Coastal Water Quality Report 2013- 2017

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1 Introduction

The Northland Regional Council (council) carries out routine state of the environment monitoring of the region's coastal water quality to assess its state, identify environmental issues and track changes in water quality over time.

This report presents the current state of Northland's water quality using results from monitoring undertaken by council between January 2013 and December 2017 (five years of data). The report includes a comparison of the results with the coastal water quality standards in the Proposed Regional Plan for Northland. It also includes a water quality index used by the Canadian Council of Ministers for the Environment (Canadian Council of Ministers of the Environment, 2001). An analysis of temporal trends is also included.

The results provide resource planners, politicians and the public with information regarding the quality of Northland's coastal waters and compliance with the proposed coastal water quality standards (Griffiths 2016). In the future, the programme will also enable council to assess, whether the Proposed Regional Plan for Northland (Northland Regional Council 2018) and council's non-regulatory management tools (such as soil conservation measures and riparian planting) have been successful at maintaining overall water quality.

2 Methodology

2.1 Sampling programmes

Council monitors coastal water quality in three main coastal systems: Whangārei Harbour; the Bay of Islands; and the Kaipara Harbour. Council has conducted routine water quality monitoring in the Whangārei Harbour since 1986. However, the monitoring programme has been adapted and modified over time, in response to changes in best practice and changes to the objectives for data collection. The programme has largely existed in its current form since May 2008. However, an additional site, Otaika Creek was added in January 2013. In May 2008, council began a routine water quality monitoring programme in the Bay of Islands. In June 2009, council initiated a routine water quality monitoring programme in the Kaipara Harbour in conjunction with Auckland Council. Initially nine sites were sampled in the northern Kaipara but one site (Otamatea Channel) was dropped from the programme in June 2014. Results from this site have previously been reported (Griffiths 2015 and Hudson 2010). In October 2016, council began a new routine water quality monitoring programme in the Mangawhai Harbour (which includes sites in the Ruakaka Estuary and Waipu Estuary). Because there is only 15 months data for these sites, they are not included in this report.

2.2 Sampling sites

Initially 16 sites were monitored in the Whangārei Harbour. These sites have been selected in order to capture the main freshwater inputs to the harbour and to ensure a good geographical spread throughout the harbour. In the inner harbour, six sites are located in the channel draining the Hātea River and two sites are located in the channel that drains the Mangapai River. A further seven sites are located along the main channel of the harbour. The sites cover a range of exposures from open water to sheltered tidal creeks. One site, Mair Bank, is located outside the entrance of the harbour and is considered to be an open coast site. An extra site was added in January 2013, at Otaika Creek, in order to monitor the water quality from this sub-catchment. There are now 17 sites sampled in the Whangārei Harbour (Figure 1).

Sixteen sites are monitored in the Bay of Islands (Figure 2), with these sites selected to capture the main freshwater inputs to the system. Five sites are located in and around the Kawakawa River and the Waikare Inlet and five sites are located in the Kerikeri Inlet, which receives freshwater inputs from the Kerikeri River and Waipapa River. Sample sites are also located in the Waitangi Estuary, Te Haumi Estuary and Te Puna Inlet. The remaining sites are located in more exposed outer estuarine locations around Paihia and Russel.

Initially nine sites were monitored in the Kaipara Harbour (Figure 3) although one of these sites (Otamatea Channel) was dropped from the programme in June 2014. The remaining eight sites are located in the different arms of the harbour (the main Wairoa arm, the Arapaoa River, the Otamatea River and the Oruawharo River) in order to capture the main freshwater inputs to this system. All site co-ordinates have been fixed using a handheld GPS (Appendix 1) so that samples are collected from the same location.

2.3 Sampling frequency

Historically, Whangārei Harbour and the Bay of Islands sites were sampled every other month (in January, March, May, July, September and November). In August 2017, the sample frequency was increased to monthly for both the Whangārei and Bay of Islands. The Kaipara Harbour has always been sampled every month.

