The maximum number of missing data points at any given site was three, which was not considered high enough to exclude a site for the water quality regional assessment.
- The data set for total nitrogen at all sites is shorter, as monitoring for this parameter only began in 2009.
- pH data is missing from all sites in 2009 and 2010 however trend analysis was still carried out for this parameter.

5.1 Water quality trends results and discussion

Seasonally adjusted water quality trends for the period 2005-2014 are shown for each parameter on a regional scale, a dominant catchment land use scale and a site specific scale. The trend information is displayed graphically with the parameters on the y axis and the percent annual change on the x axis. The significance of the trend is illustrated as a square symbol for non-significant trends and a circle for statistically significant trends at the 95% level ($P<0.05$); the colour of the circle indicates the strength of the significance (yellow: $P<0.05$, orange: $P<0.01$ and red: $P<0.001$, the lower the P value the higher the level of significance of the trend). The 1% annual change threshold for an environmentally meaningful trend is also shown as two vertical dotted lines on each graph.

5.1.1 Regional trends

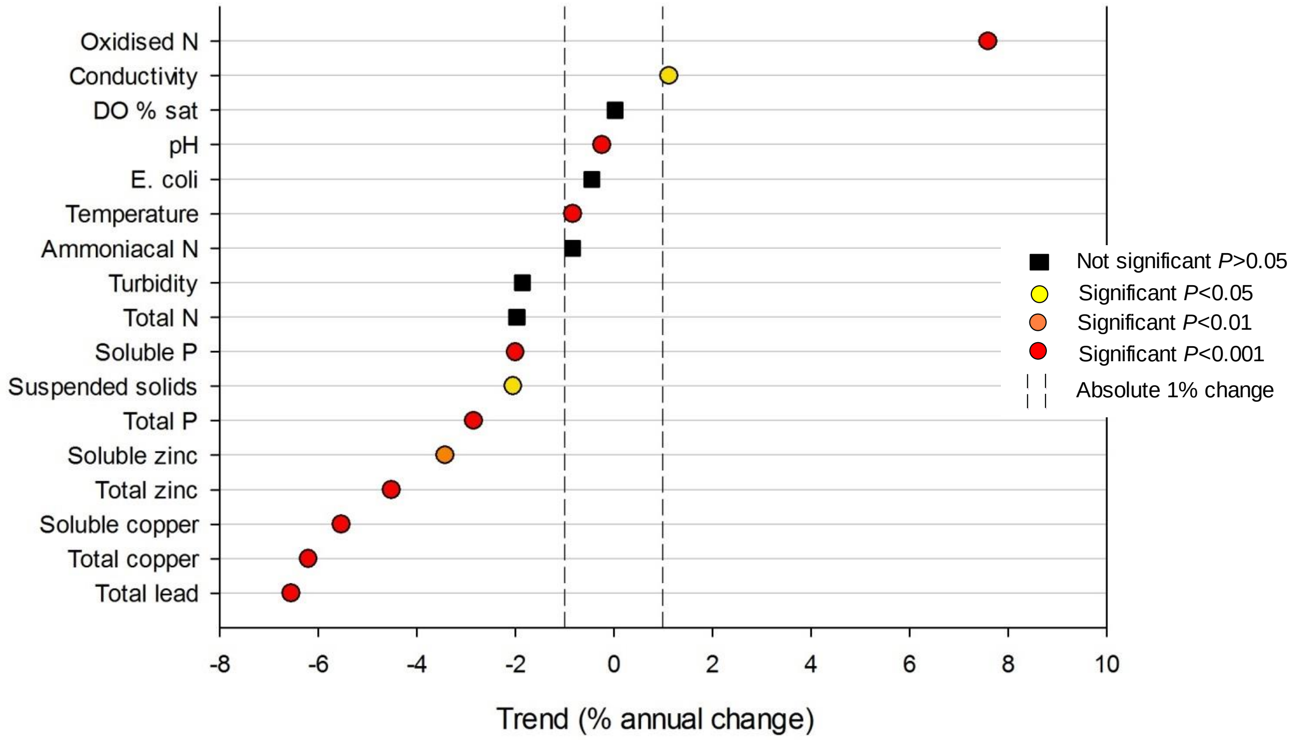
At a regional level the only notable increasing trend was for oxidised N (Figure 3). This was unexpected since a number of individual sites had decreasing trends for oxidised N. The explanation for this trend at the regional scale is the inclusion of the Whangamaire Stream from 2009 onwards (the trend analysis starts from 2005). Oxidised N concentrations in the Whangamaire Stream are an order of magnitude greater than most other sites in the region, so its addition to the programme from 2009 creates the appearance of an increasing trend. While this can be explained by the addition of a site and is not a real trend, it highlights the magnitude of the oxidised N concentrations at this site, and the need for nutrient management in its surrounding catchment.

There was a weak decreasing trend in total suspended solids. This could be partially attributed to reduced erosion, particularly in urban areas where the area of impervious surface is increasing with residential and industrial development. It also should be noted that the largest sediment depositions occur during rainfall events, and the water quality sampling regime occurs monthly and does not target these events. Over time this results in the random capture of some rainfall events and not others, thus giving an incomplete picture of the total suspended sediment levels in rivers.

There were also significant decreasing trends in total and soluble phosphorus. This is supported by the decreasing trend in total suspended solids, and could be partially attributed to a decline in the amount of sediment-associated phosphorus transported to streams. Another (stronger) likelihood is that the decreasing trend is due to a reduction in the detection limit (for both total and soluble phosphorus) in 2008-2009.

There were significant, meaningful decreasing trends in all the metal species, suggesting that from a regional perspective, water quality is improving. However, care should be taken in the interpretation of these regional trends because, apart from cases such as the total oxidised N described above, regional trend analysis does not generally highlight or take into account important site specific issues.

Figure 3: Auckland Council river water quality programme trend analysis at a *Regional* level



5.1.2 Land use trends

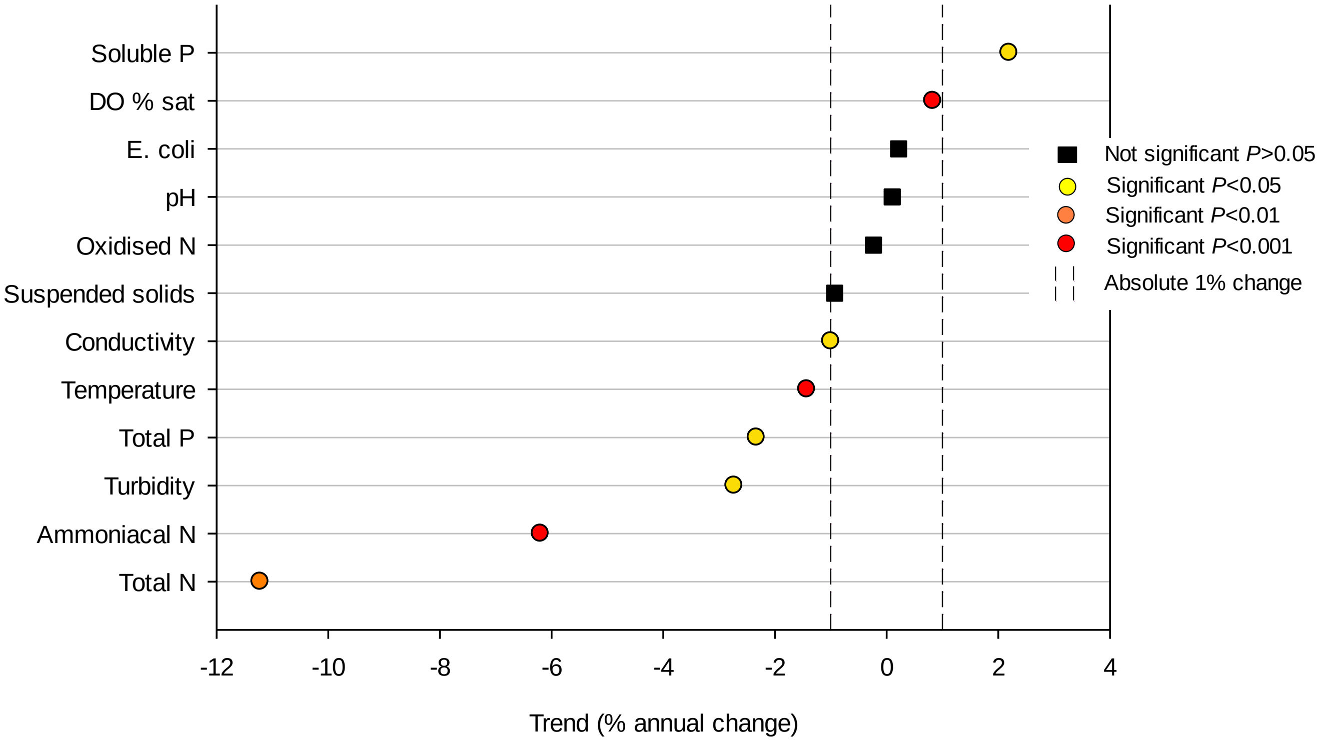
Native forest:

In the native forest streams there is a small increasing trend in soluble P, yet a decreasing trend in total P (Figure 4). This could be a result of in stream cycling of unavailable forms of P into the soluble form. So while the total amount of P in the system is declining, in stream cycling could continue to release more soluble P into the water column.

There are also significant decreasing trends in total and ammoniacal N in both native forest and exotic forest streams (Figure 4 and Figure 5). The decreasing trend in ammoniacal N can be seen as a positive outcome for improving water quality as far as decreasing the availability of bioavailable nitrogen for algae growth (notwithstanding the conflicting soluble phosphorus trend mentioned above). However, the fact that total oxidised N does not show the same decreasing trend (and in fact is increasing under exotic forest land use) suggests that there is a decreasing amount of *organic* N coming off the land.

The dominant transport pathway for total oxidised N (consisting mainly of nitrate-N) in streams is via leaching. The dominant pathway for organic and ammoniacal N is via overland flow and benthic sediment associated N. This may suggest there is a decreasing trend in sediment and associated nutrient loss in these land use systems, however counteracting this is the fact there is no trend in total suspended solids. Another possibility could be changes to the dynamics of in-stream N cycling. For example there could be anaerobic conditions in the benthic sediment and rapid denitrification of nitrate, resulting in gaseous loss of nitrogen. Anaerobic conditions are also favourable for dissimilatory reduction of nitrate to ammonia (DRNA), resulting in emission of the resulting ammonia gas.

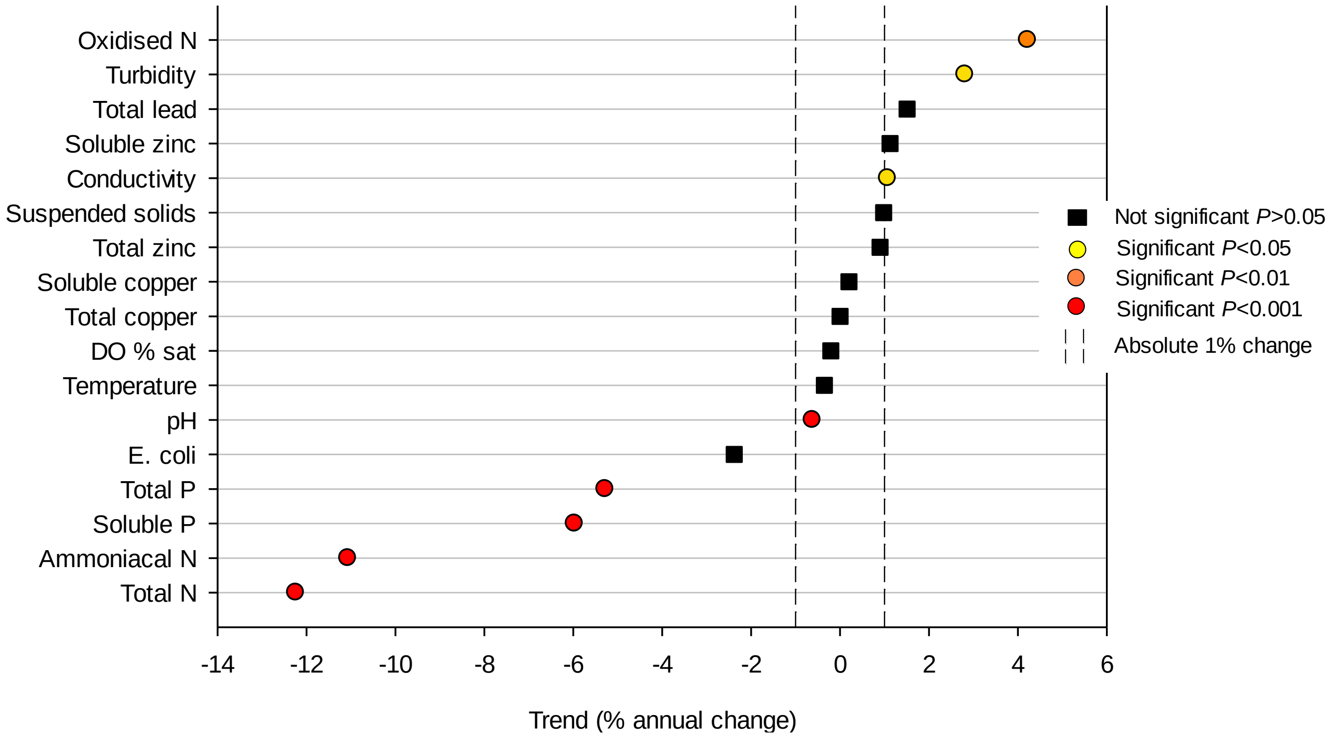
Figure 4: Auckland Council river water quality programme trend analysis at a *Land use* scale for native forest streams.



Exotic forest:

There are increasing trends in oxidised N and turbidity under exotic forest land use (Figure 5). The increasing turbidity could be associated with sediment loss, particularly if harvesting has recently occurred. However, we do not observe an increasing trend in total suspended solids, so the potential reasons behind this turbidity trend require more investigation. The increasing oxidised N concentrations could be a result of increased N fertiliser application or fertiliser application regimes. On the other hand there were significant decreasing trends in soluble and total P, ammoniacal N and total N suggesting a reduction in the amount of N and P nutrients lost from the land. It should be noted there are only 2 sites in the monitoring programme under exotic forest land use, so these results are not necessarily an accurate representation of exotic forestry land use on the whole.

Figure 5: Auckland Council river water quality programme trend analysis at a *Land use* scale for exotic forest streams.

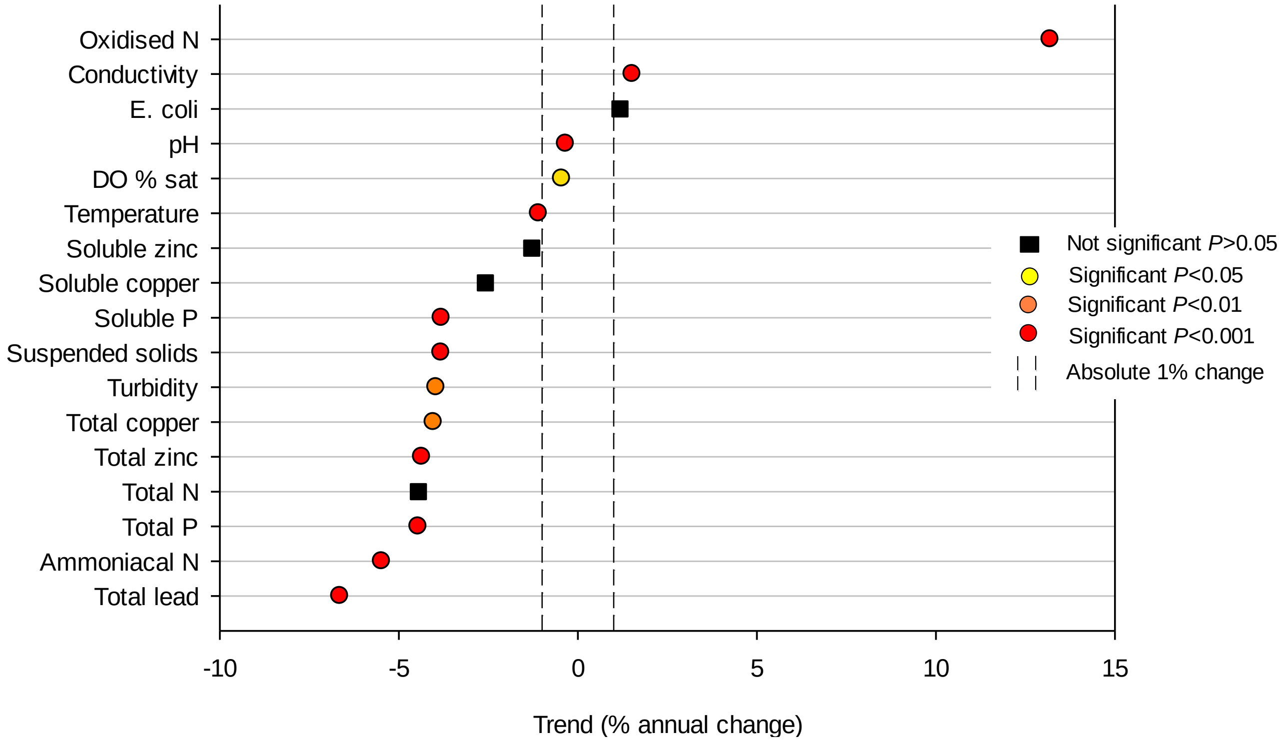


Rural:

There was a significant increasing trend in oxidised N in the rural streams (Figure 6). As with the regional trend analysis, this observation is solely due to the addition of the Whangamaire Stream to the site list in 2009, and its comparatively high oxidised N concentrations have given the impression of an increasing trend when this is in fact not the case.

There were decreasing trends in many other parameters including all metals (except soluble zinc), suspended solids, turbidity, total P, soluble P and ammoniacal N. This all suggests improving water quality in Auckland's rural streams through reduction in the loss of sediment, nutrients and metals to water. This could potentially be through improvements in rural land management on a regional scale (not withstanding some site specific issues) including, but not limited to reductions in stock access to waterways, reductions in stock density, reductions in the time that land is fallow, improvements in fertiliser use efficiency and nutrient budgeting and improvements in effluent management.

Figure 6: Auckland Council river water quality programme trend analysis at a *Land use* scale for rural streams.

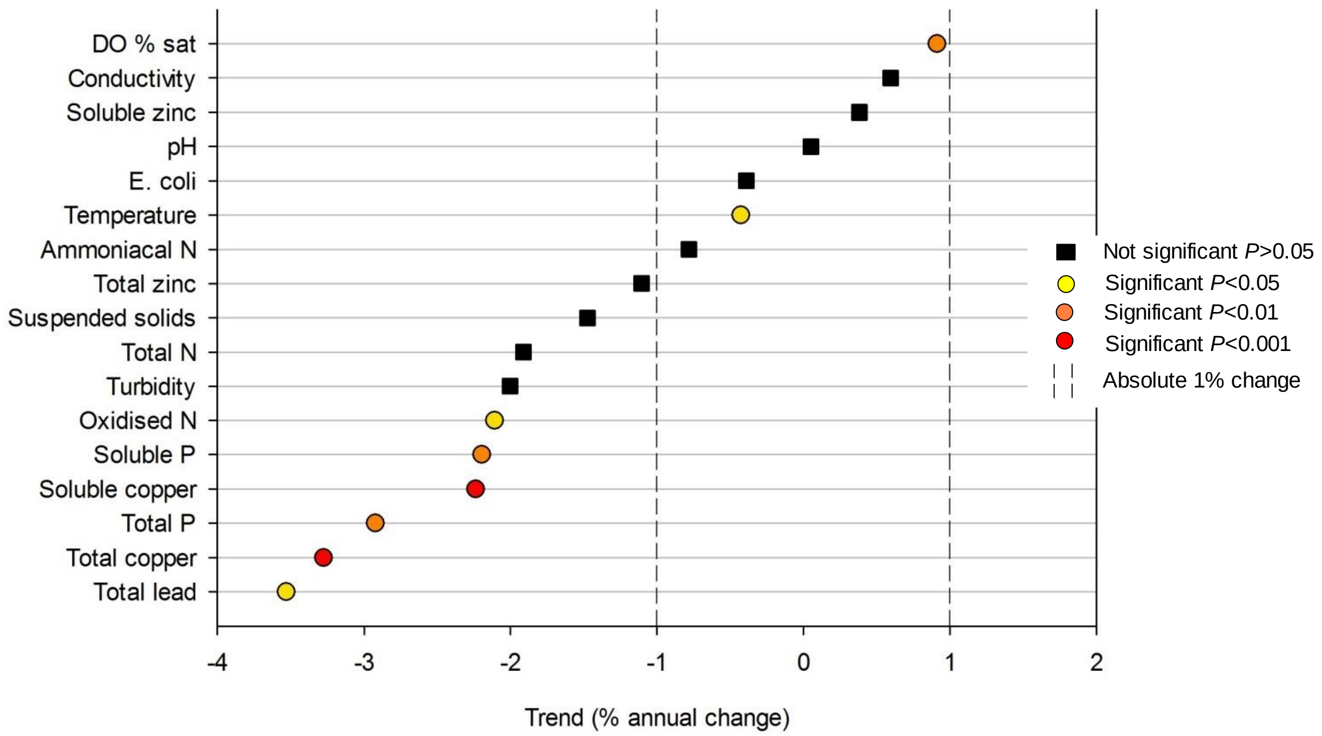


Urban:

In the urban environment there are no increasing trends for any parameters. Total and soluble copper and total lead concentrations are significantly decreasing, suggesting improving water quality (Figure 7). Total and soluble zinc show no trend at the urban land use scale, however decreasing trends in these parameters are observed in a number of the individual urban sites.