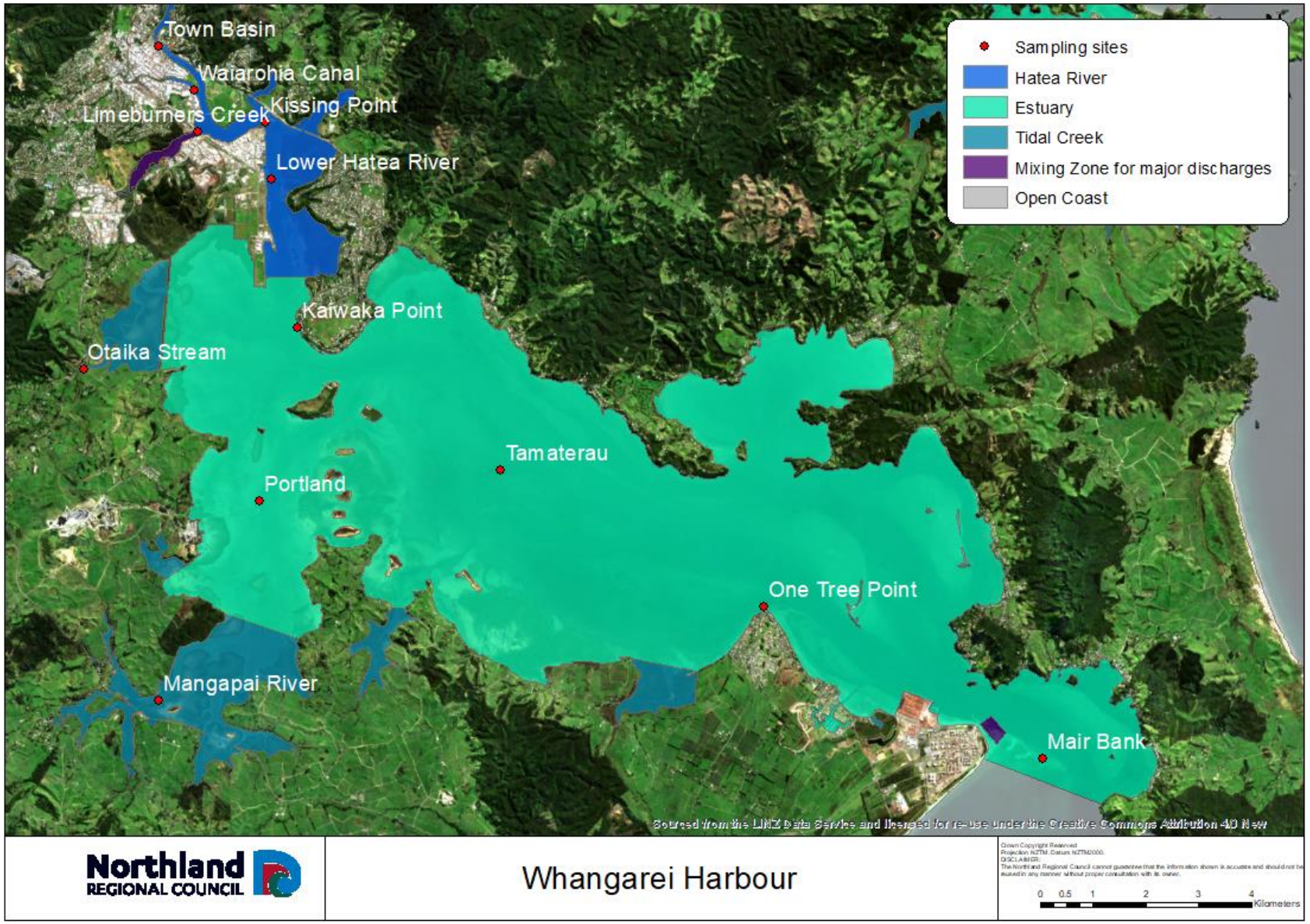

Figure 1: Location of sampling sites in Whangārei Harbour.

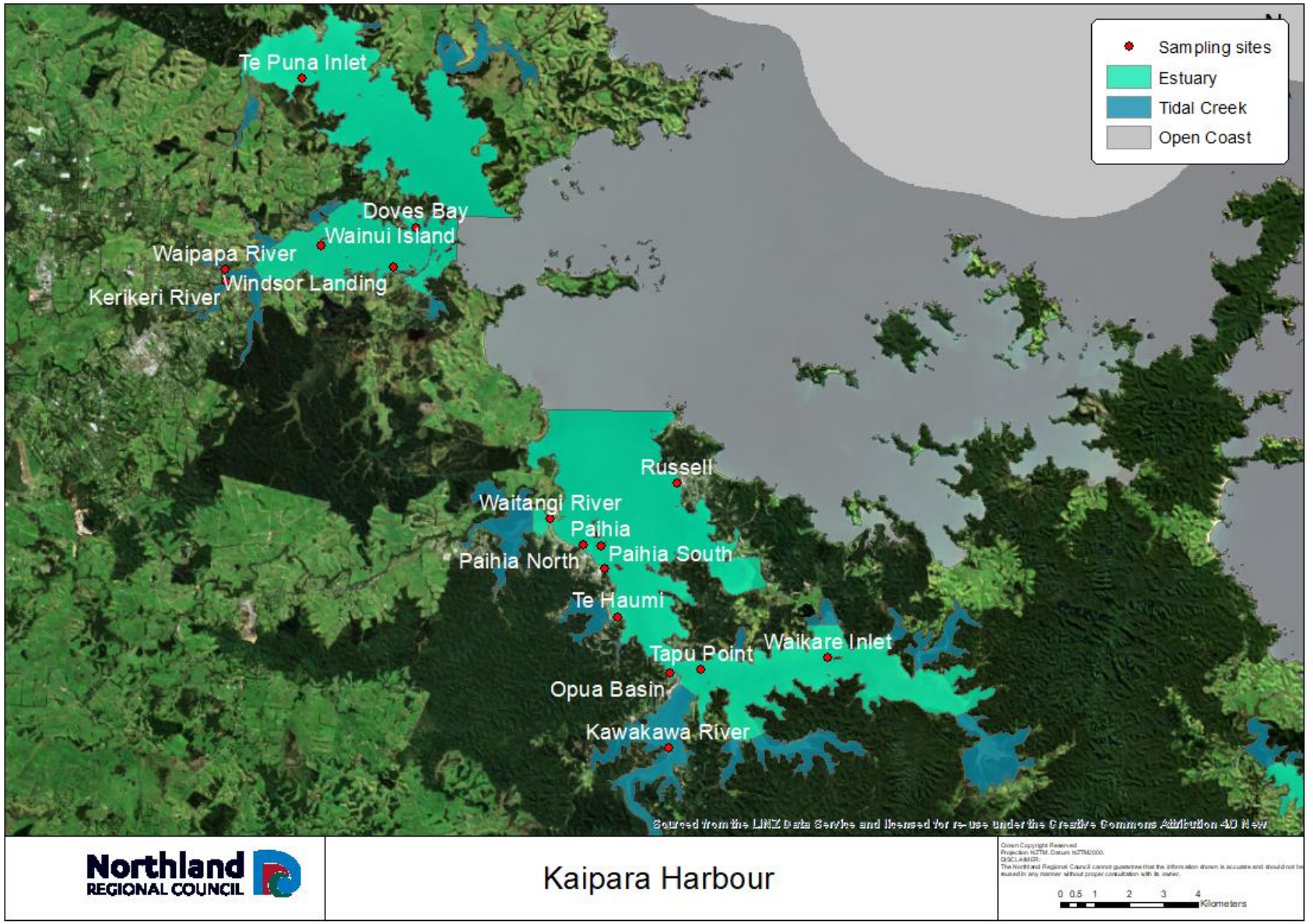

Figure 2: Location of sampling sites in Bay of Islands.