In an urban environment, there are a myriad of different contaminants and stressors from a wide range of sources that can affect a stream at any given time. It is therefore very challenging to directly pinpoint individual sources and locations of contaminant entry to these streams. On the other hand, it is also very challenging to pinpoint locations of contaminant reduction and distinct reasons for water quality improvement. Potential reasons for decreasing trends can be and are speculated on in the detailed site specific trends in Section 5.1.3; however, it should be noted that any speculations are not able to be validated for the purposes of this report.

Figure 7: Auckland Council river water quality programme trend analysis at a *Land use* scale for urban streams.



5.1.3 Site specific trends

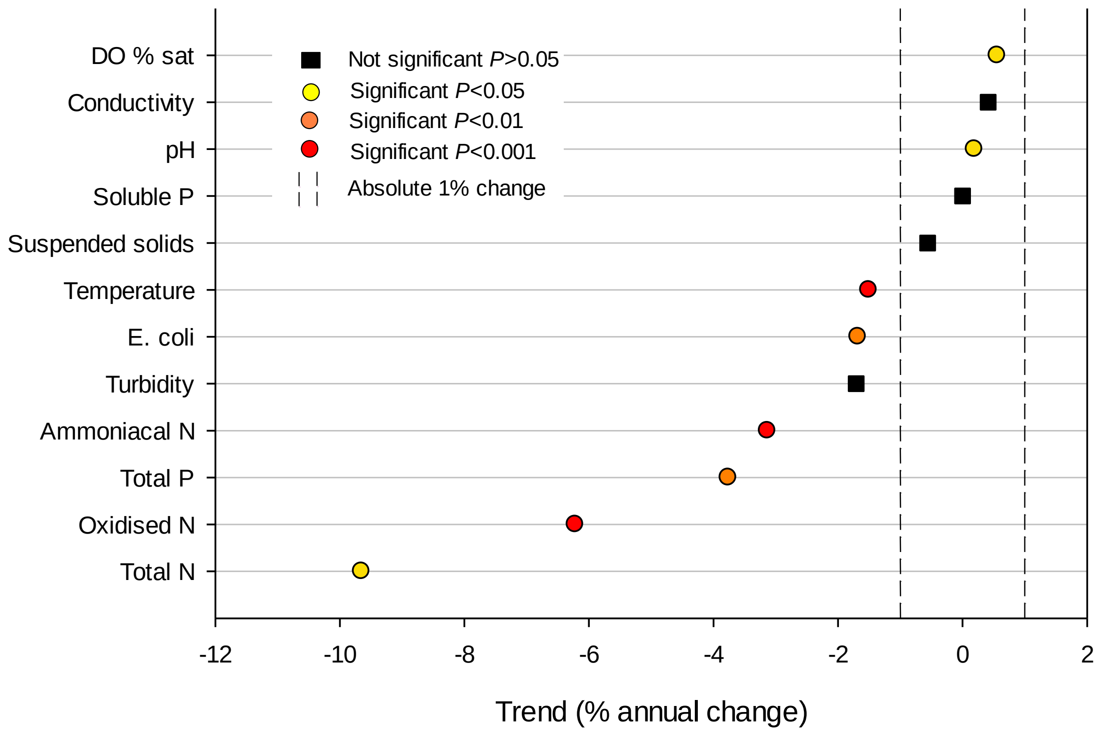
Cascades Stream (Waitakere Ranges, native forest)

There are considerable decreasing trends in all forms of N and total P in the Cascades stream. While these trends would suggest improving water quality in a catchment impacted by human land use, this result is unexpected in a native forest site with no known additional nutrient inputs. The decreasing trends in the various forms of N and total P are from a baseline of very low concentrations and could be due to a wide range of factors. Some of these could include a reduction in litter and other detritus entering the stream, or changes in in-stream benthic N and P cycling dynamics.

The declining trend in temperature could be due to increased shade resulting from changes to the surrounding tree canopy over time.

Sources of *E.coli* in native bush catchments are generally incidental as a result of animal droppings in or nearby the water. Recent research also shows that *E.coli* can replicate in aquatic environments (Devane et al., 2006) which has the potential to generate misleading results and trends.

Figure 8: Auckland Council River Water Quality Programme trend analysis for Cascades Stream from 2005-2014.

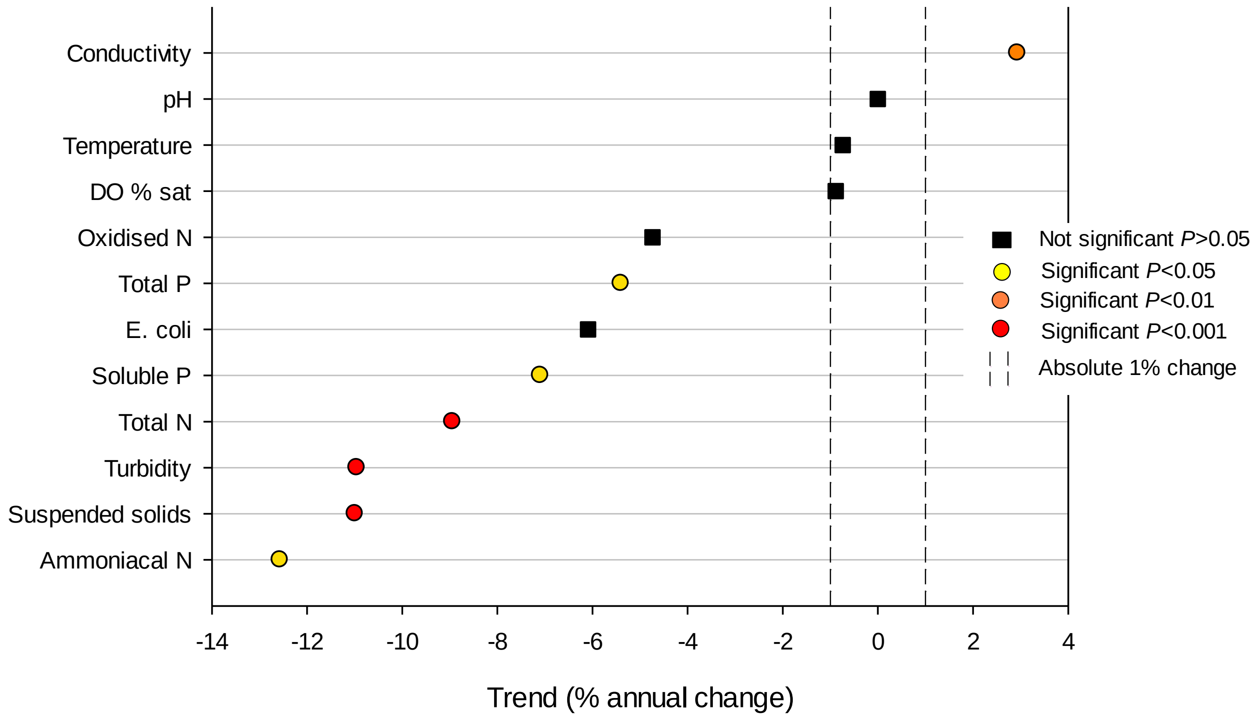


Kaukapakapa River (rural)

There are decreasing trends in total P, soluble P, total N, ammoniacal N, suspended solids and turbidity, suggesting improving water quality in this stream.

There is also an increasing trend in conductivity. Conductivity is primarily influenced by the geology and soils of the surrounding catchment, and as such, is generally expected to remain within a specific range. The increasing trend in conductivity observed here could be due to changes in catchment land use, specifically, increased urbanisation in the catchment and increased vehicle use associated with this. An increase in urban and industrial pollutants can increase conductivity. One way to gain further insight is to measure copper and zinc concentrations in the stream. If metal concentrations are above natural background concentrations and increase over time, this may further indicate that increasing urbanisation could be having an effect on water quality.

Figure 9: Auckland Council River Water Quality Programme trend analysis for the Kaukapakapa River from 2009-2014.



Kumeu River (rural)

The Kumeu River has decreasing levels of all the nutrients (all forms of N and P), turbidity and total copper. This is a clear improving trend in water quality with regards to N and P and may be attributed to lower fertiliser applications and improved fertiliser management in the catchment. It could also be influenced by increasing urbanisation in the Kumeu catchment, and therefore decreasing rural land use. The fact that there is a decreasing trend in total copper, but no trends in other metals could be linked to reductions in the rural sources of this metal entering streams, namely copper based fungicides and pesticides used on crops and orchards.

While there is a decreasing trend in turbidity and no significant trend in suspended solids, the two variables show similar characteristics over time (Figure 11).

Figure 10: Auckland Council River Water Quality Programme trend analysis for the Kumeu River from 2005-2014.

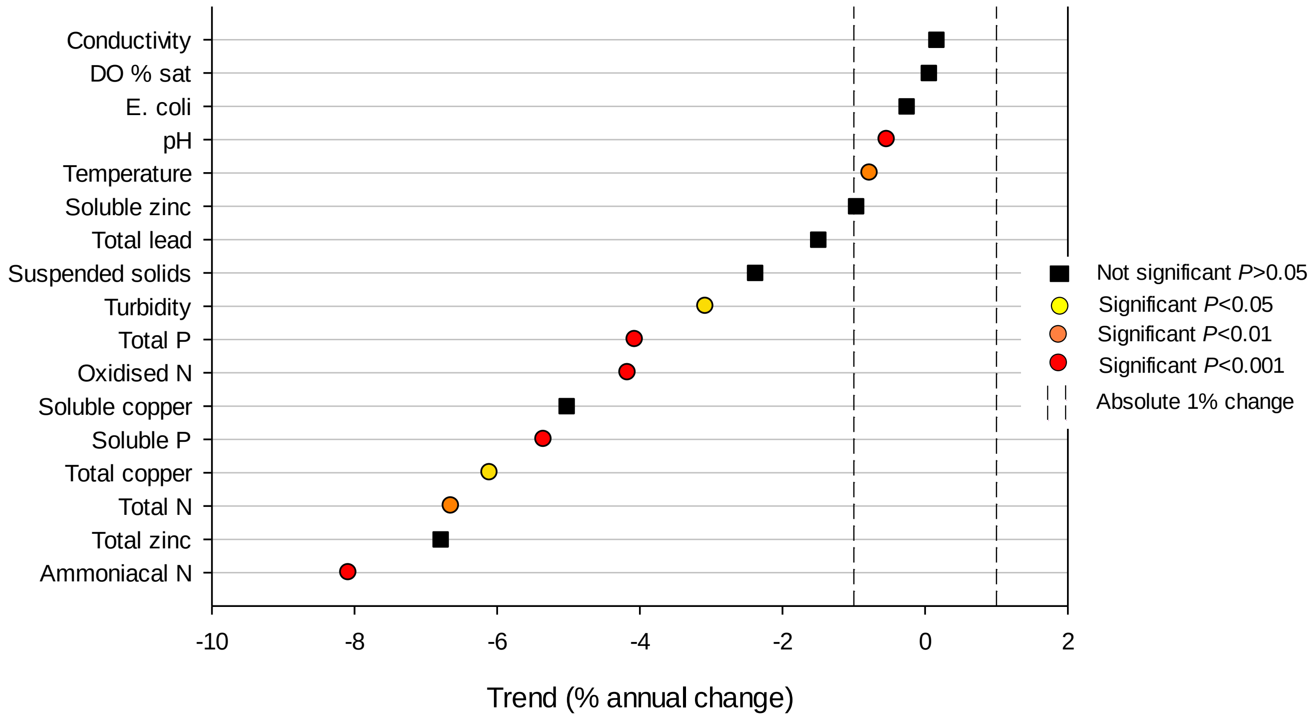
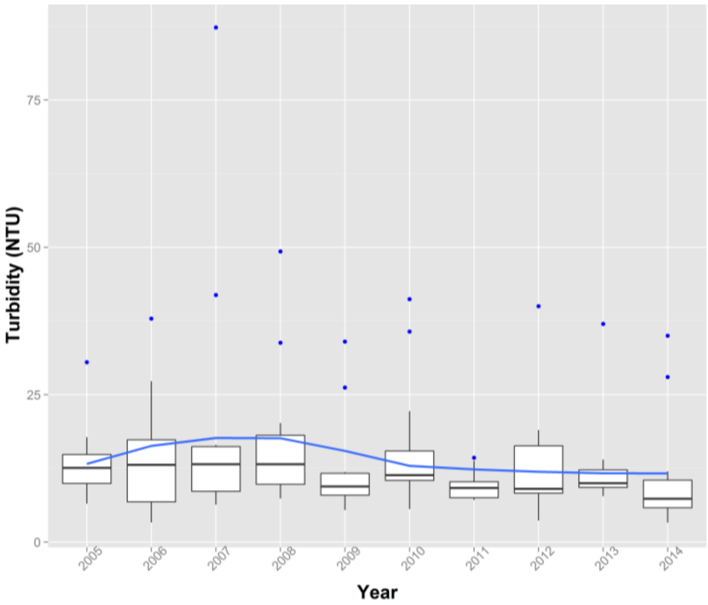
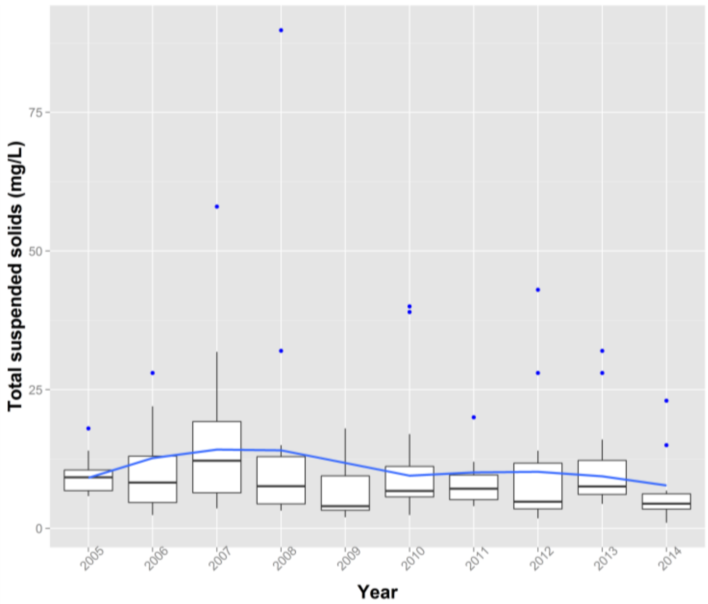


Figure 11: Box plot showing annual trend data for turbidity and total suspended solids in the Kumeu River

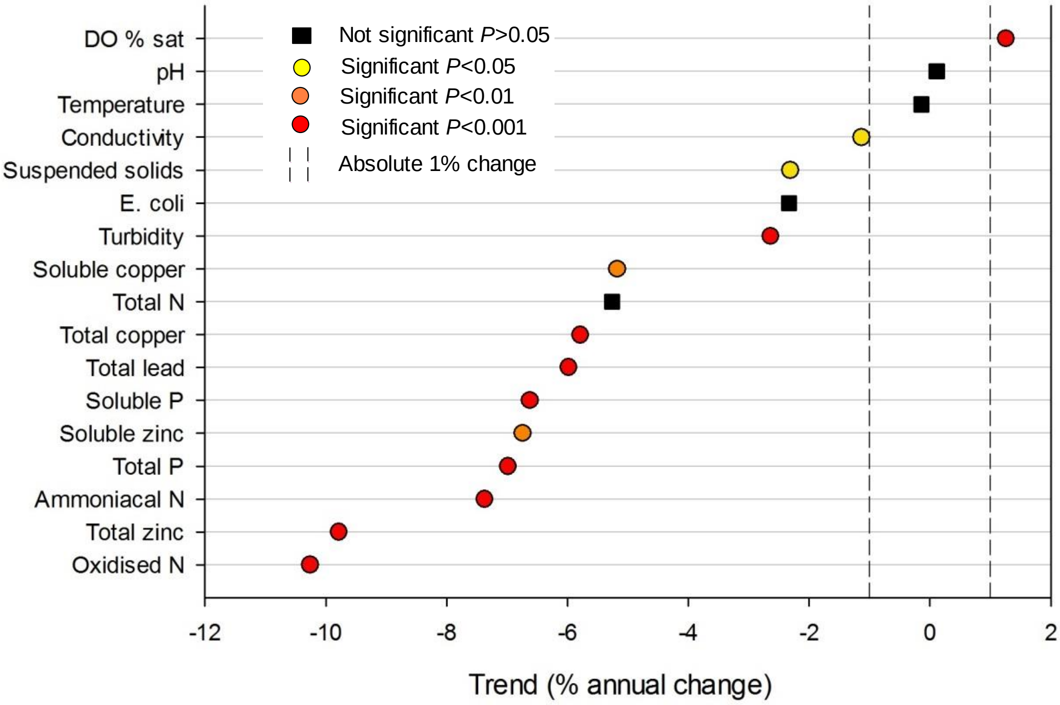




Lucas Creek (urban)

There are considerable and significant decreasing trends in nearly all water quality parameters in the Lucas Creek with the exception of E. coli, total N, temperature and pH. There is also a small but significant increase in dissolved oxygen percent saturation. All of these trends indicate improving water quality over time in the Lucas Creek.

Figure 12: Auckland Council River Water Quality Programme trend analysis for the Lucas Creek from 2005-2014.



Mahurangi River (Forestry Headquarters, exotic forest)

There is a decreasing trend in all nutrients except oxidised N which shows a significant increasing trend. This increasing trend may be due to inorganic N fertiliser inputs to the forestry land. However, oxidised N may also be entering the stream via groundwater and this N may be from a wide range of sources and extend beyond the surface water catchment.

With increasing oxidised N concentrations, we would normally expect to see increasing total N concentrations, because the oxidised N makes up a proportion of the total N. However, the opposite is true in this case. This is probably due to the length of time in the trend analysis. Oxidised N has 10 years of trend data and increases up to 2011 then decreases thereafter with an overall increasing trend (Figure 14). Total N has only 5 years of trend data from 2009 and so the overall trend is decreasing (Figure 15).

Another possibility is that a large amount of mineralisation and nitrification is occurring in the stream sediment, despite an overall reduction of the total organic N in the stream.

Figure 13: Auckland Council River Water Quality Programme trend analysis for the Mahurangi River (FHQ) from 2005-2014.

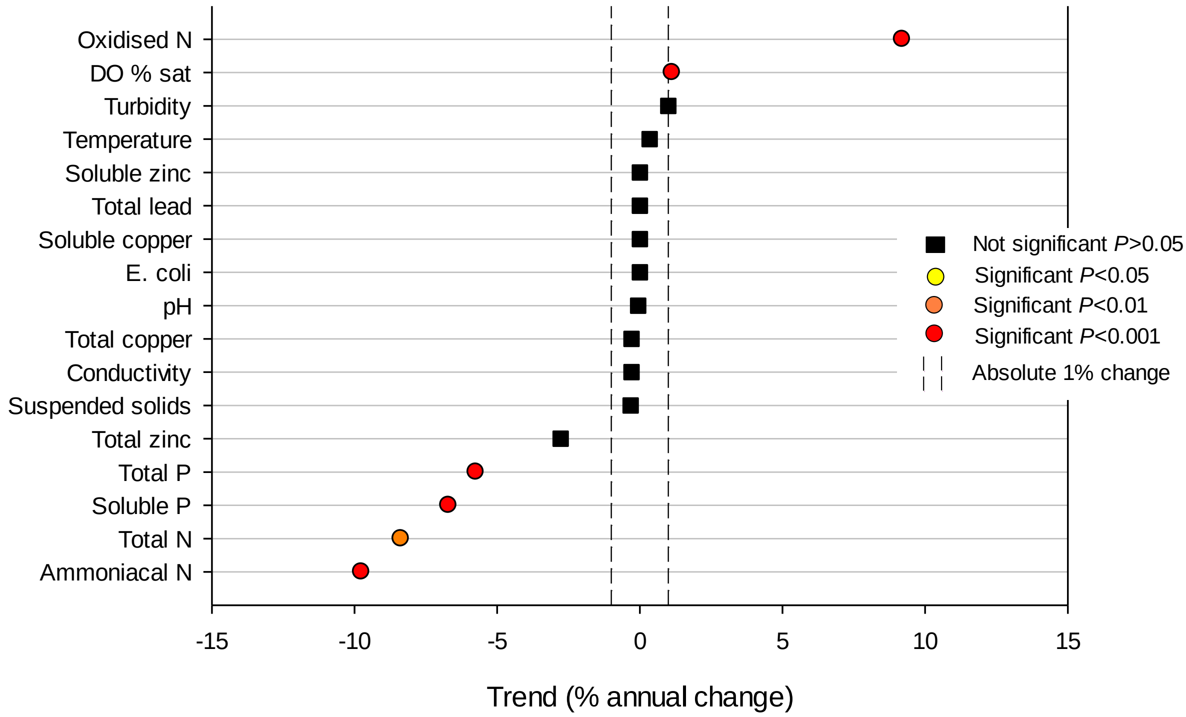


Figure 14: Box plot showing annual trend data for total oxidised N in the Mahurangi River (FHQ)

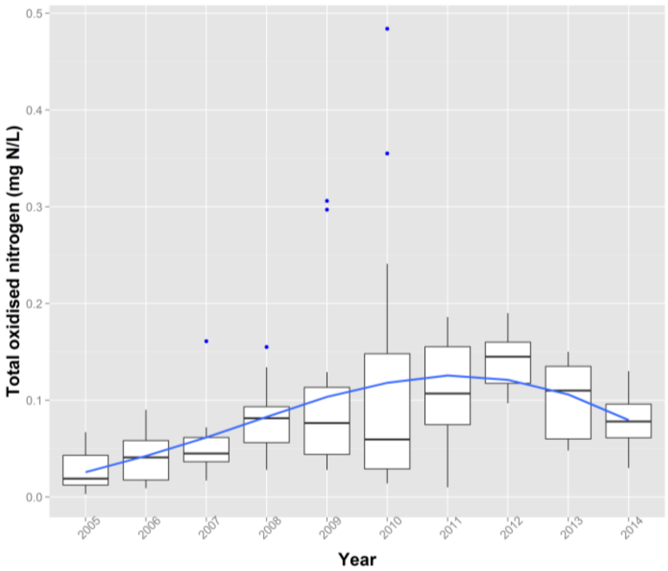
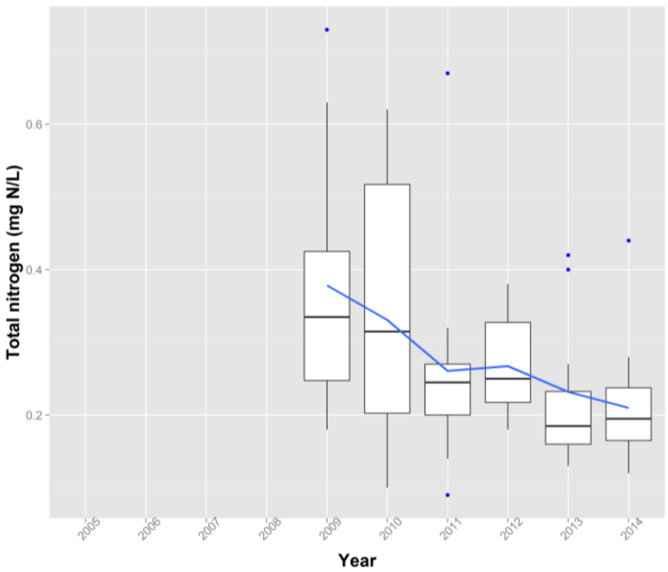


Figure 15: Box plot showing annual trend data for total N in the Mahurangi River (FHQ)



Mahurangi River (Water Supply, rural)

As with many of the other rural sites, there is a decreasing trend in nutrients (ammoniacal N, total N, soluble P and total P) indicating improving water quality through a reduction in loss of nutrients from the land. Decreasing trends were also observed in suspended solids, total lead, total copper and soluble copper, further indicating improving water quality.