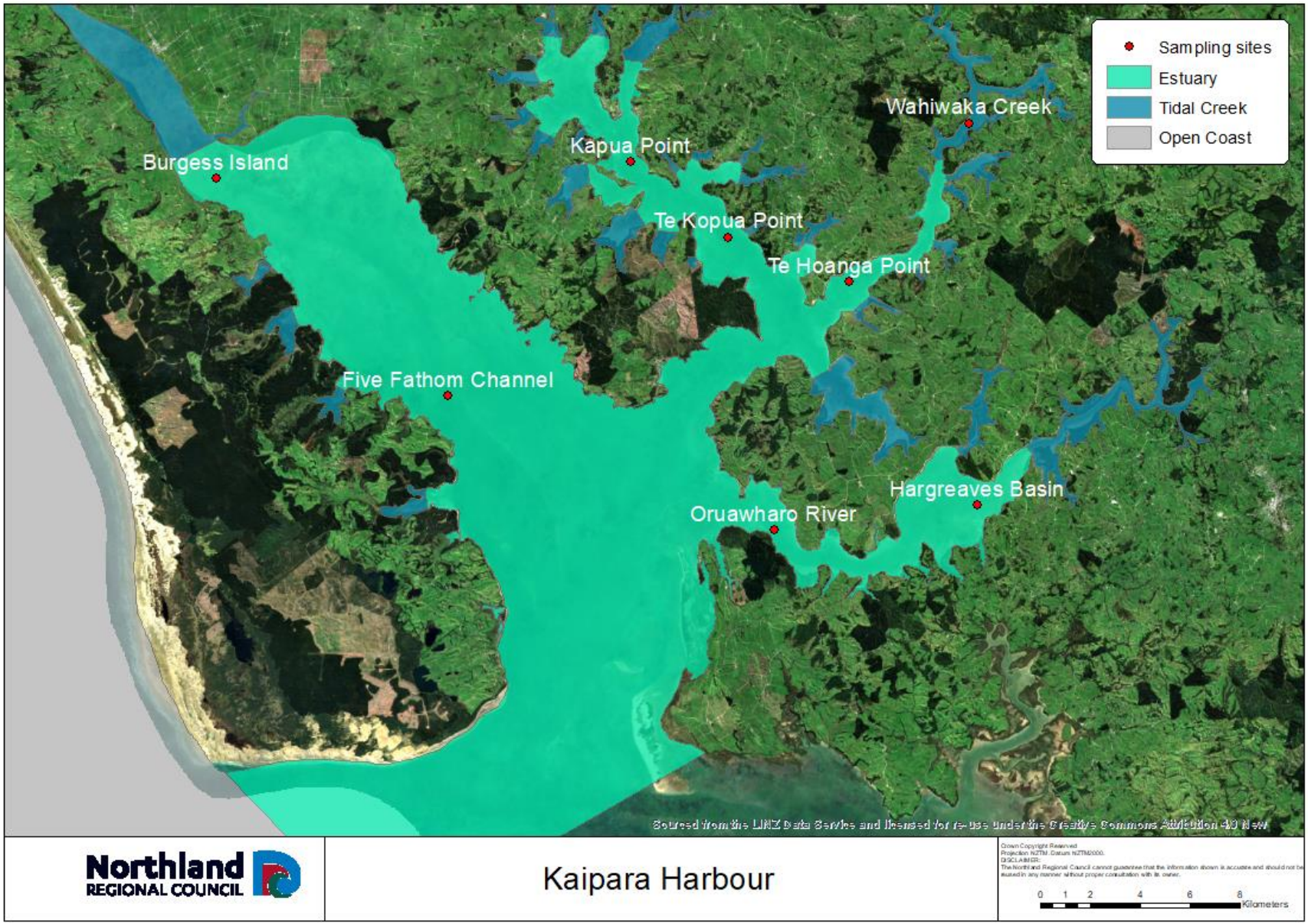

Figure 3: Location of sampling sites in Kaipara Harbour.

2.4 Sampling scheduling

Since 2008 sampling in the Whangārei Harbour and Bay of Islands has been conducted on a predetermined date with no regard to tidal state, to coincide with council's River Water Quality Monitoring Network. By collecting samples on a pre-determined date without regard to the tidal state, the sampling should provide a more representative picture of water quality over time, as the influence of tidal state is incorporated into the water quality results. In the Kaipara Harbour sampling starts at high tide, to coincide with Auckland Council's sampling. Typically, all samples are collected within three hours of high tide. Because the Kaipara Harbour is sampled at high tide, the samples will typically be more influenced by oceanic waters than samples collected from Whangārei and Bay of Islands. Oceanic waters are likely to have lower concentrations of micro bacteria, nutrients and metal contaminant so care should be taken comparing data from the Kaipara Harbour with data from Whangārei Harbour and the Bay of Islands.

2.5 Sampling parameters

In January 2013, a suite of 13 water quality variables were measured in the Whangārei and Bay of Islands. Total nitrogen was added to both programmes in November 2014 and total suspended solids was also added to the Whangārei Harbour and Bay of Islands programmes in November 2014. In July 2015 total copper and total zinc were also added.

In the Kaipara Harbour, a suite of 14 variables have been sampled since the beginning of the programme. Samples from two sites (Hargreaves Basin and Oruawharo River) were initially collected by Auckland Council using a helicopter so secchi depth was not recorded at these sites between June 2009 and June 2014. Secchi depths were recorded at these sites from July 2014 onwards. In July 2015, total zinc, total copper and total lead were added. Faecal coliforms are not currently sampled in the Kaipara Harbour.

The water quality parameters sampled by council and associated laboratory methods are presented in Table 1. A more complete history of when the different parameters were added to each programme is provided by Griffiths (2015). In this report the date range for each parameter is provided in the trend analysis.

2.6 Reporting period

State

Results of council's water quality programme has previously been reported for the period 2010-2014 (Griffiths 2015) and for Whangārei Harbour 2000-2010 (Tweedle *et al.* 2011) and the Kaipara Harbour 2009 (Hudson 2010).

The reporting period for this report is January 2013 to December 2017. When assessing 'state' there is a trade-off between a sufficient sample size to accurately estimate 'state' and the possibility that temporal trends may influence 'state' over longer periods. McBride (2005) suggests that there are diminishing returns on increasing the confidence of population statistics with sample sizes greater than 30. As the Whangārei and Bay of Islands, were sampled on alternate months (until August 2017), a five-year period yields a sample size of 30. Dudley *et al.* (2017) also suggested that assessing state over a five-year period '*represents a reasonable trade-off between sample size and resistance to effects of trends*'. A five-year reporting period is also consistent with the previous reporting for this programme (Griffiths 2015).

Trend analysis

In their analysis of New Zealand Coastal water quality Dudley *et al.* (2017) performed trend analysis for an 8-year period and an 18-year period. In this report trend analysis was only performed if a minimum of 8 years' data was available for a given site. The trend analysis was performed on all available data, so the trend periods cover different time periods for different sites and parameters. As parameters and sites have been added to

the programme over time, there are inconsistencies with the number of sites where trend analysis was performed for different parameters and as all available data was used for trend analysis there are some small differences in the date ranges for the analysis (eight years – nine years). The date range is reported for each parameter by site in the results section.

2.7 Sampling methodology

Some water quality parameters (temperature, salinity and dissolved oxygen) are measured in the field with a YSI handheld meter. The YSI meter is lowered over the side of the boat into the water within the top 0.5m depth and the measurements recorded.

Secchi depth is measured by lowering a secchi disk (with a 20cm diameter) over the side of the boat slowly down into the water. The depth at which the pattern on the disk is no longer visible is recorded as the secchi depth. The secchi reading is taken on the shady side of the boat and is made by the same observer during a sampling run.

Micro-bacteria, total suspended solids, turbidity, chlorophyll-*a*, nutrients and metal samples are collected from the top 0.5m of the water column in the appropriate sample bottle, using a gripper pole. The samples are stored on ice in dark chilli bin and transported to the laboratory for analysis. The laboratory tests for each parameter are listed in Table 1.

Table 1: Water quality parameters.

Water quality parameter	Measurement procedure	Unit/Detection limit
Temperature	In situ field measurement handheld YSI meter	^{o}C
Salinity	In situ field measurement handheld YSI meter	ppt
Secchi depth	In situ field measurement with 200mm secchi disc	m
Turbidity	Turbidity by nephelometry APHA 2130 B	0.05 NTU
Total suspended solids	Total suspended solids by gravimetry APHA 2540 D	0.2 mg/L
Enterococci	APHA (online edition) 9230D	10 MPN/100mL
Faecal coliforms	Faecal coliform (presumptive) APHA section 9222D	<10 cfu/100mL
Dissolved oxygen	In situ field measurement handheld YSI meter	% and mg/L
Chlorophyll a	Chlorophyll *a* by aqueous acetone extraction and APHA (10200 H	0.0006 mg/L
Total phosphorus	Total phosphorus by persulphate digestion and APHA 4500-P J	0.004 mg/L
Dissolved reactive phosphorus	Dissolved reactive phosphorus by colorimetry discrete analyser. APHA 4500-P F	0.002 mg/L
Total nitrogen	Total nitrogen by persulphate digestion and flow analysis. APHA 4500-P J, 4500-NO3 I	0.010 mg/L
Total Kjeldahl nitrogen	Total Kjeldahl nitrogen by calculation	0.02 mg/L
Ammonium	Ammoniacal nitrogen by flow analysis APHA 4500-NH3 H	0.005 mg/L
Nitrate-nitrite nitrogen	Total oxidised nitrogen by automated cadmium reduction/flow analysis (0.45 µm filtered) APHA 4500-NO3 I	0.002 mg/L
Copper	In house based on EPA 200.8 by ICPMS. preparation APHA 3030 E (modified, 4:1 nitric:hydrochloric acid)	0.002 mg/L
Zinc	In house based on EPA 200.8 by ICPMS. preparation APHA 3030 E (modified, 4:1 nitric:hydrochloric acid)	0.010 mg/L
Lead	In house based on EPA 200.8 by ICPMS. preparation APHA 3030 E (modified, 4:1 nitric:hydrochloric acid)	0.010 mg/L

2.8 Data analysis

The maximum, minimum, mean, standard error (S.E.) and the median were calculated for each parameter at each site and are presented in summary tables. The data is also presented in box plots. The box displays the interquartile range (middle 50% of the data) with the middle line indicating the median. The upper whisker extends to the maximum data point within 1.5 box heights from the top of the box and the lower whisker extends to the minimum data point within 1.5 box heights from the bottom of the box. Outliers are depicted by an asterisk (*).

Censored values

Prior to analysis, results reported as below the laboratory detection limit were replaced by a value of half the detection limit (Chapman 1996). For example, a value reported as less than 10 enterococci MPN/100ml by the laboratory would be replaced in the dataset as five enterococci MPN/100ml. Results reported by the laboratory as a greater than value were replaced with the greater than value. For example, a value reported as greater than 30,000 enterococci MPN/100ml by the laboratory would be included in the dataset as 30,000 enterococci MPN/100ml. This rule was not applied to greater than values for secchi depth measurements. This occurs when the secchi disk is still visible when it is on the seabed. In this situation, replacing the greater than value with that value might significantly underestimate secchi depth, particularly at shallow sites. When this occurred, the measurements were removed from the dataset.

When more than 50% of the values for a variable at a site were below the detection limit the median was reported as the detection level. Means and standard errors were still reported but should be treated with caution.