These decreasing trends in nutrients may possibly be attributed to decreasing intensity of rural land use in the catchment resulting in lower fertiliser application rates and stocking densities. Increasing urbanisation in the catchment could also be resulting in decreased rural land use.

While there was a decreasing trend in suspended solids and no trend in turbidity, both data sets were similar over time (Figure 17a and b).

Although there were significant decreasing trends in some of the metals, these have only been monitored since 2009, and while the median values are decreasing over time, in some cases, such as soluble copper and total lead the trends may be affected by outliers (Figure 17c and d).

Figure 16: Auckland Council River Water Quality Programme trend analysis for the Mahurangi River (WS) from 2005-2014.

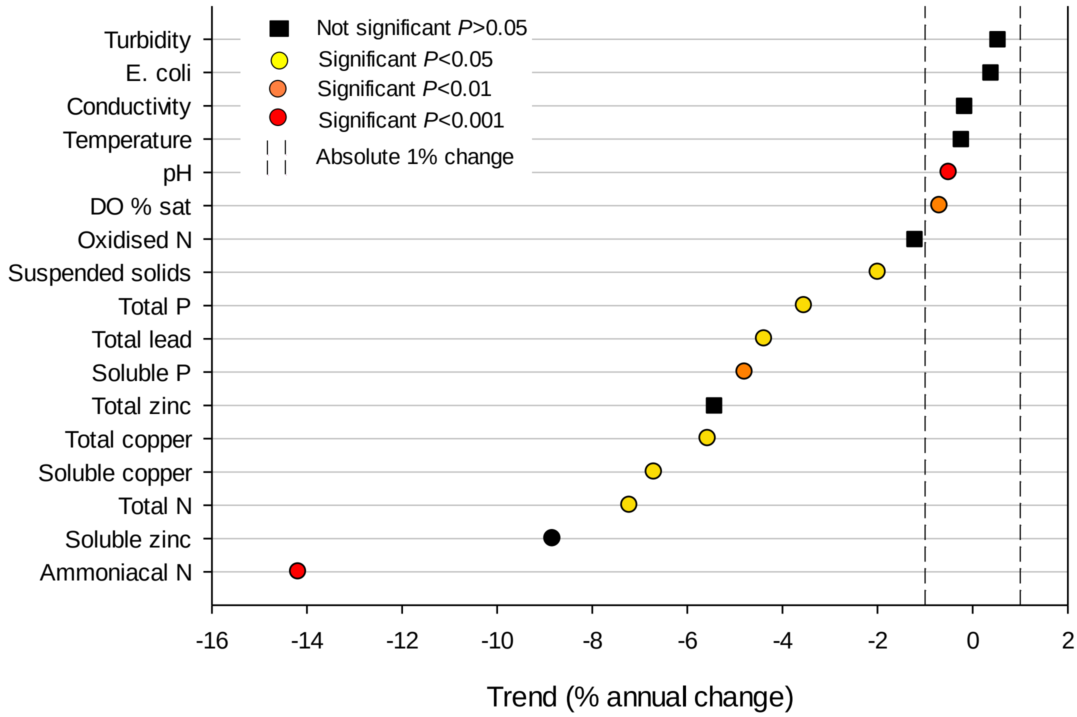
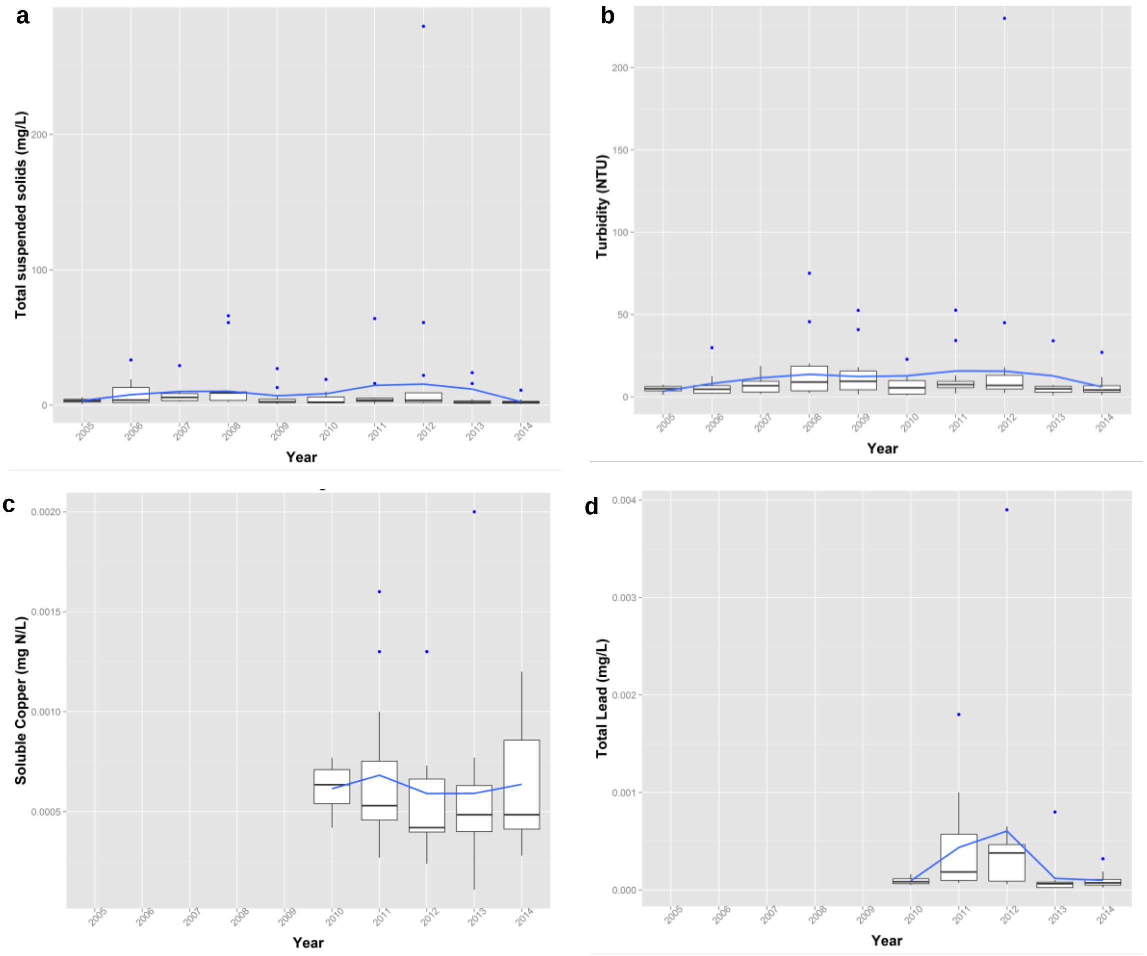


Figure 17: Box plot showing annual trend data for (a) total suspended solids, (b) turbidity, (c) soluble copper and (d) total lead in the Mahurangi River (WS)



Makarau River (rural)

There are decreasing trends in ammoniacal N, total N, and oxidised N suggesting a reduction in the total amount of N entering the stream system. There is no such trend for either total or soluble P; however, P concentrations are already low in the Makarau river (the maximum total P and soluble P values were 0.45 and 0.047 mg/L over the 10-year analysis period). There are also significant decreasing trends in suspended solids and turbidity, potentially suggesting improving water quality through reduced sediment inputs.

There were also decreasing trends in total lead, total copper, and E. coli, which is further indicative of improving water quality.

The increasing trend in conductivity is mainly due to lower and more variable conductivity readings in 2009 compared to subsequent years (Figure 19), therefore we cannot rule out incongruities with sampling equipment or calibration. Conductivity could be influenced by changes in catchment land use, particularly if agricultural land use has decreased in area and/or intensity. Metal concentrations at this site are not increasing, making it unlikely that conductivity is increasing in response to metals. However, there may be other unmonitored pollutants entering the river and influencing conductivity.

Figure 18: Auckland Council River Water Quality Programme trend analysis for the Makarau River from 2009-2014.

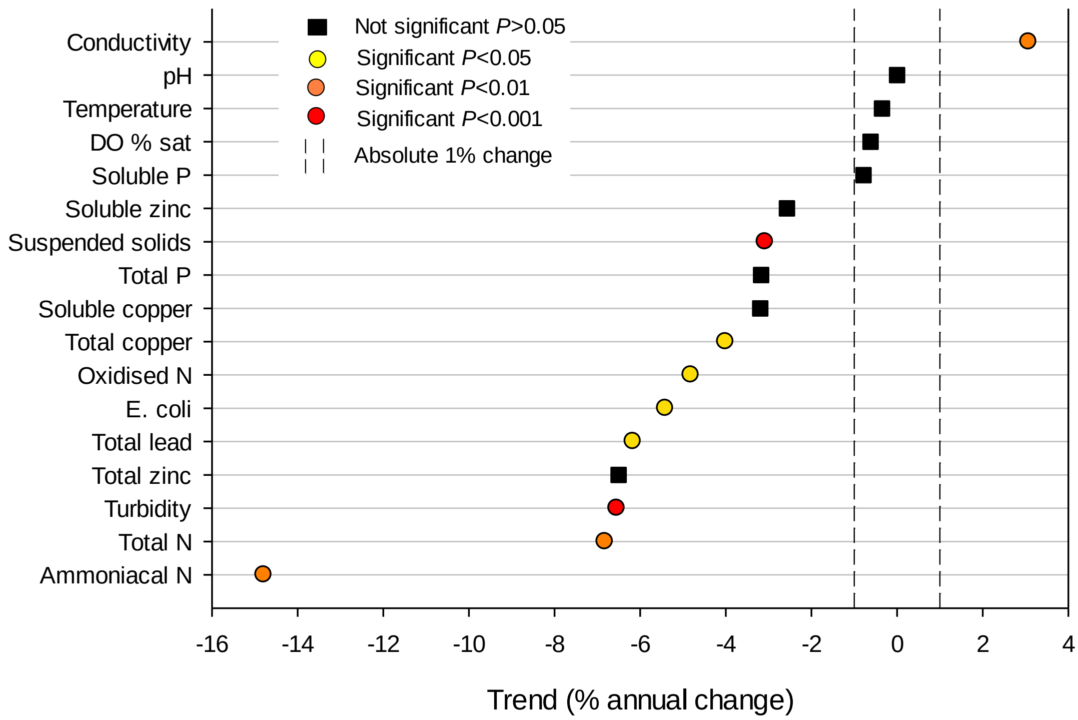
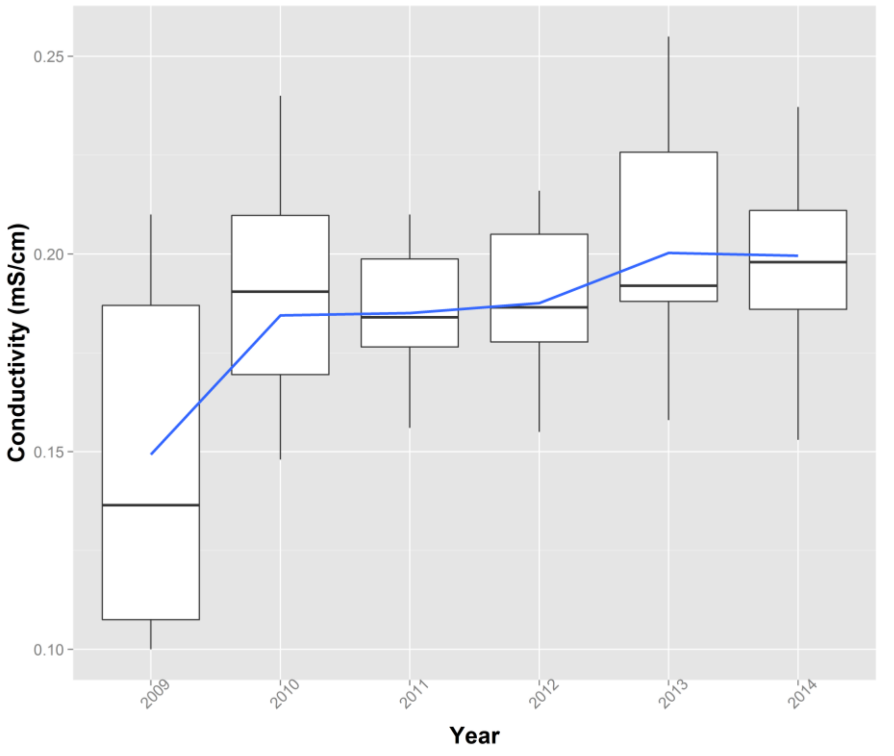


Figure 19: Box plot showing annual trend data for conductivity in the Makarau River (WS)

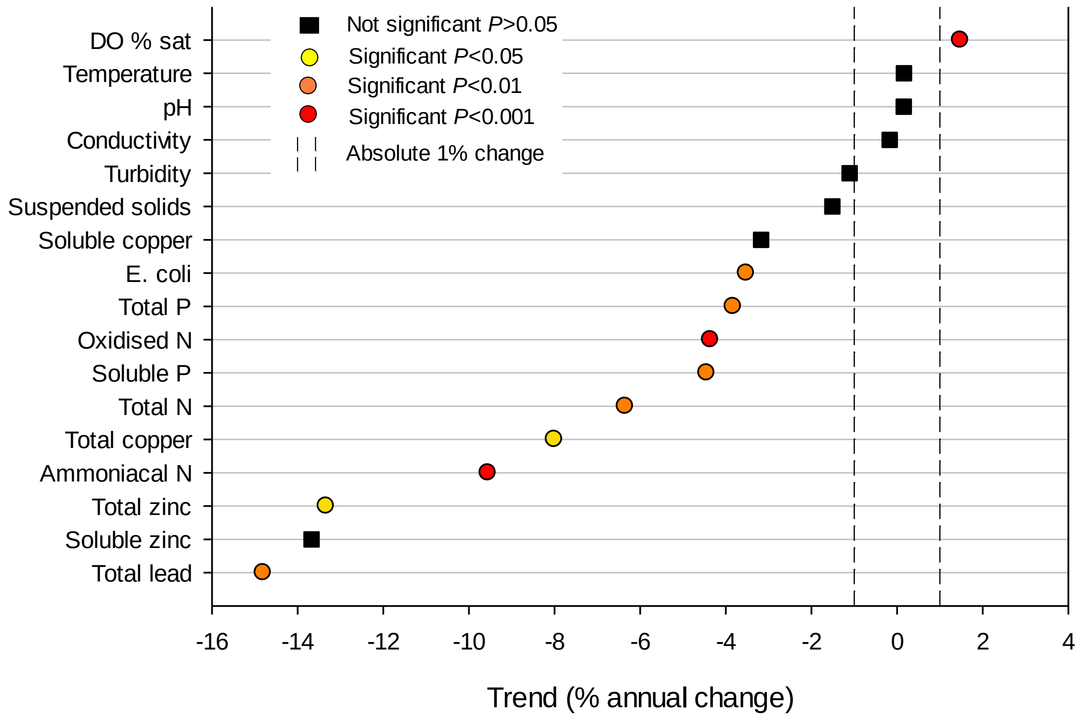


Matakana River (rural)

There are significant decreasing trends in all of the nutrient parameters (both N and P), as well as E. coli, total copper, total lead and total zinc. There is also a small but significant increase in dissolved oxygen percent saturation. This indicates improving water quality in the Matakana River.

As with some of the other rural streams in the Auckland region, these decreasing trends could possibly be related to decreasing intensity and/or improved environmental management of rural land use in the catchment (for example lower fertiliser application rates and stocking densities). Increasing urbanisation in the catchment could also be resulting in decreased rural land use.

Figure 20: Auckland Council River Water Quality Programme trend analysis for the Matakana River from 2005-2014.



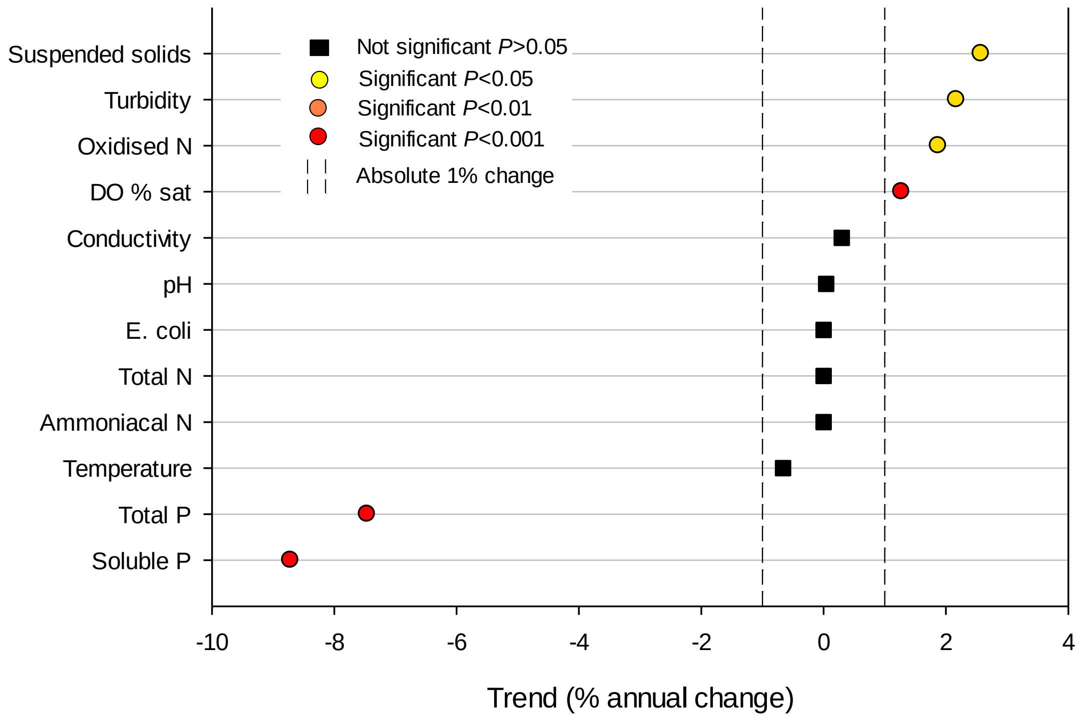
Ngakaroa Stream (rural)

There are significant decreasing trends in both forms of P in the Ngakaroa Stream, while turbidity and suspended solids are increasing. Phosphorus loss to streams is generally associated with erosion and sediment loss due to the way P binds to soil (particularly clay) particles. Therefore we would generally expect to see a decreasing trend in suspended sediment (and/or turbidity) alongside a decreasing trend in P, but in the Ngakaroa stream, the opposite is true.

This could be explained by reductions in the detection limit for total and soluble P between 2008 and 2009. Other possible reasons could include a considerable reduction in the application of P fertiliser higher in the catchment such that while sediment loss is increasing, the amount of P lost is much less. Another possibility is increased stream bank erosion, which would increase the sediment loss, but not necessarily P loss.