2.8.1 Coastal water quality standards

In the Proposed Regional Plan for Northland (PRP), Northland's coastal marine environment has been classified into four management units: open coast, estuaries, tidal creeks and the Hātea River (Figure 1, 2 & 3). This is an acknowledgement that water quality varies significantly in these different zones and there are different resource uses and values in the different zones (Griffiths 2016). For example, tidal creeks are the immediate receiving environment for streams and rivers so nutrient concentrations will be higher and more variable than estuarine and open coast environments. Tidal creeks are also less likely to be used for primary contact recreation (swimming), shellfish gathering and aquaculture compared to estuarine and open coast environments. Three main resources uses and values are covered by the standards: ecosystem health, contact recreation and shellfish consumption. Griffiths (2016) recommended that all four management units be managed for ecosystem health, and that the estuarine and open coast management units be managed for contact recreation and shellfish consumption.

Consequently, there are different coastal standards for each of the management zones (Table 2). The standards for the different management units were developed using: ANZECC 2000 guideline values for metal contaminants; Microbiological Water Quality Guidelines for Marine and Freshwater Areas (Ministry for the Environment 2003) for micro-bacteria; and reference data for secchi depth, turbidity, dissolved oxygen, chlorophyll-*a* and nutrient concentrations (Griffiths 2016).

For the 'open coast' management unit, there are no numerical values in the PRP for turbidity, secchi depth and nutrient concentrations. Instead the PRP includes a narrative standard for these parameters in the open coast: '*No discernible change'*. For these parameters, the one open coast site (Mair Bank) was assessed against the numerical standards for the 'estuaries' management unit.

In the PRP, the compliance metric for a number of the parameters is the ‘annual median’. Rather than calculating annual medians for each of the five years in the reporting period, compliance has been assessed against the median for all data during the reporting period (2013-2017).

Table 2: Coastal water quality standards for Northland waters (Proposed Regional plan for Northland).

Values	Water Quality Parameter	Compliance metric	Hātea River	Tidal creeks	Estuaries	Open coast
Ecosystem Health - Water clarity	Turbidity (NTU)	Annual median	<7.5	<10.8	<6.9	No discernible change
	Secchi depth (m)	Annual median	>0.8	>0.7	>1.0	No discernible change
Ecosystem Health - Trophic state	Dissolved oxygen (mg/L)	Minimum	4.6	4.6	4.6	4.6
	Dissolved oxygen (mg/L)	Annual median	>6.2	>6.3	>6.9	No discernible change
	Chlorophyll-a (mg/L)	Annual median	<0.003	<0.004	<0.004	No discernible change
	Total nitrogen (mg/L)	Annual median	<0.860	<0.600	<0.220	No discernible change
	Total phosphorus (mg/L)	Annual median	<0.119	<0.040	<0.030	No discernible change
	Dissolved reactive phosphorus (mg/L)	Annual median	<0.092*	<0.021*	<0.017*	No discernible change
Metal contamination	Total zinc (mg/L)	Maximum	0.015	0.015	0.015	0.0070
	Total copper (mg/L)	Maximum	0.0013	0.0013	0.0013	0.0003
Recreation	Enterococci (per 100ml)	Annual 95th percentile	≤500	≤200	≤200	≤40
Shellfish consumption	Faecal coliforms (MPN per 100ml)	Annual median	Not applicable	Not applicable	≤14	≤43
	Faecal coliforms (MPN per 100ml)	Annual 90th percentile	Not applicable	Not applicable	≤14	≤43

* (From Griffiths 2016)

2.8.2 Water quality index

A water quality score was also calculated for each site using a water quality index used by the Canadian Council of Ministers for the Environment (CCME) (Canadian Council of Ministers of the Environment 2001). This index is based on a formula developed by the British Columbia Ministry of Environment, Lands and Parks and modified by Alberta Environment. The index incorporates three elements; scope – the number of parameters not meeting water quality standards; frequency – the number of times that these water quality standards were not met; and amplitude – the amount by which the water quality standards were not met. The index produces a score between 0 (worst water quality) and 100 (best water quality). This analysis was performed based on the different management units and the standards associated with those units.

Seven water quality parameters were selected for inclusion in the water quality index: dissolved oxygen; chlorophyll-*a*; total nitrogen; total phosphorus; turbidity; enterococci; and zinc (Table 3). The calculator allows for the inclusion of multiple parameters. However, there is a risk that by adding additional parameters, the results may be biased by 'double counting' a contaminant. For example, dissolved reactive phosphorus is a constituent of total phosphorus (and the two are typically highly correlated) so including both will increase the influence that phosphorus loading has on the overall score. Equally nitrate-nitrite nitrogen and ammoniacal nitrogen are constituents of total nitrogen so including all three will increase the influence of any nutrient enrichment on the overall score.

Turbidity was selected as the indicator for water clarity, as total suspended solids was only added to Whangārei and Bay of Islands programmes in November 2014 and some sites had a high number of censored values for secchi depth (i.e. the bottom could be seen). Enterococci was selected as the indicator for faecal contamination as 'The New Zealand Marine Bathing Study' showed that enterococci are the indicator most closely correlated with health effects in New Zealand marine waters and not all management units are managed for shellfish consumption so do not have standards for faecal coliforms. Zinc was selected as the laboratory detection limit for copper is <0.002, which is above the coastal water quality standard.

Table 3: Water quality parameters and the standards used to calculate water quality indices.

Water Quality Parameter	Values	Hātea River	Tidal creeks	Estuaries	Open coast
Enterococci (per 100ml)	Suitability for recreation	≤500	≤500	≤200	≤40
Turbidity (NTU)	Water clarity	<7.5	<10.8	<6.9	<6.9
Dissolved oxygen (mg/L)	Trophic state	>6.2	>6.3	>6.9	>6.9
Chlorophyll-*a* (mg/L)	Trophic state	<0.003	<0.004	<0.004	<0.004
Total nitrogen (mg/L)	Trophic state	<0.860	<0.600	<0.220	<0.220
Total phosphorus (mg/L)	Trophic state	<0.119	<0.040	<0.030	<0.030
Total zinc (mg/L)	Metal contamination	<0.015	<0.015	<0.015	0.0070

2.8.3 Trend analysis

Any changes over time (trends) were calculated using the Trend and Equivalence Analysis software Version 5.0, developed by the National Institute of Water and Atmospheric Research (NIWA). The seasonal Kendall test was applied to data for each parameter at each site in order to identify any significant trends in the data. Trend analysis was only performed if the number of censored values in a trend period was less than 15% Dudley *et al*. (2017).