There is also an increasing trend in oxidised N. This is likely to be a result of increasing concentrations of nitrate entering the stream via groundwater influx. Concentrations of nitrate are increasing in the shallow volcanic aquifers in the Franklin region, resulting in increasing concentrations in groundwater-fed streams.

Figure 21: Auckland Council River Water Quality Programme trend analysis for the Ngakaroa Stream from 2005-2014.

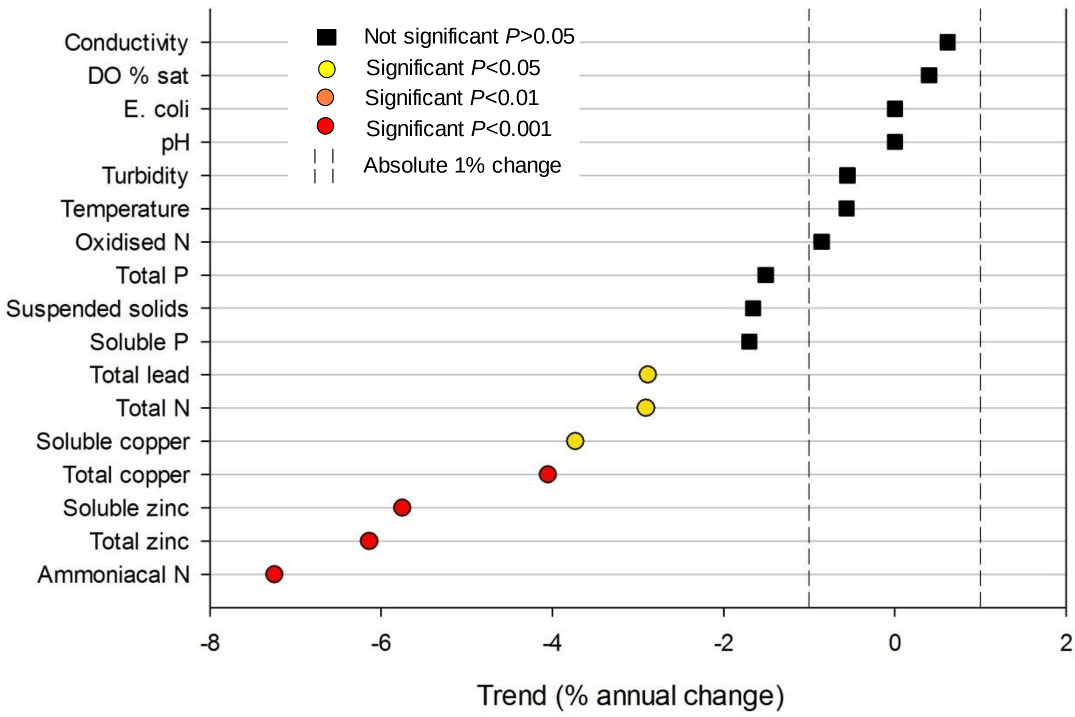


Oakley Creek (urban)

There are significant decreasing trends in all the metal species as well as total N and ammoniacal N. This suggests there are decreasing numbers of sources of these contaminants and/or decreasing amounts of contaminant discharged from sources.

The Oakley Creek catchment consists mainly of industrial and residential areas. The decreasing trend in zinc could partly be due to the increasing use of coated roof products in new buildings and roof replacements as opposed to uncoated or painted roof products. There are a myriad of different sources for copper in urban areas, however some of the well-known sources include vehicle brake pads, architectural copper (e.g. spouting), wood preservatives and pesticides. There may be reductions in some or all of these sources in the Oakley Creek catchment, and/or reductions due to historic land use operations (e.g. agriculture or timber yards) that are no longer occurring.

Figure 22: Auckland Council River Water Quality Programme trend analysis for the Oakley Creek from 2005-2014.



Okura Creek (rural)

There is an increasing trend in electrical conductivity which could potentially be due to the influence of sea water. The sample site at the Okura Creek could possibly be slightly tidally influenced, and while every effort is made to sample at low tide, there may be small amounts of salt water influencing the conductivity levels. Another possibility could be small amounts of sea level rise over time, slowly influencing conductivity levels.

There are considerable decreasing trends in suspended solids, turbidity, most metals, total N and total P suggesting improving water quality at this site.

The data suggests the decreasing trend in total P is not due to the reduction in the detection limit between 2008 and 2009, however it may be influenced by the unusually high total P concentrations observed in 2010 (Figure 24).

Figure 23: Auckland Council River Water Quality Programme trend analysis for the Okura Creek from 2005-2014.

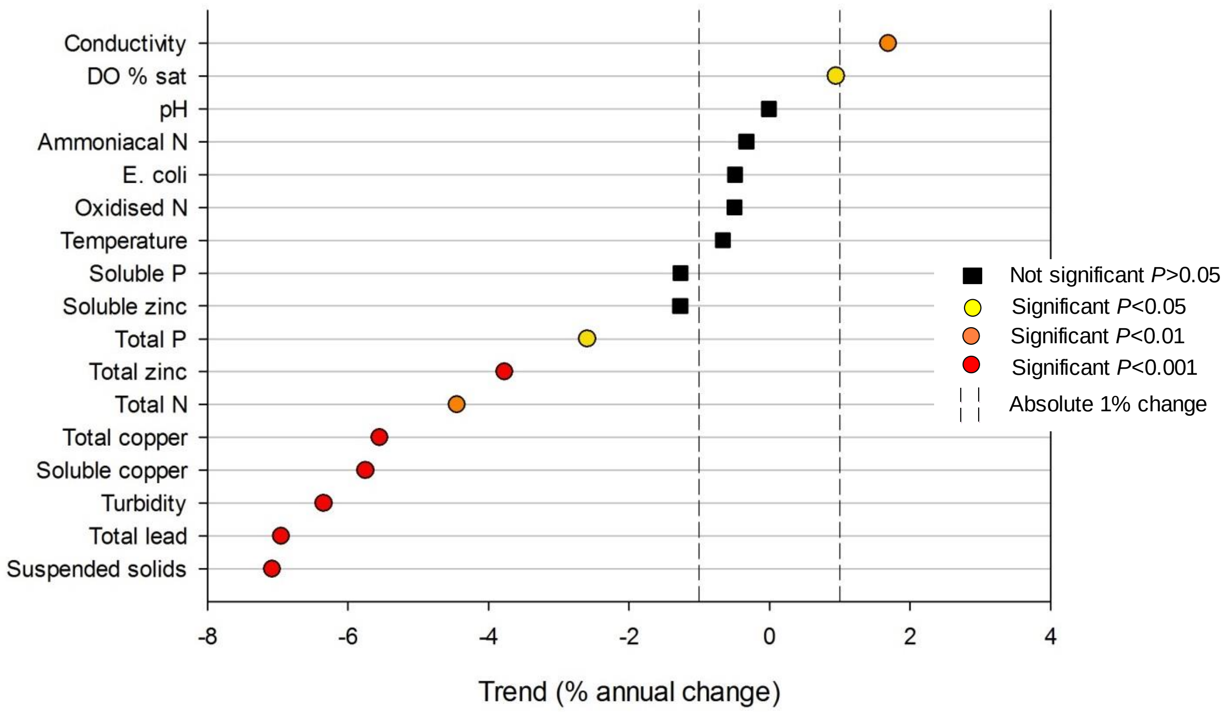
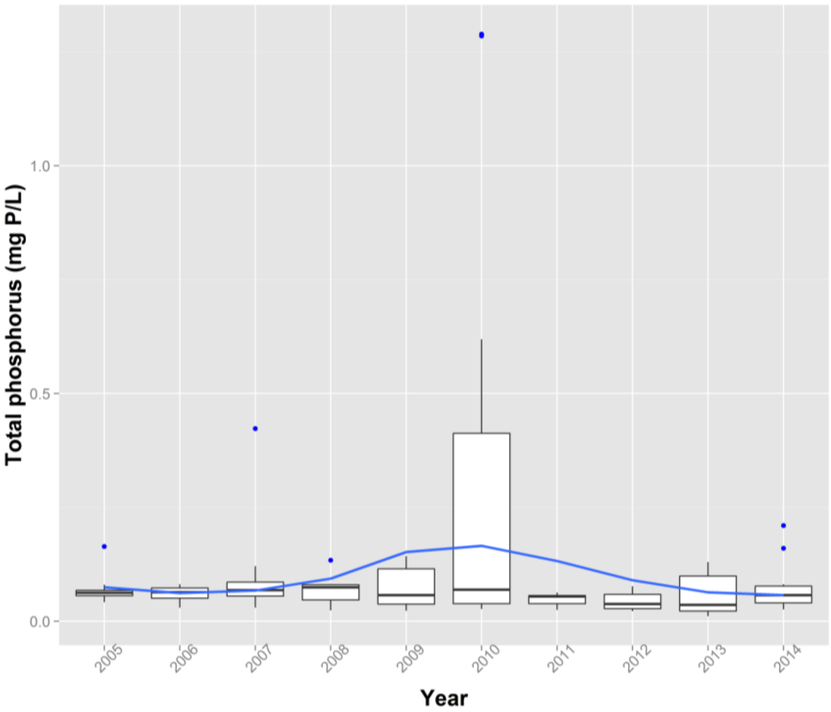


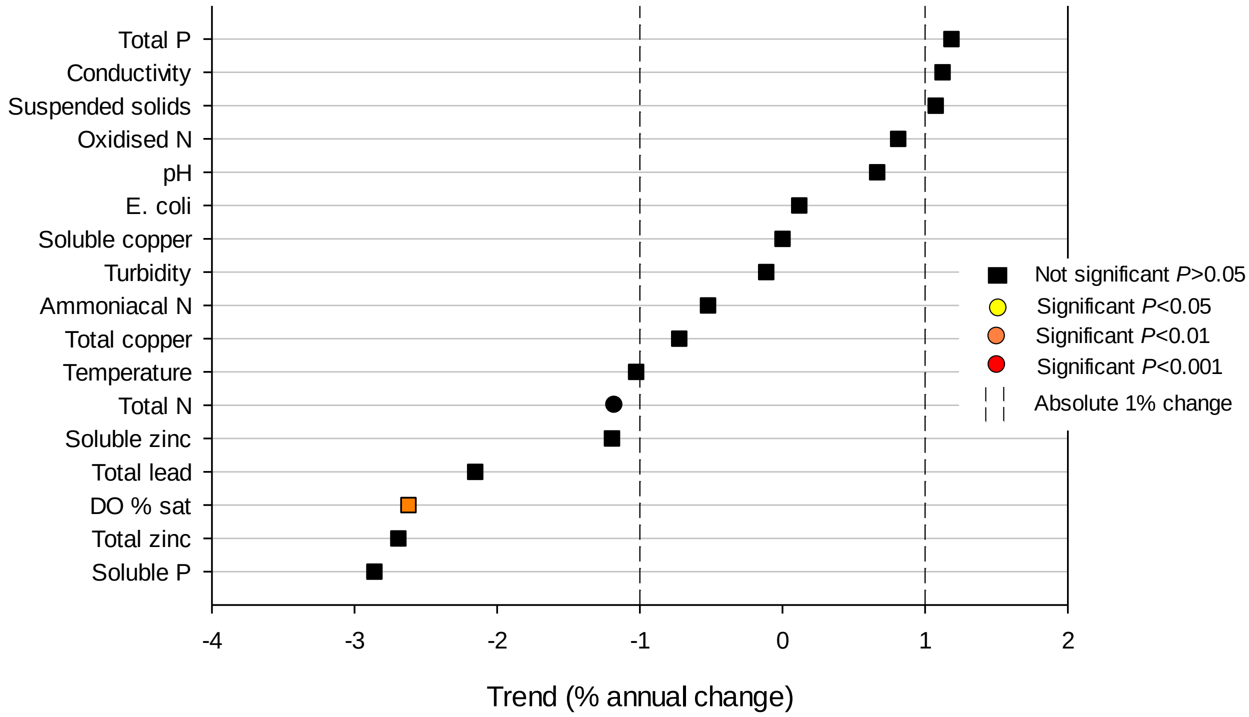
Figure 24: Box plot showing annual trend data for total phosphorus in the Okura Creek.



Omaru Creek (urban)

There is only one statistically significant trend in the Omaru Creek which is a decline in dissolved oxygen levels suggesting declining water quality overall. This declining trend is from an already highly degraded baseline (Holland and Buckthought, 2015), thus making an already poor quality stream slightly worse. The lack of any other discernible trends suggests there has not been a large amount of land use and/or behaviour change in the last 10 years in this catchment.

Figure 25: Auckland Council River Water Quality Programme trend analysis for the Omaru Creek from 2009-2014.



Opanuku Stream (rural)

There are considerable decreasing trends in all nutrient species, suspended solids and turbidity in the Opanuku stream, indicating improving water quality. One possible reason for these decreasing trends could be the reduction in the amount of land used for agricultural purposes and therefore a reduction in the amounts of fertilisers applied to the land in this catchment. Correspondingly, there has been an increase in urbanisation in the catchment, and the increased impermeable area may be resulting in less soil erosion and therefore a reduction in suspended sediments and turbidity in the stream. Fluctuations in the frequency and/or intensity of rainfall events could also be influencing the suspended sediments and turbidity in the stream. It is important to note that increasing urbanisation can also temporarily increase suspended sediments and turbidity in streams because exposed soil during earthworks is easily transported during rainfall. The sampling regime of this monitoring programme does not necessarily capture these rainfall events.

The decreasing trend in total P is at least partially due to the reduction in detection limit between 2008 and 2009, as shown by the step change in the data at this time in Figure 27.

Restoration efforts in the Opanuku catchment may also be contributing to the decreasing trends in suspended solids and nutrients. Riparian planting can trap dislodged particles of sediment and prevent it from entering the stream, and riparian plants can take up some of the nutrients associated with this sediment, preventing them from entering the stream also.

Figure 26: Auckland Council River Water Quality Programme trend analysis for the Opanuku Stream from 2005-2014.

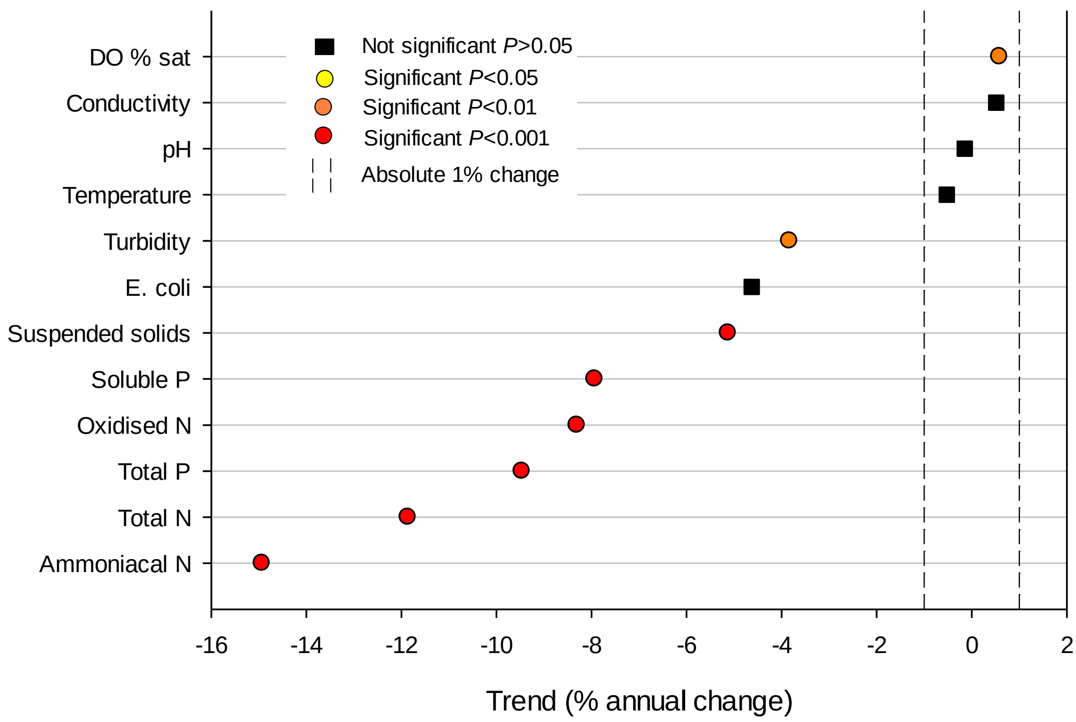
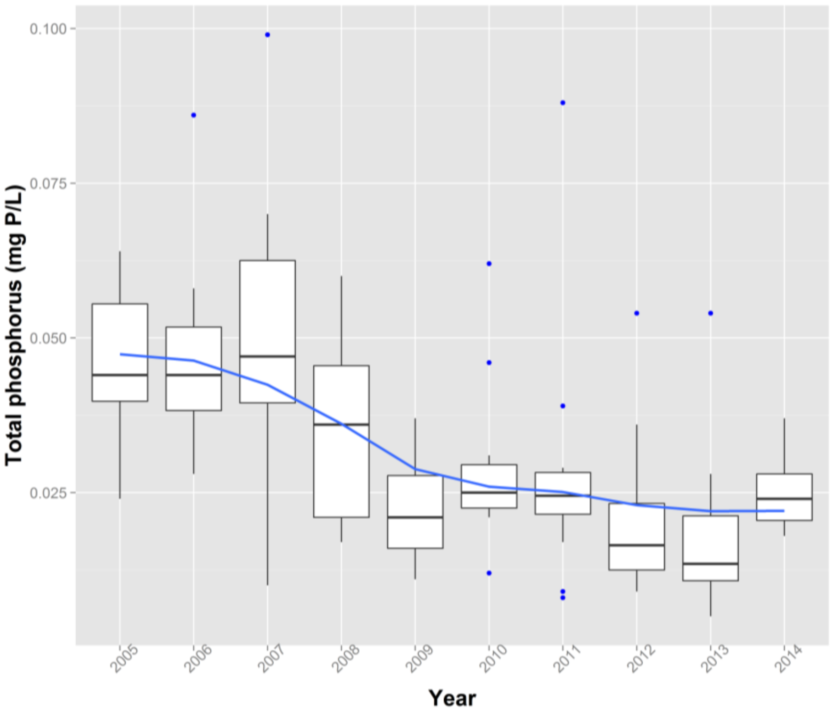


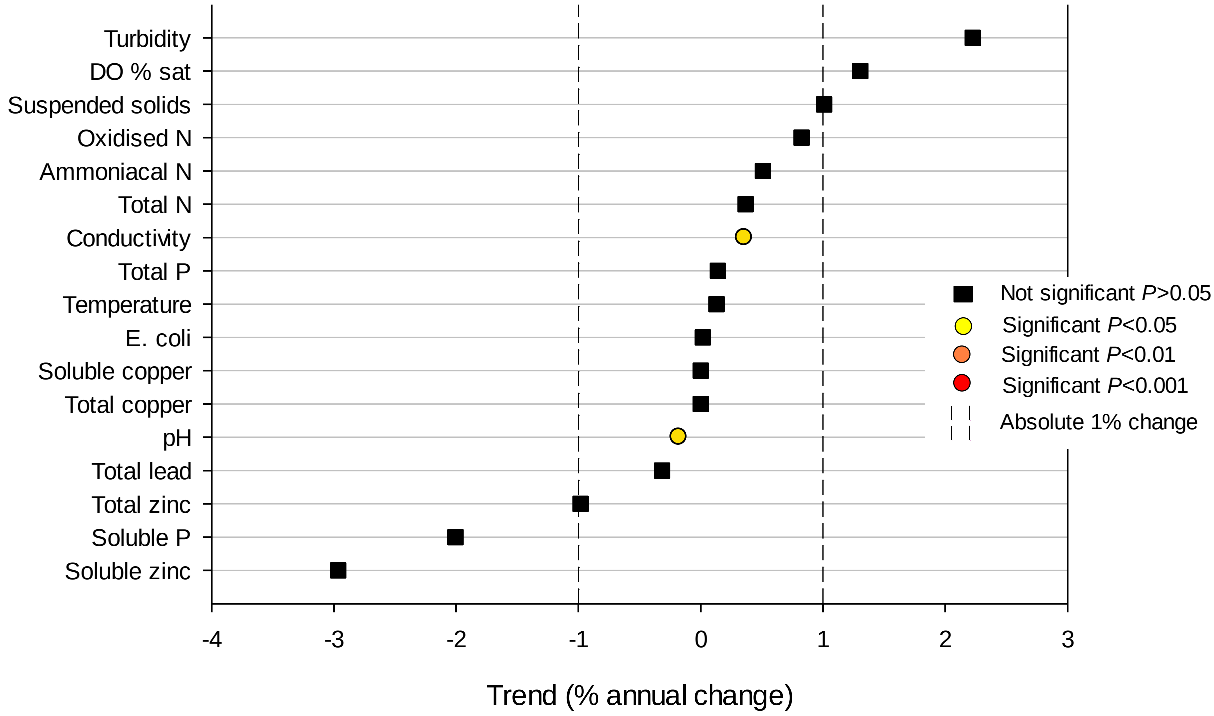
Figure 27: Box plot showing annual trend data for total phosphorus in the Opanuku Stream.



Otaki Creek (urban)

There were no environmentally meaningful and significant trends in the Otaki Creek. This creek is in a highly degraded state (Holland and Buckthought, 2015). The land use in the Otaki Creek catchment is predominantly residential and as this trend analysis suggests, there has not been a large amount of land use change in this catchment in the last 10 years. This also indicates the measured contaminants are continuing to enter this stream at a relatively constant rate over time.

Figure 28: Auckland Council River Water Quality Programme trend analysis for the Otaki Creek from 2005-2014.



Otara Creek (East Tamaki, urban)

There are decreasing trends in soluble P, total P, ammoniacal N, oxidised N, total lead and total copper. The reduction in the bioavailable fractions of N and P suggest there may be a reduction in nutrient loss in the upper, rural parts of the catchment. Increased lifestyle blocks in the upper catchment may have decreased the proportion of land under farming in this area.

The reduction in total P is likely a result of the reduction in detection limit in 2008-2009 because there is a notable step-change in the median total P concentrations between these two years (Figure 30). However this is less likely to be the case for the decreasing trend in soluble P because such a step-change was not observed for this parameter (Figure 31).

Continued reductions in total lead are widespread throughout the region and are from a very low baseline of lead concentrations. The reduction in copper could be from a range of different sources in the catchment including reductions in industrial discharge, reduction in the use of copper based sprays in residential gardens, and changes in the copper content of brake pads over time, or changes in vehicle use patterns.

Figure 29: Auckland Council River Water Quality Programme trend analysis for the Otara Creek (ET) from 2005-2014.

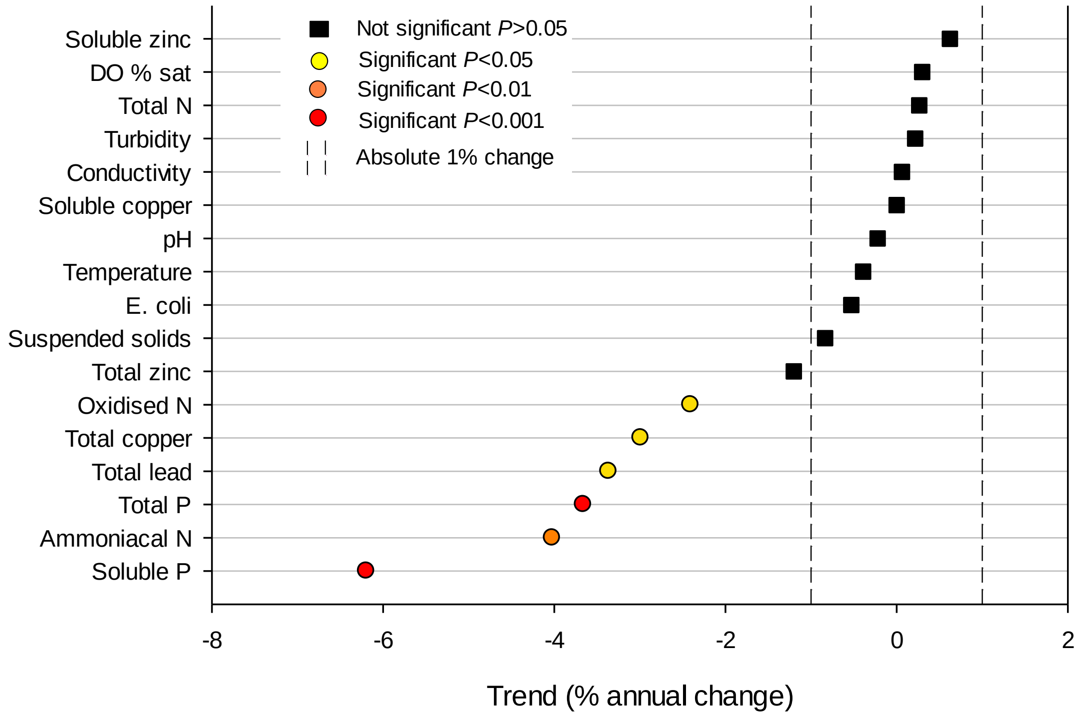


Figure 30: Box plot showing annual trend data for total phosphorus in the Otara Creek (East Tamaki).

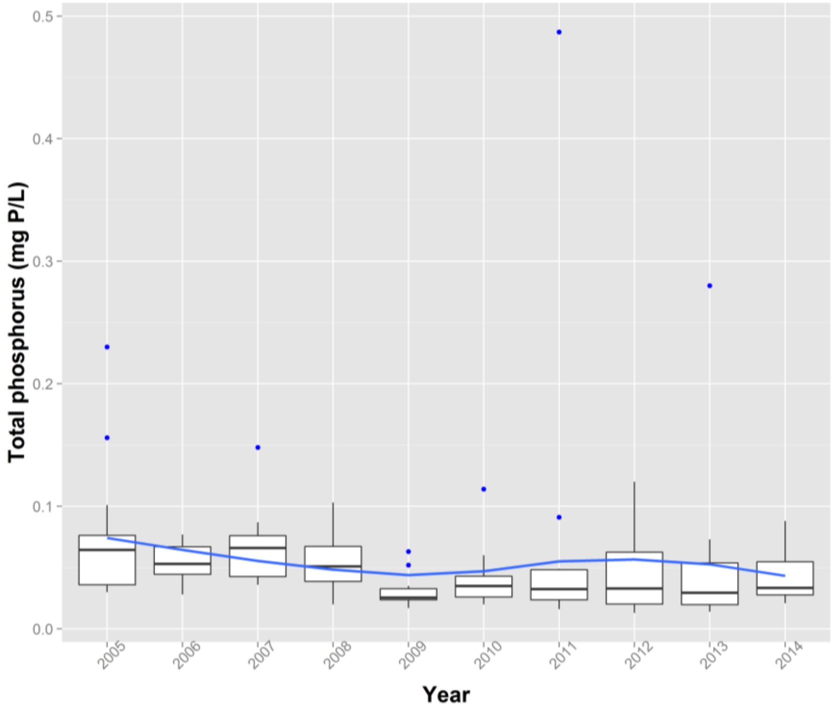
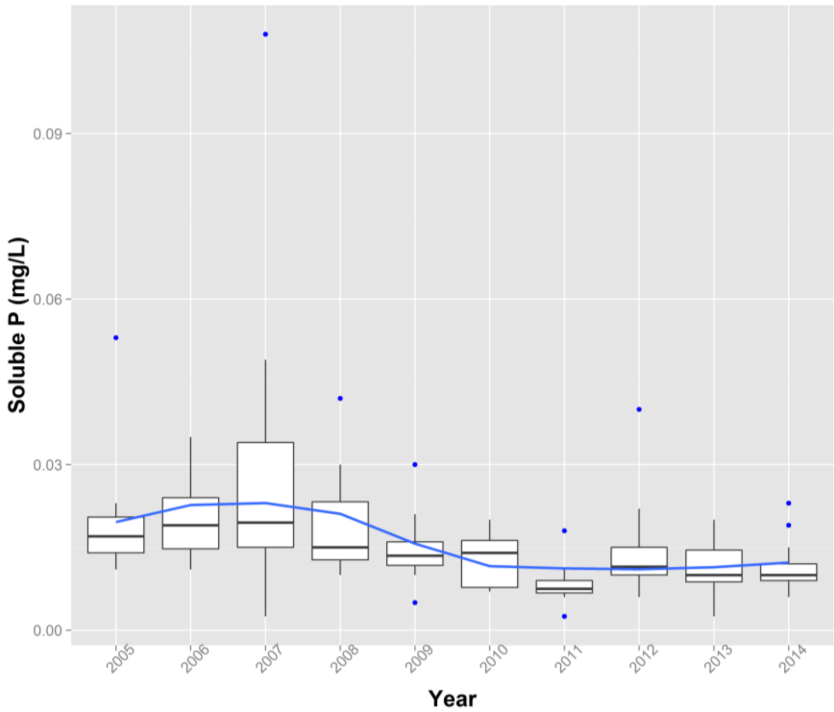


Figure 31: Box plot showing annual trend data for soluble phosphorus in the Otara Creek (East Tamaki).



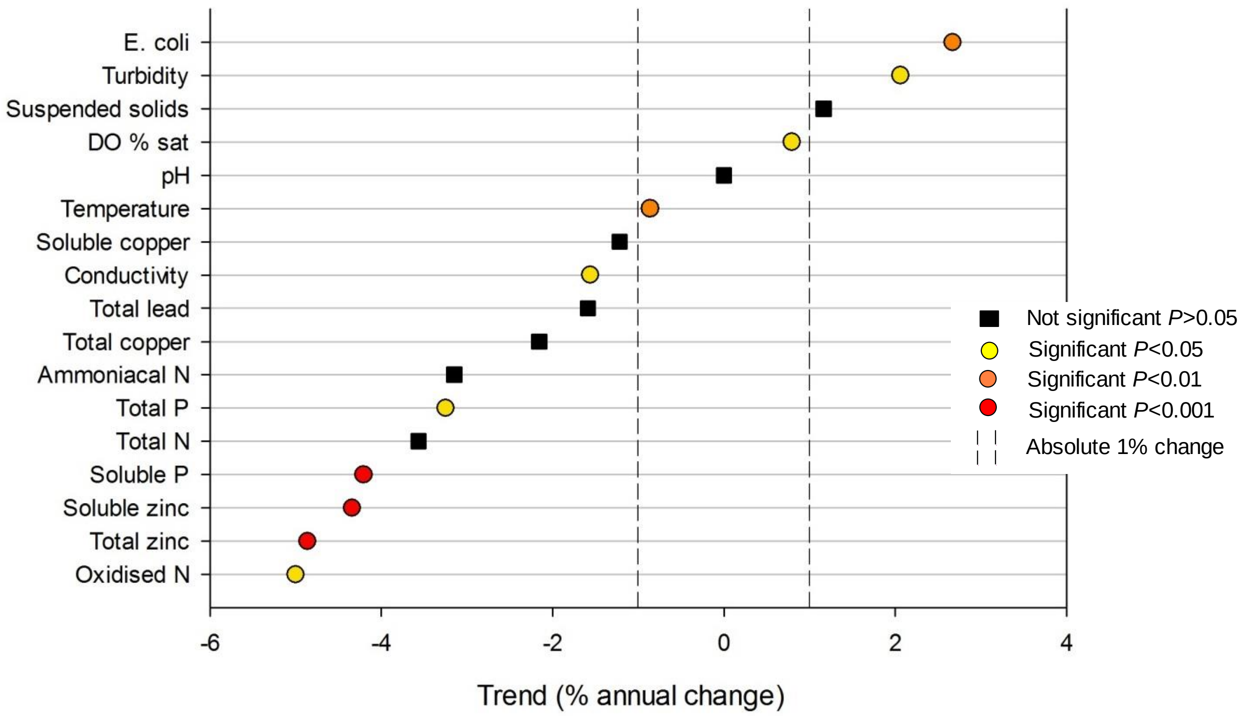
Otara Creek (Kennell Hill, urban)

There are increasing trends in *E. coli* and turbidity at the Otara Creek (Kennell Hill) site. The increase in turbidity could be due to the large amount of new development that has occurred in the past 10 years in the upper parts of this catchment and the associated sediment loss during rainfall events.

The increasing trend in E.coli could be due to a wide range of factors including wastewater overflow events, increased stress on existing wastewater infrastructure due to increased catchment population, cross connections between wastewater and stormwater infrastructure, damage to wastewater infrastructure via tree roots, cracking and other impacts. E. coli contamination is also not limited to humans. Other sources such as dogs, birds, and cattle may also significantly contribute to the E. coli load in the Otara Creek.

There are significant decreases in conductivity, total P, soluble P, oxidised N, total zinc and soluble zinc. This again suggests there may be a reduction in nutrient loss in the upper, rural parts of the catchment. The decreasing zinc trend was not evident in the Otara Creek (East Tamaki) and may be related to the newer, lower contaminant yielding building materials being used in this catchment. Interestingly, there is no decreasing trend in total lead at the Kennell Hill site as there is at the East Tamaki site.

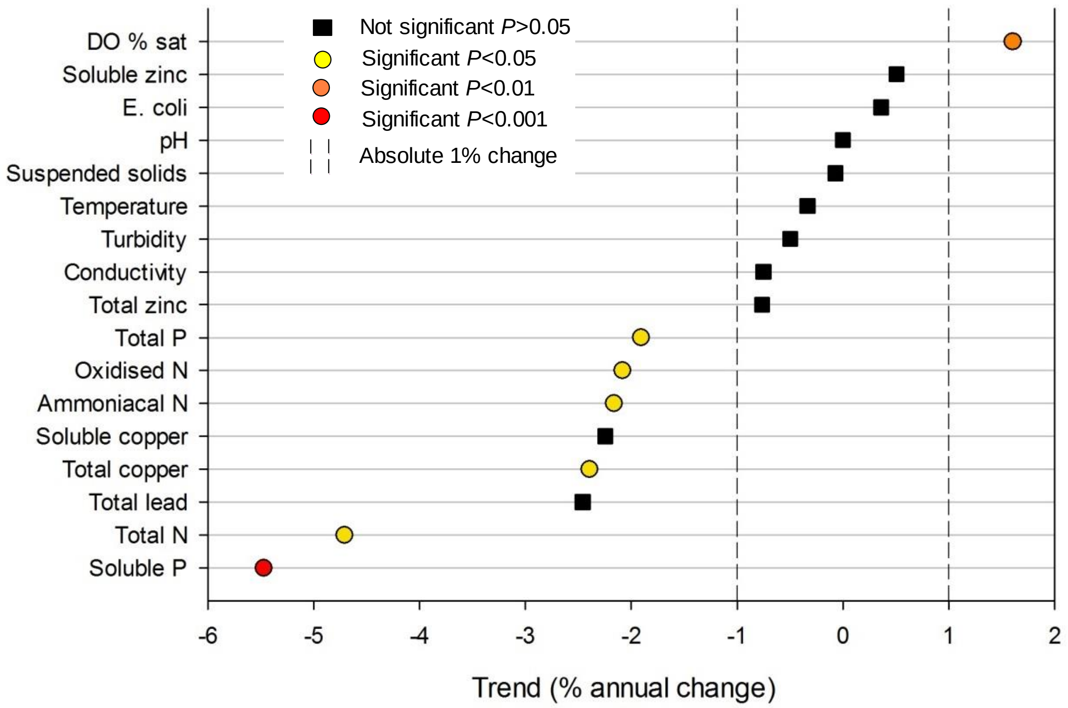
Figure 32: Auckland Council River Water Quality Programme trend analysis for the Otara Creek (KH) from 2005-2014.



Oteha Stream (urban)

There is an increasing trend in dissolved oxygen suggesting improving water quality at this site. This is supported by decreasing trends in all of the nutrient species as well as total copper. This could be due to a decline in the amount of nutrient loss from soils in the catchment as a result of increased urbanisation.

Figure 33: Auckland Council River Water Quality Programme trend analysis for the Oteha Stream from 2005-2014.

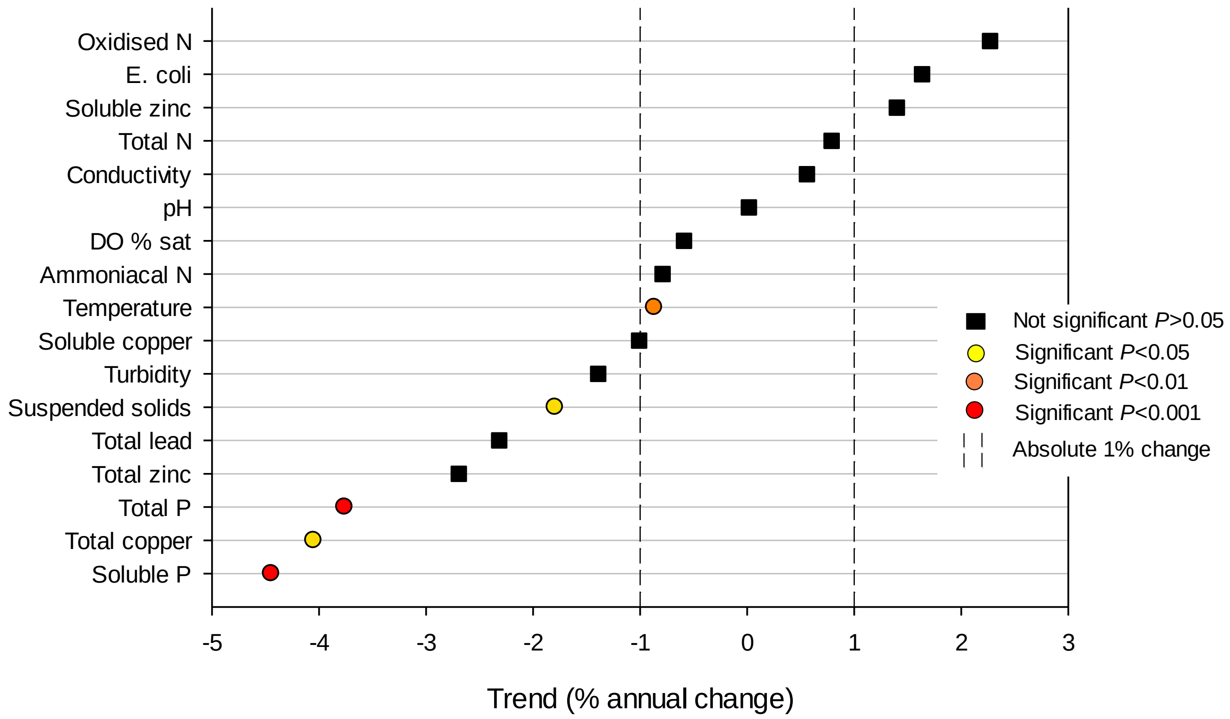


Pakuranga Creek (Botany Road, urban)

There are decreasing trends in total P, soluble P, suspended solids suggesting that there has been a reduction in sediment loss and sediment associated P from this catchment. The decreasing trends in total and soluble P could be due to an increase in the amount of impervious surface area as a result of industrial and residential development in the catchment. This could have resulted in a decline in the amount of soil erosion and sediment-associated P runoff into the Pakuranga Creek. It is unlikely the laboratory detection limit change in 2008-2009 influenced decreasing trends in total and soluble P because there was no step-change or unusual data observed at this time.

There is also a decreasing trend in total copper which could arise from reductions in a range of different sources in the catchment including reductions in industrial discharge, reduction in the use of copper based sprays in residential gardens, and changes in the copper content of brake pads over time, or changes in vehicle use patterns.

Figure 34: Auckland Council River Water Quality Programme trend analysis for the Pakuranga Creek (Botany Rd) from 2005-2014.



Pakuranga Creek (Greenmount Drive, urban)

There are increasing trends in ammoniacal and total N in the Pakuranga Creek at Greenmount Drive. The increase in ammoniacal N suggests there may be some kind of bioavailable or readily mineralisable N source that is entering the stream via a discharge point or runoff. The increase in total N is likely to be purely a consequence of the increase in ammoniacal N.

Although there is an increasing trend in turbidity at this site, but no trend in suspended solids, both parameters follow a similar pattern over time (Figure 36 and Figure 37).

The only decreasing trend in the Pakuranga Creek (Greenmount Drive) is total copper, and this could be due to the same range of factors discussed for the Pakuranga Creek (Botany Road).

Figure 35: Auckland Council River Water Quality Programme trend analysis for the Pakuranga Creek (Greenmount Dr) from 2005-2014.

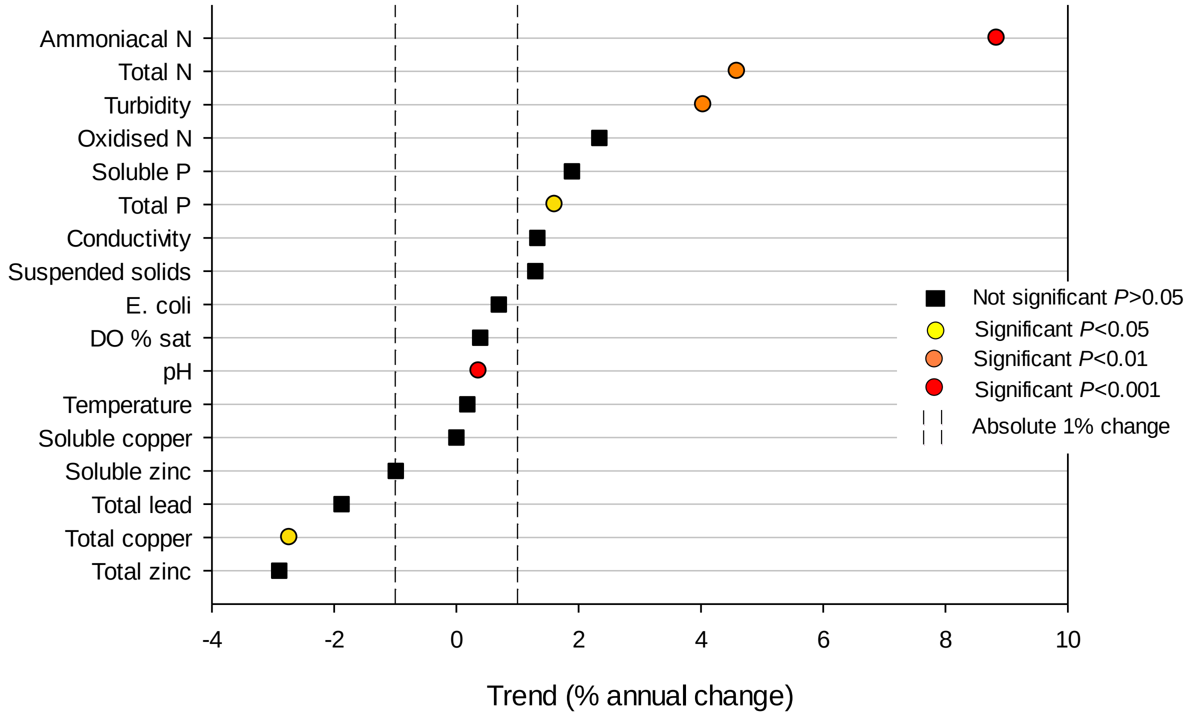


Figure 36: Box plot showing annual trend data for total suspended solids in the Pakuranga Creek (Greenmount Drive).