3 Results

3.1 Physical properties

3.1.1 Salinity

The highest median salinity was recorded at sites near the entrance of Whangārei Harbour, at Te Puna and Russel in the Bay of Islands (Table 4 and Figure 4). The lowest median salinity was recorded at Otaika Creek, the Town Basin and Waiarohia Canal in the Whangārei Harbour and at Waipapa River and Kerikeri River in the Bay of Islands. The lowest median salinity in the Kaipara Harbour was recorded at Wahiwaka Creek. These sites are all located in the tidal creek or Hātea Rover management units.

Compliance with coastal water quality standards

There are no standards in the Proposed Regional Plan for salinity and there is no relevant guideline value to make an assessment.

Trend analysis

Trend analysis was not performed for salinity.

Table 4: Salinity data collected from January 2013 to December 2017. Ranked highest to lowest median.

Site	Count	Minimum	Maximum	Mean	S.E.	Median
Mair Bank	33	24.5	36.7	33.9	0.41	34.3
Marsden Point	33	24.5	36.7	34.0	0.39	34.3
Snake Bank	33	24.5	54.8	34.4	0.75	34.3
Blacksmiths Creek	33	23.2	36.7	33.4	0.51	34.1
Te Puna Inlet	31	23.8	37.7	33.2	0.48	33.8
One Tree Point	33	24.4	36.7	33.4	0.42	33.7
Russell	31	23.1	37.2	33.1	0.45	33.6
Windsor Landing	31	21.4	36.4	32.4	0.51	33.1
Tamaterau	33	24.3	36.6	32.6	0.49	33.1
Paihia	31	18.7	37.1	31.6	0.63	32.5
Onerahi	33	23.6	36.2	32.1	0.53	32.5
Paihia South	31	16.4	37.0	31.6	0.66	32.5
Paihia North	31	18.9	36.1	31.2	0.65	32.4
Doves Bay	31	22.3	36.6	32.3	0.47	32.3
Portland	33	23.4	36.2	31.4	0.61	32.1
Te Haumi	31	16.0	36.7	30.9	0.79	32.0
Ōpua Basin	30	18.3	36.9	31.0	0.71	31.9
Tapu Point	30	11.8	36.5	29.3	1.18	31.9
Waitangi River	31	14.2	36.2	28.6	1.16	31.8
Kaiwaka Point	33	20.0	35.9	30.5	0.70	31.6
Waikare Inlet	30	14.0	36.4	29.6	0.96	31.4
Wainui Island	31	18.0	35.7	30.0	0.78	31.3
Mangapai River	33	19.1	36.8	29.1	1.00	31.3
Oruawharo River	58	20.2	35.6	30.0	0.49	30.4
Five Fathom Channel	60	20.1	36.6	29.8	0.51	30.2
Te Kopua	60	18.8	37.3	29.1	0.55	29.5
Lower Hātea River	33	17.5	35.4	29.0	0.74	29.3
Kapua Point	60	17.8	37.2	28.6	0.57	29.3
Te Hoanga Point	60	18.2	37.2	28.9	0.57	29.2
Hargreaves Basin	58	17.6	35.7	28.6	0.60	28.7
Kissing Point	33	18.5	35.1	27.7	0.78	28.0
Wahiwaka Creek	60	13.9	37.4	26.6	0.76	27.7
Limeburners Creek	33	9.0	32.8	25.3	0.98	25.6
Burgess Island	60	12.0	33.6	24.5	0.80	25.3
Kawakawa River	31	2.9	35.5	24.1	1.49	24.2
Waiharohia Canal	33	2.2	30.8	21.2	1.21	22.6
Upper Hātea River	33	6.9	31.4	20.7	1.23	20.7
Town Basin	33	3.2	31.4	16.9	1.56	16.2
Waipapa River	30	3.4	28.1	15.8	1.49	15.8
Kerikeri River	30	3.7	28.0	14.5	1.33	12.2
Otaika Creek	32	0.1	31.8	9.7	1.56	7.5