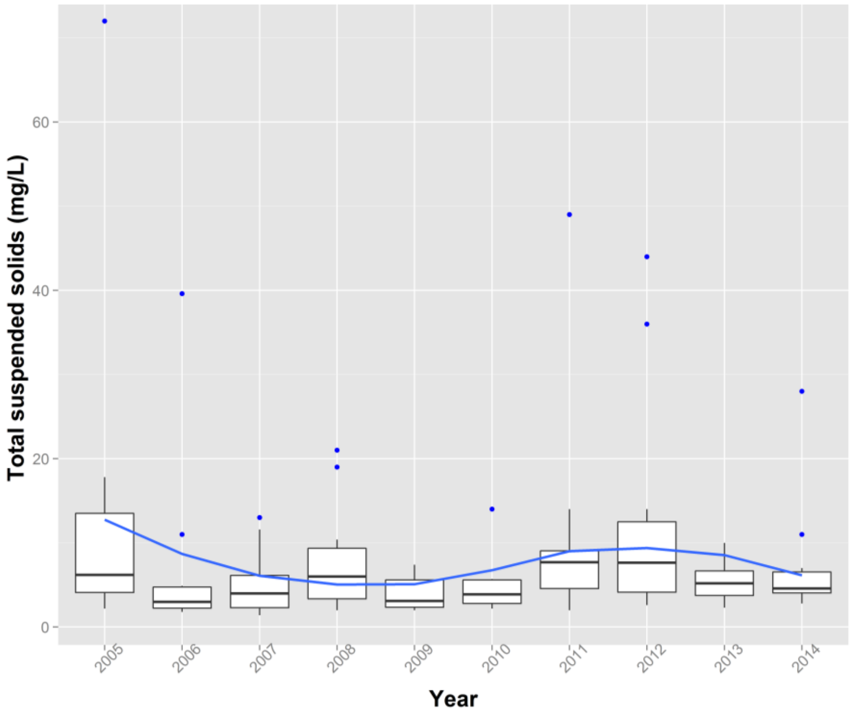
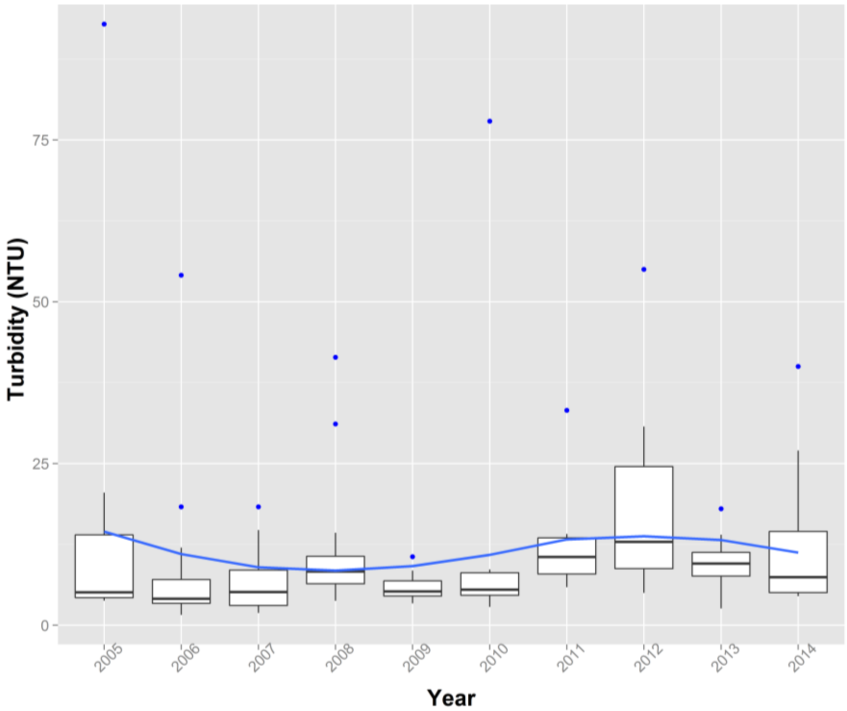


Figure 37: Box plot showing annual trend data for turbidity in the Pakuranga Creek (Greenmount Drive).



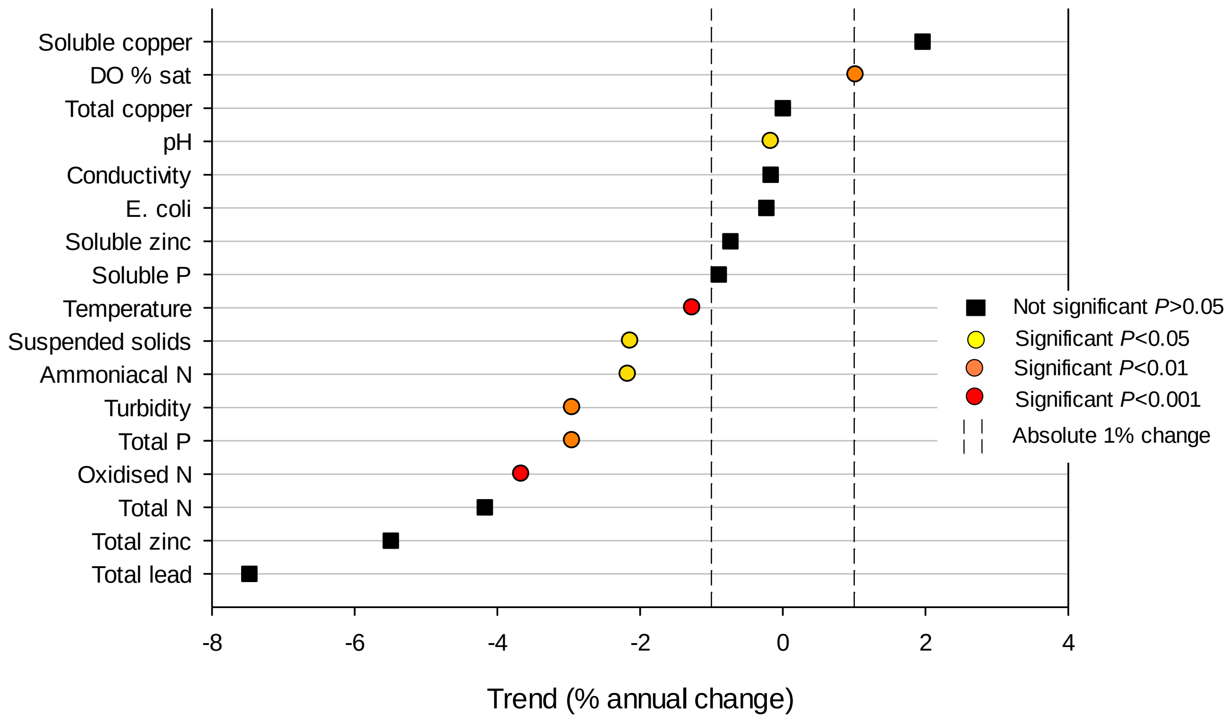
Papakura Stream (rural)

There are decreasing trends in oxidised N, ammoniacal N, total P, suspended solids and turbidity in the Papakura Stream.

The trend in total P is due to the reduction in the detection limit in 2008-2009, and there was no trend in soluble P.

The small decreasing trends in ammoniacal and oxidised nitrogen suggest there may be less nutrient loss via leaching in this catchment. The declines in suspended solids and turbidity suggest a reduction in erosion and the transfer of sediment to the stream. This could be due to a reduction in the intensity of farming in the upper Papakura catchment with lower rates of fertiliser application. It may also be a reflection of the increasing urbanisation and occurrence of lifestyle blocks in the Papakura catchment, reducing the area of actively farmed agricultural land.

Figure 38: Auckland Council River Water Quality Programme trend analysis for the Papakura Stream from 2005-2014.



Puhinui Stream (urban)

There are significantly decreasing trends in all forms of nitrogen, soluble P, total zinc, total lead and total copper suggesting improving water quality in the Puhinui Stream. The reduction in nutrients may be a result of changes to rural land use in the upper parts of the catchment. This might include changes from previously farmed grassland to lifestyle block land use. It could also arise from reduced fertiliser application and nutrient use on farms.

The decreasing trend in total copper is due to an outlier that occurred in 2011 (Figure 40) and should be disregarded. There is a possibility that new development in the lower, urban part of the catchment has resulted in improvements in the treatment of stormwater, where there previously was none (or substandard treatment), resulting in the decreasing total zinc trend.

Figure 39: Auckland Council River Water Quality Programme trend analysis for the Puhinui Stream from 2005-2014.

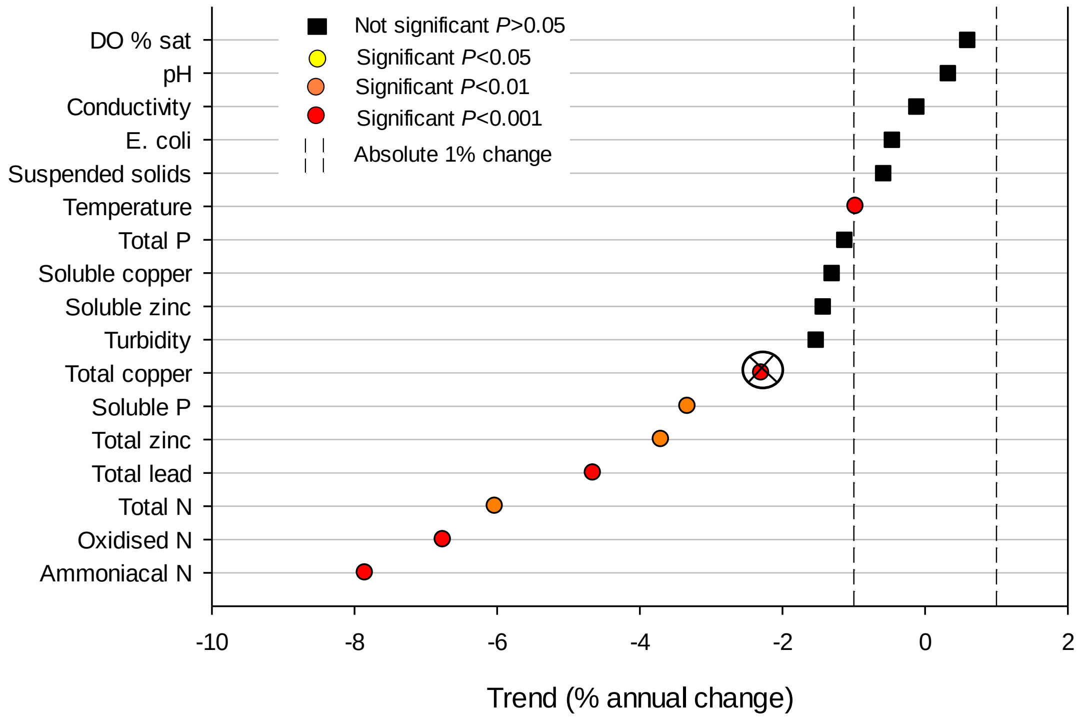
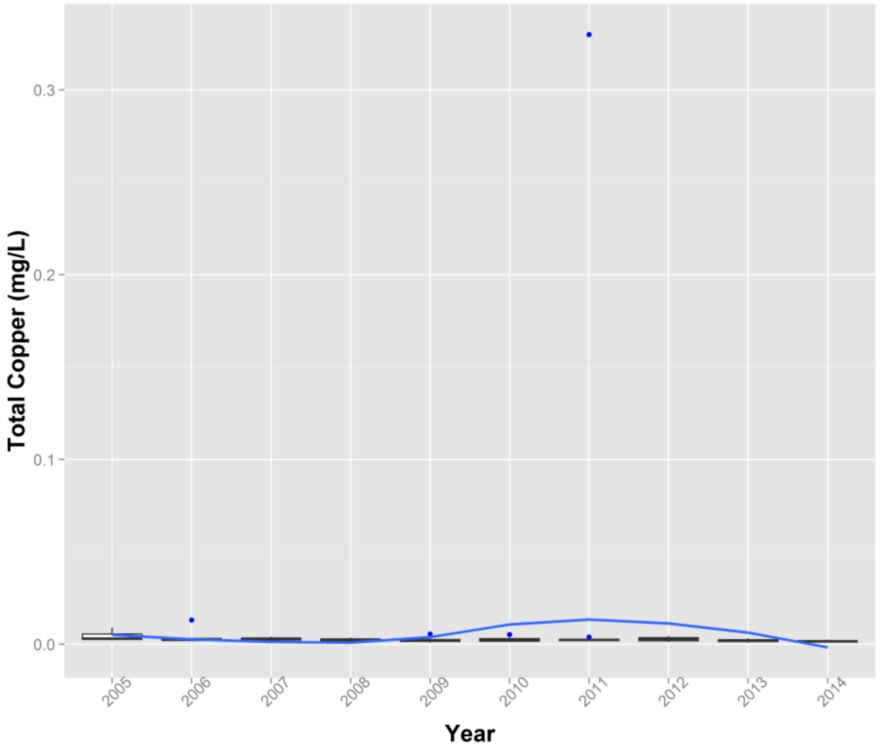


Figure 40: Box plot showing annual trend data for total copper in the Puhinui Stream.



Riverhead Forest Stream (exotic forest)

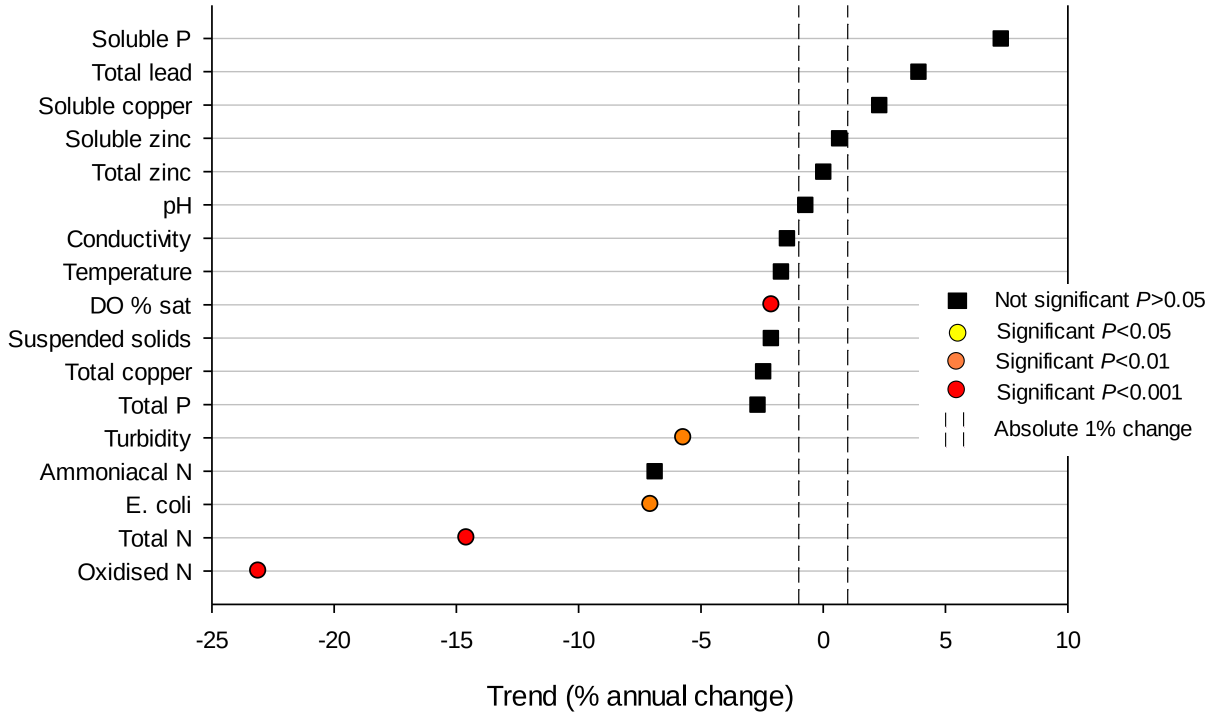
There are strong decreasing trends in total N and oxidised N in the riverhead stream (since 2009). This could be due to a reduction in nitrogen fertiliser application in the catchment, or could be a function of fertiliser regime and/or the relative age of the pine trees in the catchment.

There is also a significant decreasing trend in E. coli. Because the vast majority of this catchment is in pine forest, the most likely reason for this may be changes in the resident animal populations and a reduction in the amount of animal droppings in or nearby the stream.

The decreasing trend in turbidity could be attributable to a growing canopy of trees over the monitoring period, and therefore increased interception of rainfall and reducing soil erosion.

There is also a decreasing trend in dissolved oxygen. This is likely to be a result of an increasing amount of decomposing organic material (pine needles, branches, twigs etc) from the surrounding land use. Another possibility is in-stream macrophytes using dissolved oxygen at night, however, we would expect shade from the forestry to inhibit macrophyte growth.

Figure 41: Auckland Council River Water Quality Programme trend analysis for the Riverhead Forest Stream from 2009-2014.



Vaughan Stream (rural)

The increasing trend in conductivity is likely to be a result of the more frequent occurrence of outliers since 2010 (Figure 43).

There is an overall decreasing trend in total suspended solids and turbidity, however, this overall trend is characterised by an increasing trend from 2005-2007, then a sharp decrease in 2008, a slight decreasing trend until 2012 and then indications of an increasing trend since then (Figure 44 and Figure 45). These changes in suspended solids and turbidity could possibly be attributed to land use change (development and urbanisation) however more investigation is required to confirm this.

There is a significant decreasing trend in E. coli. E. coli trends are sometimes difficult to identify due to the large number of outlier results however in this case, the median E.coli value has progressively decreased over the 10-year period 2005-2014 (Figure 46).

There is also a significant decreasing trend in total and soluble P. This, along with the other decreasing trends is all indicative of improving water quality.

Figure 42: Auckland Council River Water Quality Programme trend analysis for the Vaughan Stream from 2005-2014.

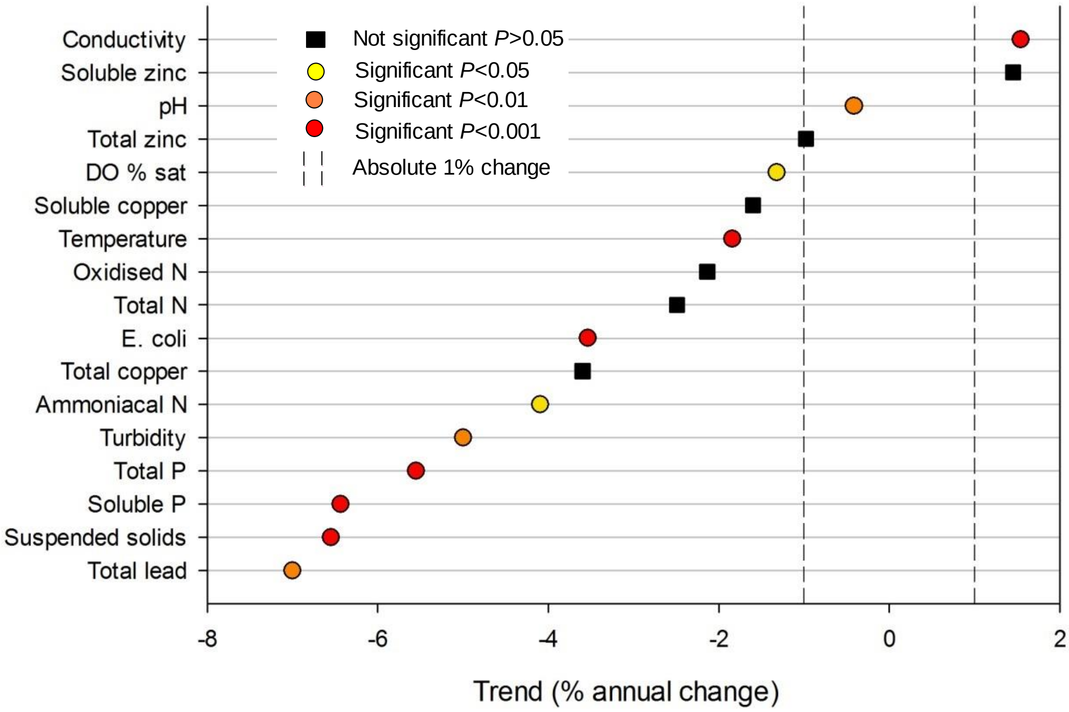


Figure 43: Box plot showing annual trend data for conductivity in the Vaughan Stream.

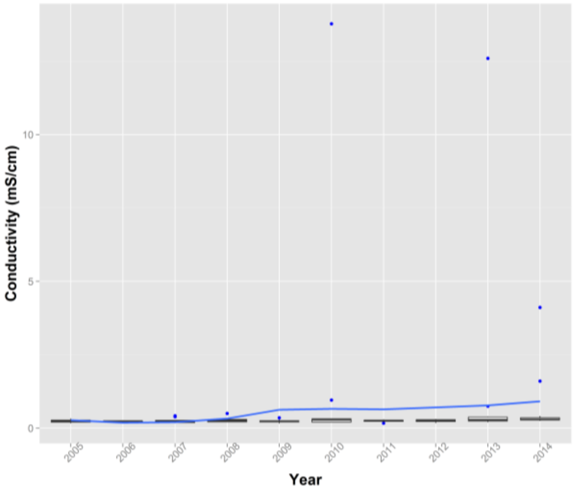


Figure 44: Box plot showing annual trend data for total suspended solids in the Vaughan Stream.

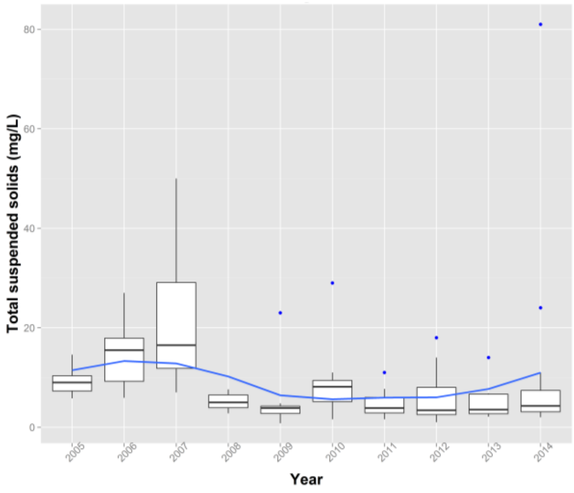


Figure 45: Box plot showing annual trend data for turbidity in the Vaughan Stream.

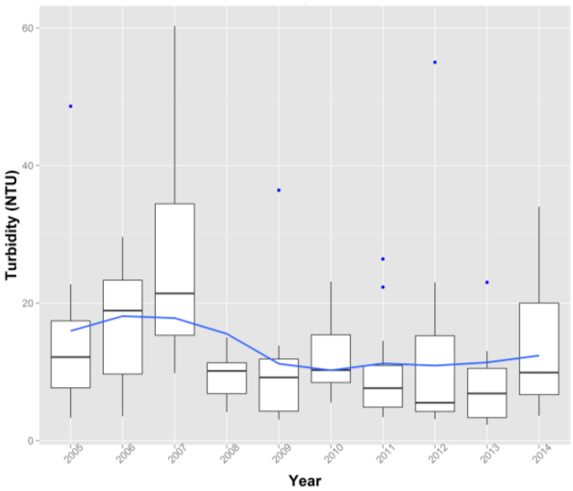
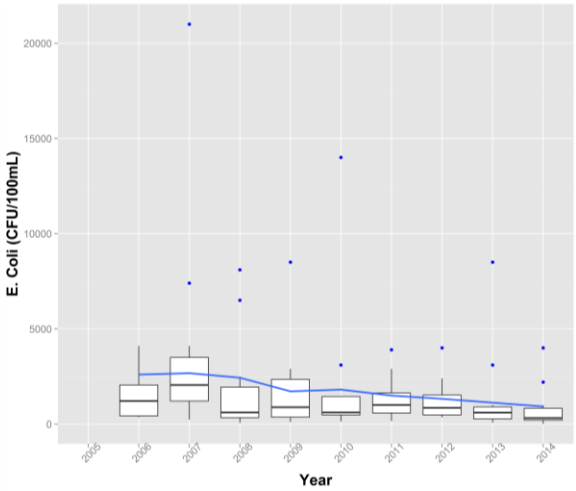


Figure 46: Box plot showing annual trend data for E. coli in the Vaughan Stream.



Wairoa River (rural)

Concentrations of total zinc and lead declined significantly from 2010-2014, with the exception of 2012 where there was a considerable increase in total lead (Figure 48) and total zinc (Figure 49), and also copper (although no significant trend was detected for this parameter) (Figure 50). This suggests there was an incident or a period in 2012 where inputs of all these metals increased. This would require further investigation to confirm.

There is a significant decline in all forms of N and P indicating a reduction in nutrients and improvement in water quality. However; care should be taken in interpreting these trends as some may be an artefact of a detection limit change between 2009 and 2010.

There is a significant decline in *E.coli*; however, the median values have not changed dramatically over time, rather the outlier values have become smaller over time (Figure 51). This may still represent an improvement in water quality in terms of reduced bacterial contamination.

Figure 47: Auckland Council River Water Quality Programme trend analysis for the Wairoa River from 2005-2014.

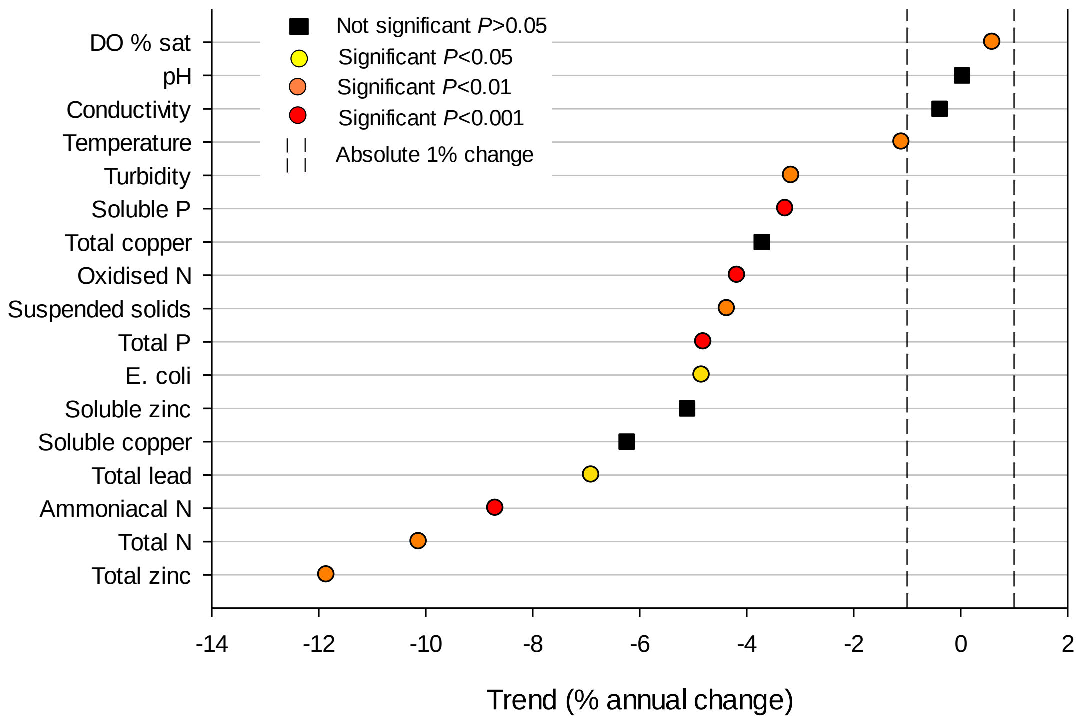


Figure 48: Box plot showing annual trend data for total lead in the Wairoa River.

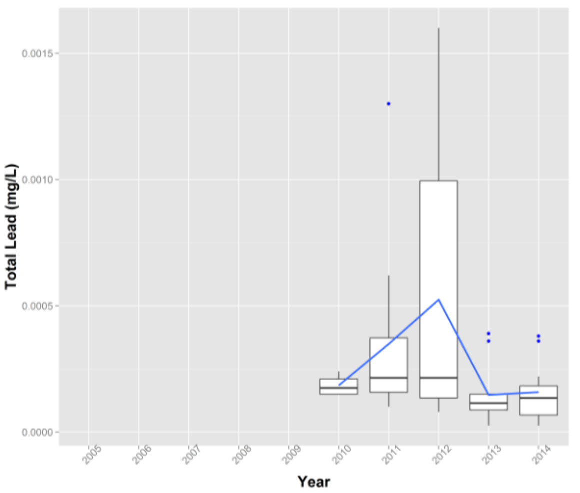


Figure 49: Box plot showing annual trend data for total zinc in the Wairoa River.

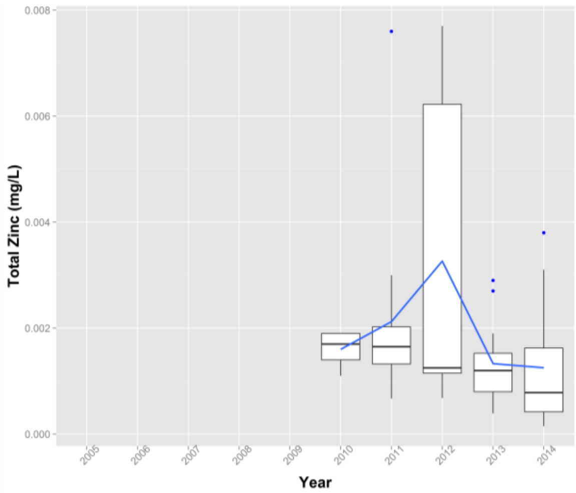


Figure 50: Box plot showing annual trend data for total copper in the Wairoa River.

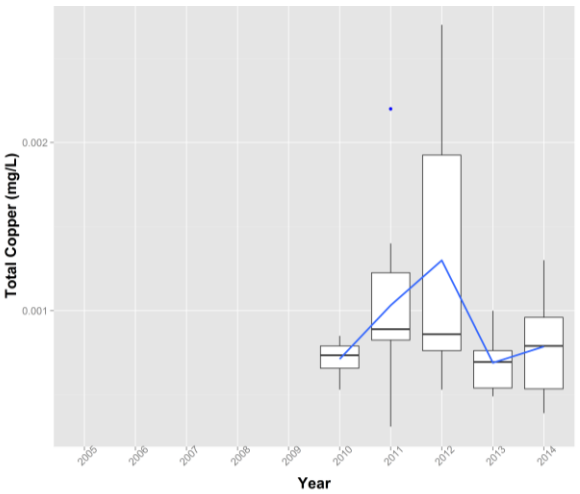
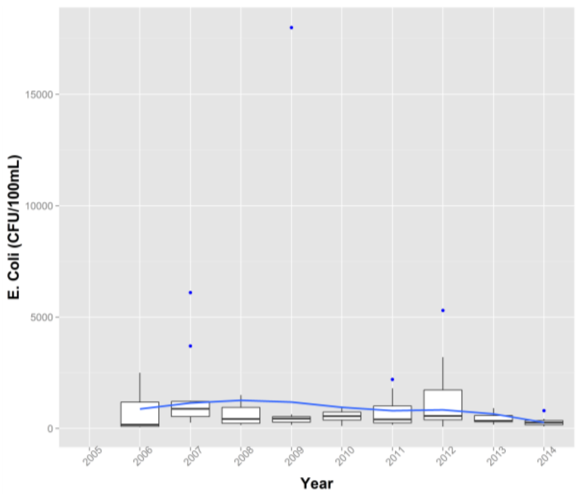


Figure 51: Box plot showing annual trend data for E. coli in the Wairoa River.



Wairoa Tributary (native forest)

There is a decreasing trend in oxidised N in the Wairoa Tributary since 2009. This trend is from an already low median oxidised N concentration (Figure 53), and may be a function of the higher outliers in 2009 and 2011 compared to the later years.

The apparent decreasing trend in turbidity is due to an increasing trend up to 2011 and a subsequent decreasing trend since then (Figure 54). The suspended solids data follows the same trend as turbidity over time, but is not statistically significant.

There are no other significant and meaningful trends in the Wairoa Tributary.

Figure 52: Auckland Council River Water Quality Programme trend analysis for the Wairoa Tributary from 2009-2014.

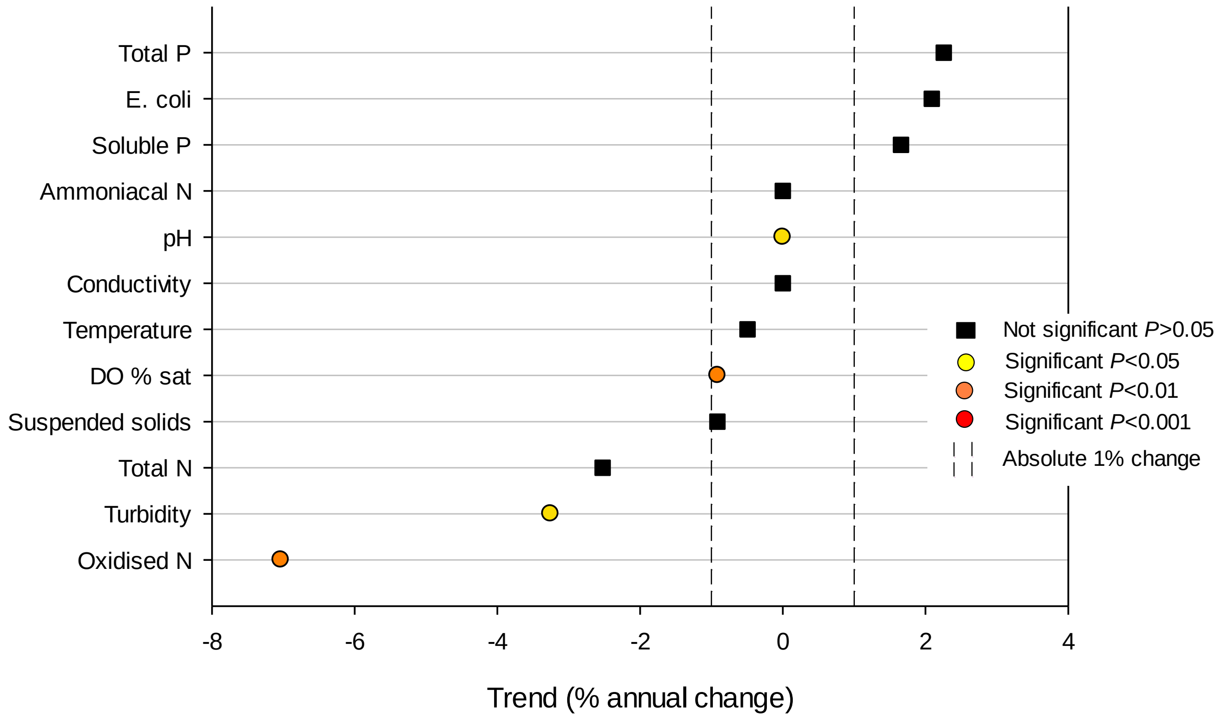


Figure 53: Box plot showing annual trend data for total oxidised N in the Wairoa Tributary

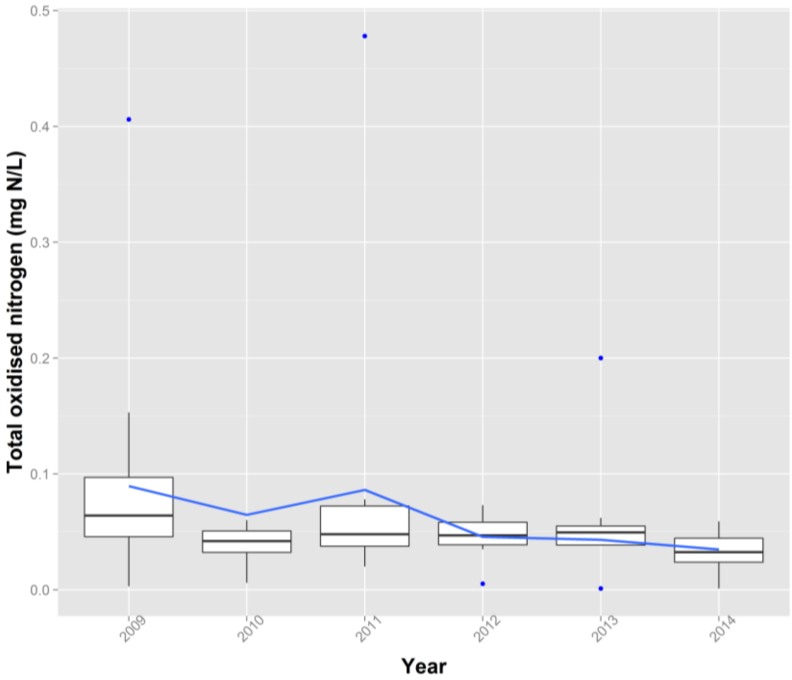
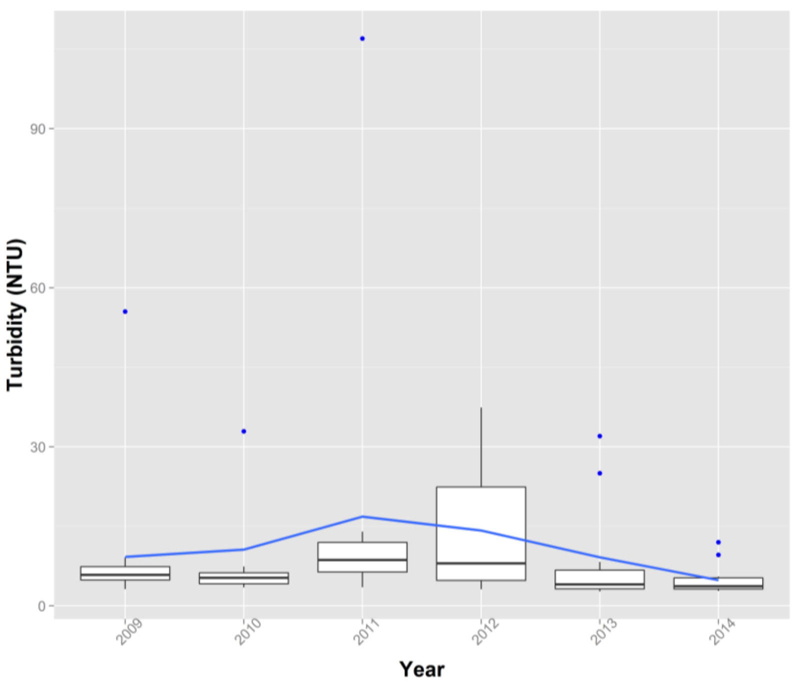


Figure 54: Box plot showing annual trend data for total turbidity in the Wairoa Tributary



Waitangi River (rural)

There is a strong significant decreasing trend in ammoniacal N, but there are no such trends in any other nitrogen parameters. This suggests there are no significant changes to the inputs of nitrogen from the surrounding landscape; otherwise we would expect to see changes or trends in total oxidised N and/or total N. This might indicate that the trend in ammoniacal N is a result of in-stream processes, for example, reduction of ammonium at anaerobic sites or the benthic-water column interface. Another, more likely possibility is increased uptake of ammonium from the water column by in stream macrophytes.

There is also a decreasing trend in soluble phosphorus. While this could be due to decreased application of phosphorus in the surrounding catchment, Figure 56 illustrates that this decreasing trend arises from only the last 3 years data (2012-2014), as there was an increasing trend from 2009-2011. This trend should therefore be interpreted with caution.

There is a small but statistically significant decline in pH. However, due to the short length of the data set for this parameter (2011-2014) it would be prudent to interpret this trend with caution, and perhaps re-analyse the data after a few more years' data accumulation.

Figure 55: Auckland Council River Water Quality Programme trend analysis for the Waitangi River from 2009-2014.

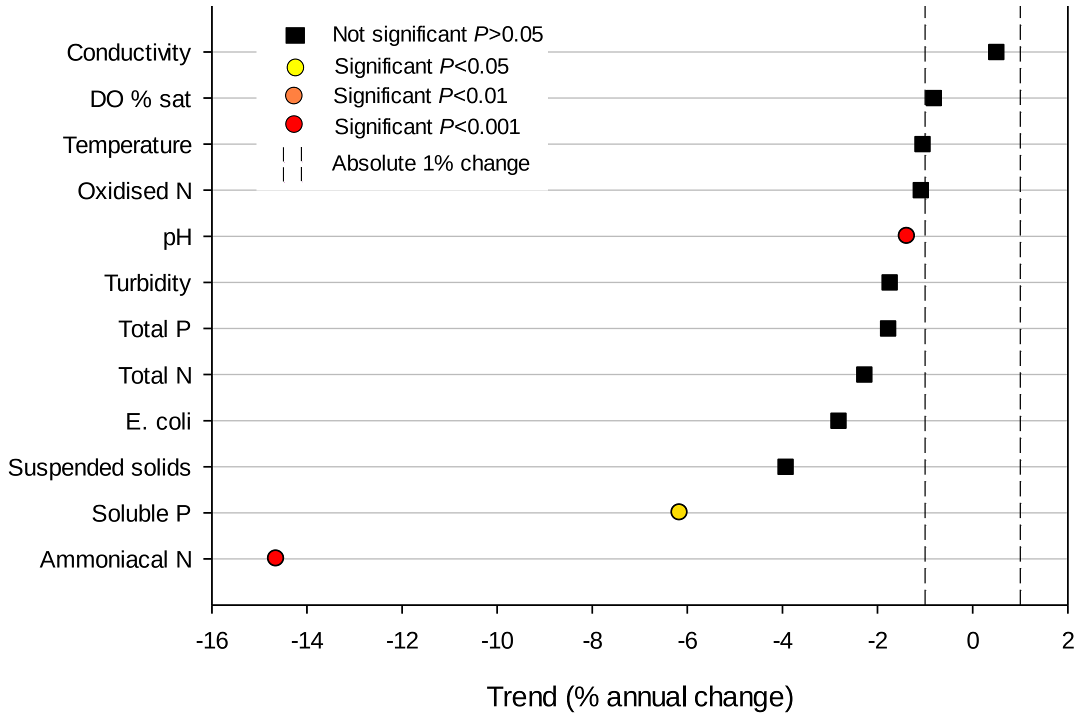
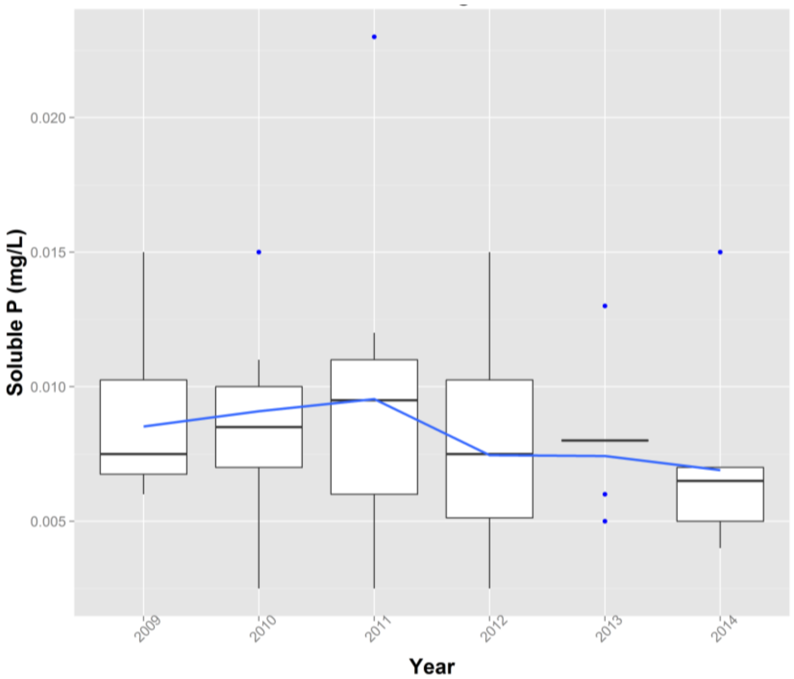


Figure 56: Box plot showing annual trend data for soluble phosphorus in the Waitangi River



Waiwera River (rural)

There are decreasing trends in all forms of nitrogen and phosphorus measured, which suggests losses of nitrogen and phosphorus from land are decreasing. This could be due to changes in land use over time, such as increased urbanisation, and improvements in nutrient management on farms in the catchment, and/or reduction in the overall amount of nutrients applied to land.