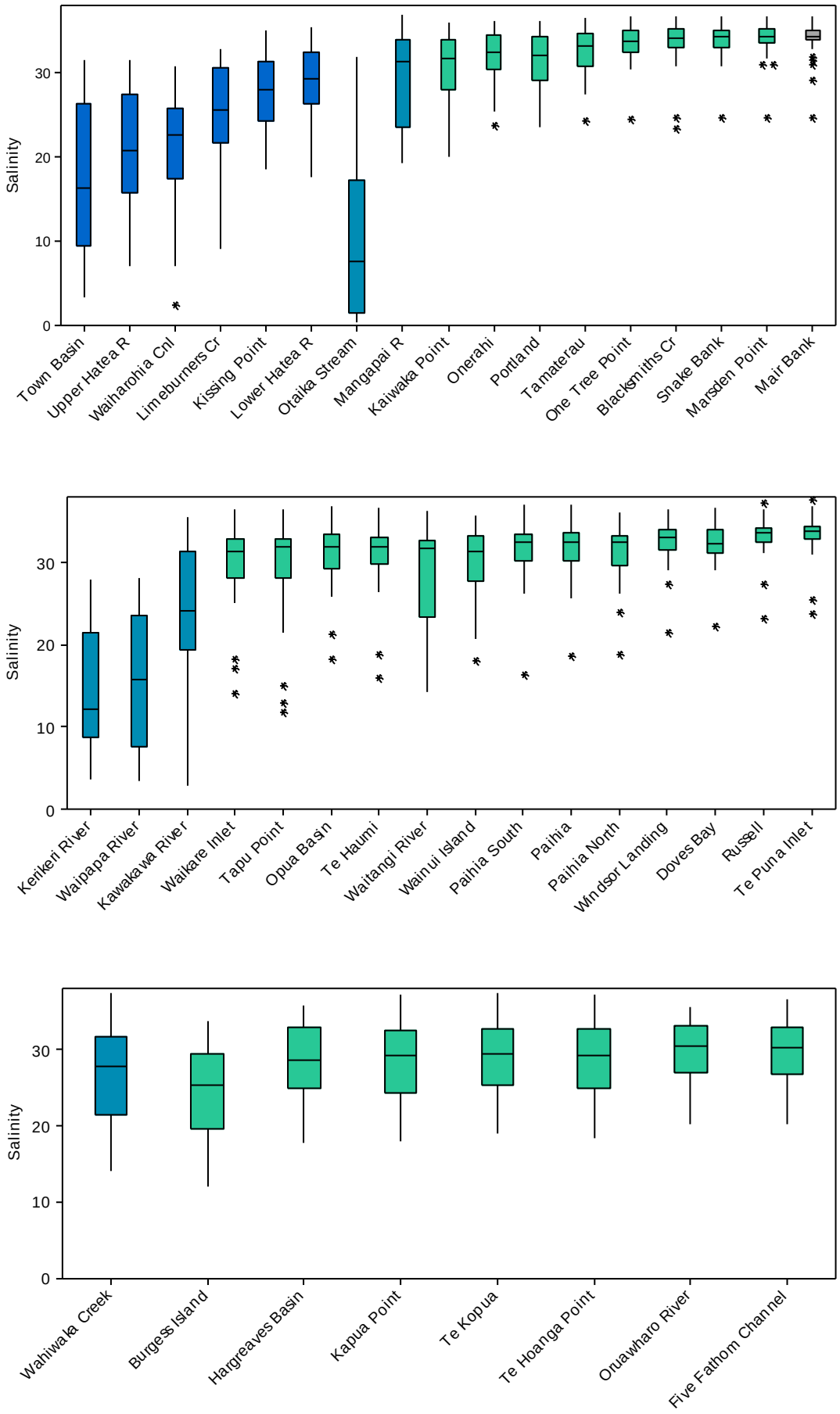

Figure 4: Salinity data collected from January 2013 to December 2017.

3.2 Water clarity

Water clarity is important for the healthy functioning of marine ecosystems. Increased suspended solid loads that reduce water clarity can affect the amount of photosynthesis (primary production) of aquatic plants. Reduced water clarity can also affect the feeding efficiency of visual predators like fish and sea birds and sediment particles can clog the feeding structures and gills of fish and suspension feeding animals like cockles and pipi. Water clarity is also an important attribute for recreation and aesthetics values as poor water clarity makes the water less desirable for swimming and recreational activities.

3.2.1 Secchi depth

The highest median secchi depths were recorded at sites close to the entrance of the Whangārei Harbour (Marsden Point, Mair Bank, One Tree Point, Blacksmith Creek and Snake Bank). All these sites had a median secchi depth of at least 3.15m and the secchi depth at these sites consistently exceeded 2.0m, which suggests that water clarity at these sites is very good (Table 5 and Figure 5). In the Bay of Islands, the highest median secchi depth was at Russel (2.25m) and Doves Bay (2.03m). Doves Bay is located towards the entrance of the Kerikeri Inlet and Russel is a relatively exposed outer estuarine site. In the Kaipara Harbour, the highest secchi depth was recorded at Five Fathom Channel (2.00m), which is located close to the entrance of the harbour.

The lowest median secchi depths were recorded at Limeburners Creek (0.78 m), Mangapai River (0.80m) Kawakawa River (0.81m), Waikare Inlet (0.90m) and Wahiwaka Creek (0.95m). Except for the Waikare Inlet all these sites are all located in either the tidal creek management unit or the Hātea River management unit. They are therefore likely to be influenced by sediment inputs from freshwater streams and rivers. These sites are also likely to be affected to some extent by the resuspension of sediment from the seabed as they are all relatively shallow.

Compliance with coastal water quality standards

Two sites located in the estuarine management unit (Hargreaves Basin and Waikare Inlet had a median secchi depth below the relevant standard (>1.00m) and Limeburners Creek (0.75m) had a median below the standard for the Hātea River management unit(>0.80m). It should be noted that there were two censored values recorded at Limeburners Creek (>0.4m and >2.00m). If the secchi depth had been 0.8m on the sampling occasion when it was recorded as >0.4m (because the seabed was visible) then the median secchi depth would have been 0.8m and the site would have complied with the coastal water quality standards.

Trend analysis

Trend analysis identified increasing (positive) trends at three sites (Table 6). Two of these sites Oruawharo River and Hargreaves Basin are in the Kaipara Harbour and a third site Russel, is in the Bay of Islands. Decreasing (negative) trends were identified at seven sites (Table 6). These sites are located in the Whangārei Harbour, and four of them were within the Hātea River management unit. Trend analysis was not performed at three sites (Blacksmith Creek, Mair Bank and Snake Bank) as there were too many censored values at these sites.

Table 5: Secchi depth (m) data collected from January 2013 to December 2017. Ranked highest to lowest median.