While there are statistically significant decreasing trends in turbidity and total suspended solids, the (slight) downward trend has only occurred since 2012, with no obvious trend prior to this. It is likely the trend is influenced by the very high outlier in 2012 (Figure 58 and Figure 59).

The decreasing trends in total lead and total zinc are influenced by very large outliers that occurred in 2012. However, a declining trend is still present without the outlier and, in the case of total lead, this trend is occurring from an already very low baseline (Figure 60 and Figure 61).

There is also a statistically significant decreasing trend in soluble copper. This could possibly be influenced by increased vehicle use in this catchment and road runoff into the river.

Figure 57: Auckland Council River Water Quality Programme trend analysis for the Waiwera River from 2005-2014.

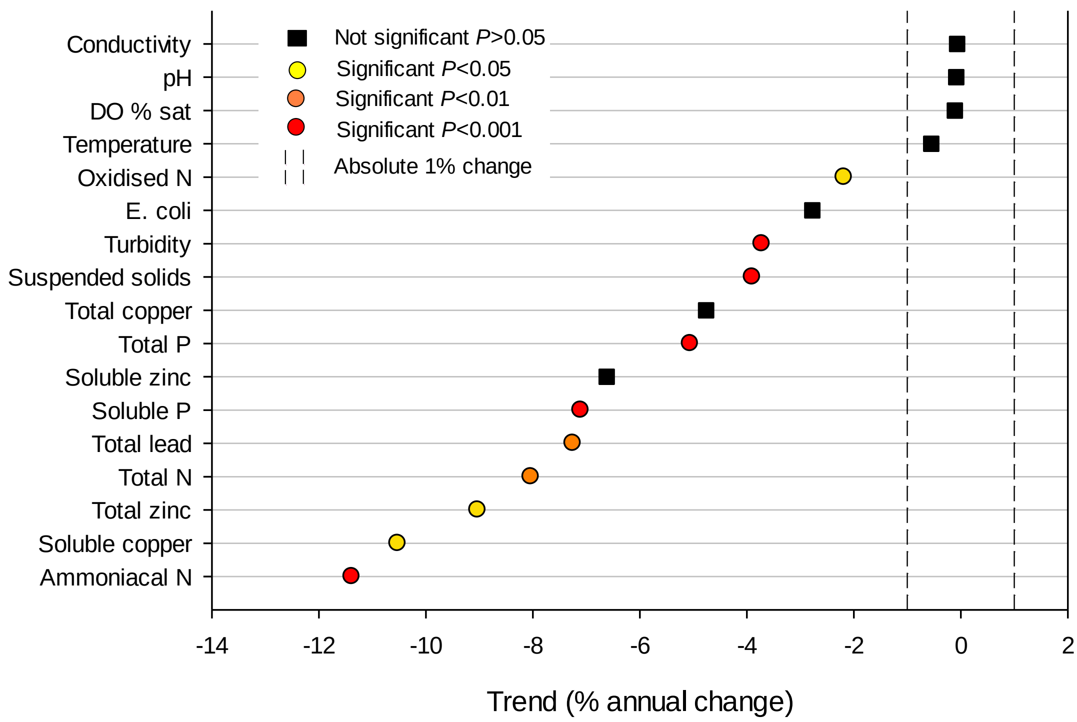


Figure 58: Box plot showing annual trend data for turbidity in the Waiwera River

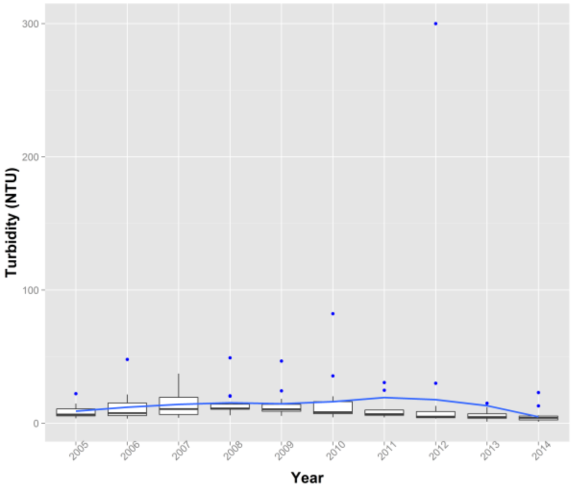


Figure 59: Box plot showing annual trend data for total suspended solids in the Waiwera River

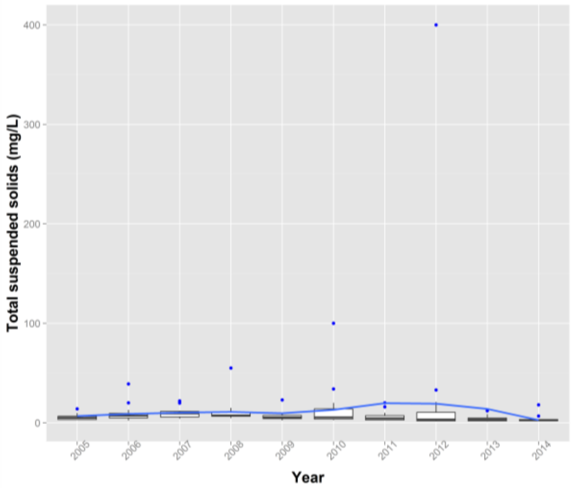


Figure 60: Box plot showing annual trend data for total lead in the Waiwera River

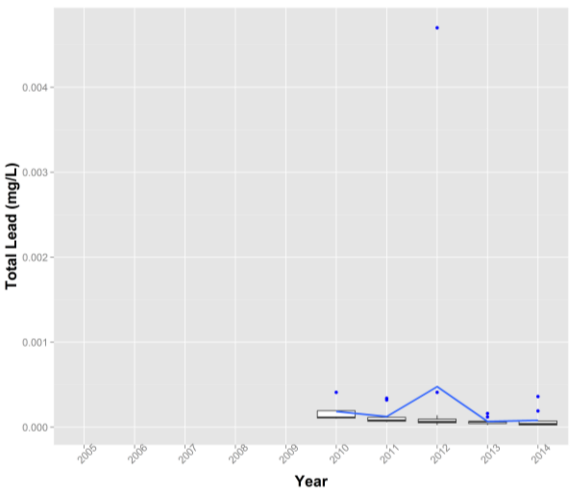
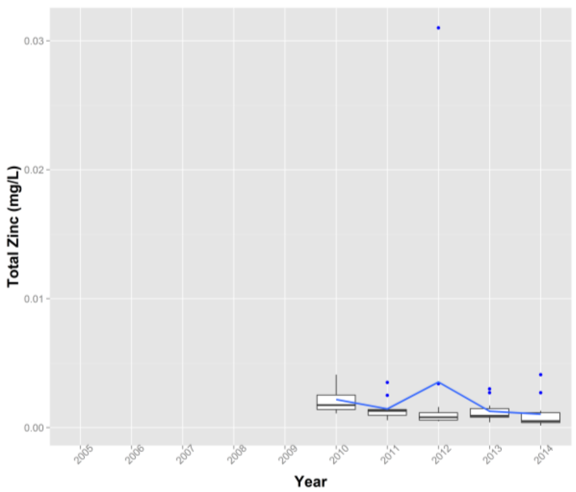


Figure 61: Box plot showing annual trend data for total zinc in the Waiwera River

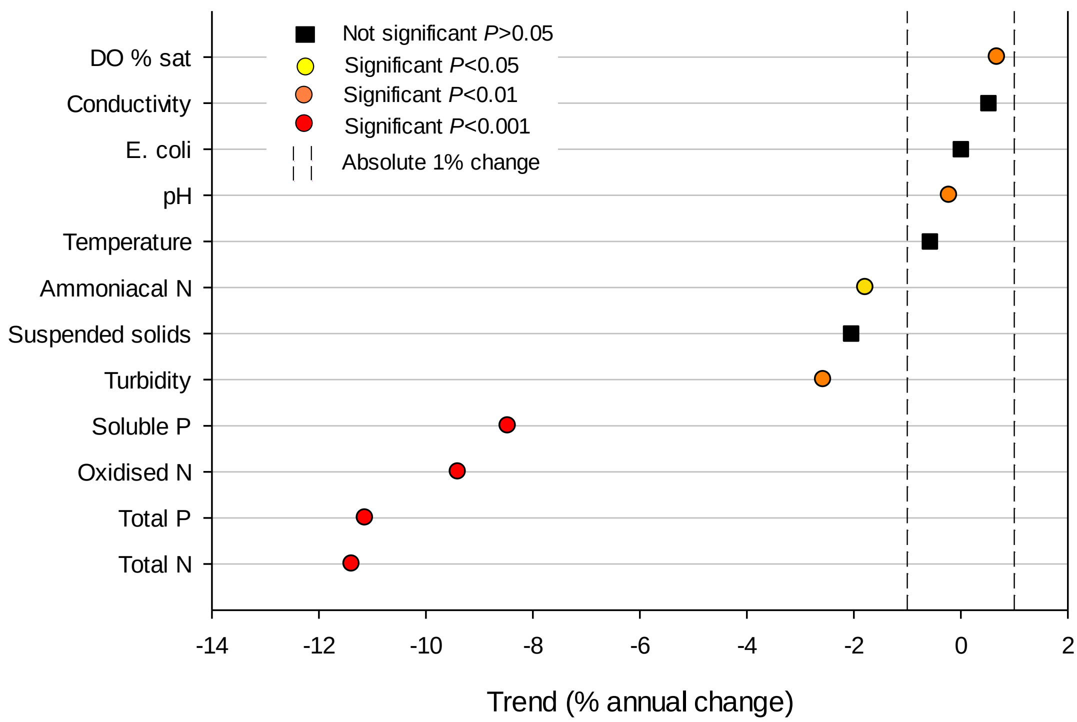


West Hoe Stream (native forest)

There are decreasing trends in all forms of nitrogen and phosphorus. While the background levels of nutrients in the West Hoe Stream are already low, there is still a decreasing trend. With very little to no human influence in this catchment, it is unlikely that these trends are linked to changes in any kind of human land use. There may have been changes over time in the amount and/or type of forest litter near the site, which may have changed the cycling dynamics of nitrogen and phosphorus and therefore, changed the amount of these nutrients entering the stream.

There is also a small decreasing trend in turbidity, and while a similar pattern over time is observed in total suspended solids, it is not statistically significant. This decline in turbidity could also be a reflection of changing litter characteristics over time, as well as a potential reduction in erosion-causing events.

Figure 62: Auckland Council River Water Quality Programme trend analysis for the West Hoe Stream from 2005-2014.



Whangamaire Stream (rural)

The only statistically significant and environmentally meaningful trend in the Whangamaire stream is a weak increase in turbidity, and it is possible that this trend is influenced by a very large outlier in 2011 (Figure 64). Total suspended solids follows the same pattern as turbidity, but is not statistically significant. This trend needs to be interpreted with caution, but may be due to an increase in susceptibility of erosion in the catchment. Land in this catchment is predominantly under intensive horticulture, therefore increased erosion could be arising from soil compaction from heavy machinery use and from land left fallow, particularly during rainfall events.

It should be noted that although there is no trend in total oxidised N at this site, the concentrations of total oxidised N are very high (median of 18 mg/L) and nearly 3 times the NOF national bottom line value for this parameter (6.9 mg/L). This is a result of the intensive horticultural vegetable production land use in the surrounding catchment. Heavy nitrogen fertiliser application over time has resulted in large amounts of nitrate leaching to the shallow volcanic aquifers below. These aquifers are a source of baseflow to the Whangamaire Stream, hence why we are seeing such high concentrations of oxidised N.

Figure 63: Auckland Council River Water Quality Programme trend analysis for the Whangamaire Stream from 2009-2014.

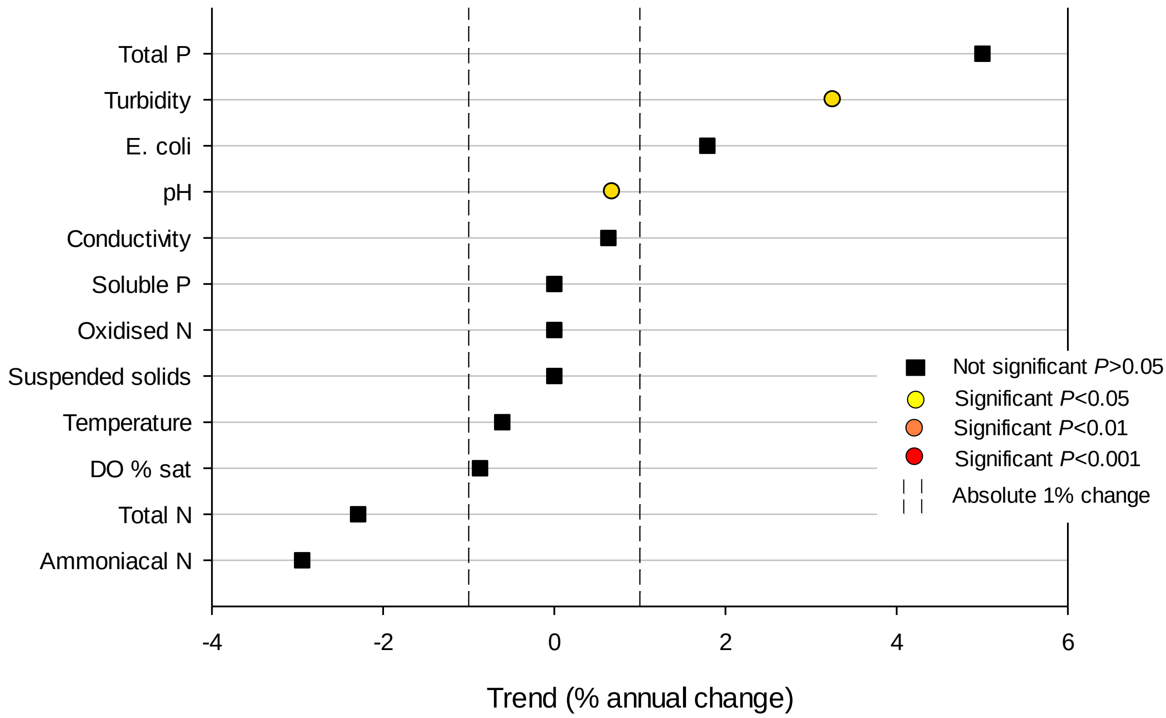
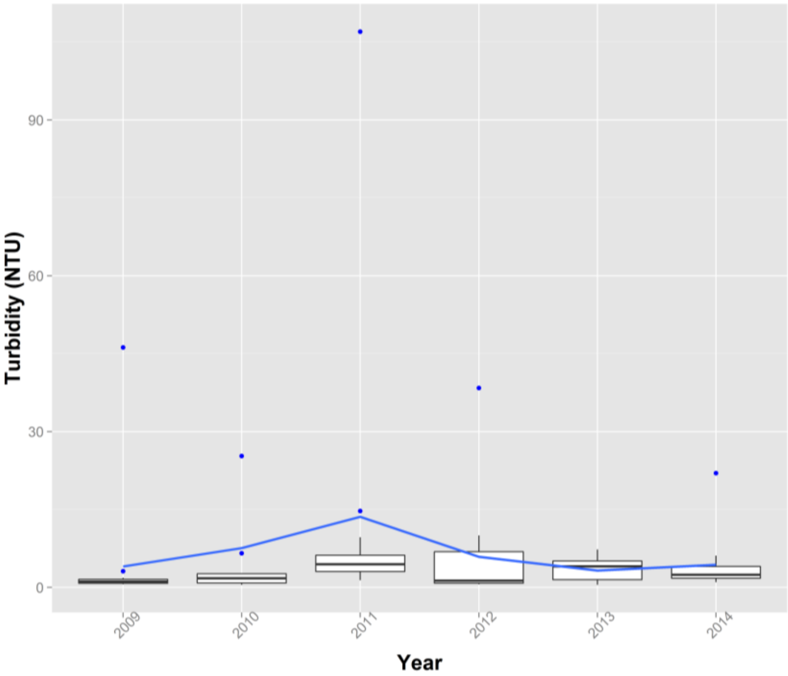


Figure 64: Box plot showing annual trend data for turbidity in the Whangamaire Stream



6 Conclusions and recommendations

6.1 Water quality state

- The water quality state section gives an overview of all the water quality parameters measured on a regional scale, but can hide some very important site specific or even land use specific issues. However, in general, water quality is excellent in native forest catchments, good in rural catchments and poor in urban catchments.
- Outliers in the regional data set for total oxidised N highlight an issue with high concentrations of total oxidised N. Further investigation of this data shows that concentrations in the Whangamaire Stream were responsible for these outliers.
- The water quality state graphs show decreasing trends in many of the metal species that are later confirmed by the trend analysis.

6.2 Water quality trends

- At a *regional* level, decreasing trends in all soluble and total metals (zinc, copper and total lead), are largely attributable to decreasing trends in these parameters in urban streams. Decreasing trends in total zinc, copper and lead in the rural environment may also be playing a smaller role in the overall regional picture. Possible reasons behind these trends may include an increase in the use of pre-coated roofing material for new buildings and to replace uncoated or poorly maintained roofs. Stormwater retention and treatment could be improving in its capture of all these contaminants, reducing the contaminant load of road runoff. Point sources from industry may also be declining in many catchments.
- The regional decreasing trend in total suspended solids is likely due to the increasing amount of impervious surfaces associated with land development.
- Regional decreasing trends in total and soluble phosphorus occurred irrespective of land use, and this is likely to be partially or wholly attributed to a reduction in the detection limits of total and soluble phosphorus. Some of these trends may also be associated with the decreasing trend in total suspended solids.
- The increasing regional trend in total oxidised N was explained by the addition of the Whangamaire Stream to the monitoring network in 2009. Concentrations of total oxidised N were sufficiently high at this site to affect the trend on a regional basis. While this is not a true trend per se, it highlights the important issue of high total oxidised N (namely nitrate) concentrations in this and other streams.

6.3 Recommendations

Based on the water quality state assessment and trend analyses, the following recommendations are suggested:

- Although every effort is made to sample each river at the same time each month, slight differences in time could affect the dissolved oxygen concentrations and percent saturation. Therefore it might be worth considering installing continuous DO monitoring equipment at some strategic sites, particularly those within the lowest (5^{th}) percentile rivers for DO, to investigate diurnal variability and how DO results may be affected by sampling time.
- Consider discontinuing the routine analysis of soluble and total lead due to the large number of samples that are below laboratory detection levels. Sites could be re-checked intermittently say every 3-5 years.
- Consider compiling and reporting laboratory detection limits with the data for the laboratory analysed parameters. This could provide context for low values and important information on when detection limits change.
- Consider the value of the regional level water quality state analysis in the next river water quality state and trends report. In many cases, site specific or even land use specific issues were hidden amongst the large amount of data included. Furthermore, a more detailed view of water quality state can be obtained each year from the state of the environment river water quality annual reports. The findings of this report should be considered in conjunction with the latest "state of the environment river water quality annual report" (Holland and Buckthought, 2015). This state and trends report only indicates the median, magnitude and direction of change in the various water quality parameters, however it does not indicate the background levels from which these changes are occurring (which is available in the annual data reports). For clear and accurate context, the information from both reports needs to be considered together to enable effective policy and management decision making.

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