Site	Count	Minimum	Maximum	Mean	S.E.	Median	Compliance
Marsden Point	33	1.50	8.50	4.29	0.331	4.00	✓
Mair Bank	33	1.70	9.00	4.11	0.298	3.60	✓
One Tree Point	33	1.50	6.50	3.82	0.258	3.50	✓
Blacksmiths Creek	33	0.93	5.50	2.87	0.289	3.25	✓
Snake Bank	33	1.00	6.10	3.60	0.259	3.15	✓
Russell	33	0.92	4.89	2.46	0.159	2.25	✓
Five Fathom Channel	60	1.10	3.70	2.20	0.084	2.10	✓
Doves Bay	33	1.27	4.15	2.31	0.127	2.03	✓
Tamaterau	33	1.00	5.00	2.29	0.163	2.00	✓
Paihia North	33	0.60	4.02	2.01	0.147	2.00	✓
Paihia	33	0.63	3.92	1.94	0.142	1.95	✓
Windsor Landing	33	1.00	4.40	1.93	0.131	1.70	✓
Paihia South	33	0.75	4.16	1.81	0.140	1.70	✓
Waitangi River	33	0.25	3.02	1.59	0.124	1.60	✓
Te Puna Inlet	33	0.75	2.68	1.52	0.088	1.50	✓
Oruawharo River	58	0.70	2.45	1.44	0.067	1.45	✓
Wainui Island	33	0.57	2.23	1.36	0.064	1.35	✓
Onerahi	33	0.20	2.00	1.24	0.083	1.35	✓
Te Kopua	60	0.60	2.80	1.32	0.065	1.25	✓
Te Haumi	33	0.45	2.60	1.32	0.092	1.20	✓
Kaiwaka Point	33	0.60	2.90	1.29	0.081	1.20	✓
Kerikeri River	33	0.60	2.20	1.22	0.060	1.20	✓
Te Hoanga Point	60	0.45	2.00	1.15	0.049	1.10	✓
Town Basin	33	0.30	2.25	1.12	0.067	1.10	✓
Portland	33	0.43	2.25	1.11	0.083	1.10	✓
Ōpua Basin	33	0.50	3.11	1.24	0.091	1.05	✓
Tapu Point	33	0.41	3.37	1.15	0.094	1.05	✓
Waipapa River	33	0.53	1.72	1.09	0.051	1.05	✓
Waiharohia Canal	33	0.60	1.50	0.94	0.046	1.00	✓
Lower Hātea River	33	0.50	3.50	1.20	0.096	1.00	✓
Burgess Island	60	0.50	2.80	1.11	0.057	1.00	✓
Kissing Point	33	0.50	2.00	1.10	0.080	1.00	✓
Kapua Point	60	0.40	2.05	1.09	0.055	1.00	✓
Upper Hātea River	33	0.40	> 2.00	1.05	0.054	1.00	✓
Hargreaves Basin	58	0.55	1.75	0.98	0.041	0.95	×
Wahiwaka Creek	60	0.25	2.20	0.97	0.049	0.95	✓
Waikare Inlet	33	0.44	1.76	0.95	0.062	0.90	×
Kawakawa River	33	0.19	2.52	0.88	0.078	0.81	✓
Mangapai River	33	0.40	>2.00	0.86	0.058	0.80	✓
Limeburners Creek	33	0.43	>2.00	0.86	0.063	0.75	×

*Secchi not measured at Otaika

Table 6: Mann-Kendall seasonal trend analysis of secchi depth.

Site	Sampling period	Count	Censored values	Trend	P-value	% annual change
Oruawharo River	2/6/11-14/12/17	48	0	Increasing	<0.001	19.9
Hargreaves Basin	2/6/11-14/12/17	48	0	Increasing	<0.001	19.7
Lower Hātea River	26/3/08-16/11/17	59	0	Decreasing	<0.001	-3.5
Limeburners Creek	26/3/08-16/11/17	59	5	Decreasing	<0.001	-6.2
Kissing Point	26/3/08-16/11/17	59	1	Decreasing	0.001	-5.6
Waiharohia Canal	26/3/08-16/11/17	59	2	Decreasing	0.001	-5.0
Onerahi	26/3/08-16/11/17	59	4	Decreasing	0.020	-4.6
Portland	26/3/08-16/11/17	59	0	Decreasing	0.022	-4.5
Tamaterau	26/3/08-16/11/17	59	0	Decreasing	0.044	-3.0
Russell	14/1/09-16/11/17	54	1	Increasing	0.046	2.9
Paihia	14/1/09-16/11/17	54	0	None detected	0.054	5.8
Burgess Island	3/11/09-14/12/17	94	0	None detected	0.060	2.5
Windsor Landing	14/1/09-16/11/17	54	0	None detected	0.063	3.0
Paihia North	14/1/09-16/11/17	54	0	None detected	0.065	5.2
Upper Hātea River	26/3/08-16/11/17	59	1	None detected	0.068	-2.3
Town Basin	26/3/08-16/11/17	60	0	None detected	0.069	-2.1
Paihia South	14/1/09-16/11/17	54	0	None detected	0.096	4.4
Te Puna Inlet	14/1/09-16/11/17	54	0	None detected	0.096	3.5
Five Fathom Channel	3/11/09-14/12/17	94	0	None detected	0.100	2.7
Doves Bay	14/1/09-16/11/17	53	0	None detected	0.165	2.9
Waitangi River	14/1/09-16/11/17	54	1	None detected	0.193	3.8
Te Hoanga Point	3/11/09-14/12/17	92	0	None detected	0.230	-1.4
Marsden Point	26/3/08-16/11/17	58	8	None detected	0.241	-3.1
Ōpua Basin	14/1/09-16/11/17	54	0	None detected	0.277	1.8
Waipapa River	14/1/09-16/11/17	54	0	None detected	0.277	-1.8
One Tree Point	26/3/08-16/11/17	59	2	None detected	0.287	-2.2
Kaiwaka Point	26/3/08-16/11/17	59	0	None detected	0.303	-1.5
Te Kopua	3/11/09-14/12/17	93	0	None detected	0.310	-1.1
Mangapai River	26/3/08-16/11/17	59	1	None detected	0.397	0.0
Kapua Point	3/11/09-14/12/17	93	0	None detected	0.410	1.3
Tapu Point	14/1/09-16/11/17	54	0	None detected	0.556	0.7
Te Haumi	14/1/09-16/11/17	53	7	None detected	0.578	0.9
Wahiwaka Creek	3/11/09-14/12/17	93	0	None detected	0.600	0.0
Waikare Inlet	14/1/09-16/11/17	54	0	None detected	0.651	0.0
Kerikeri River	14/1/09-16/11/17	54	2	None detected	0.652	0.7
Kawakawa River	14/1/09-16/11/17	53	0	None detected	0.743	0.0
Wainui Island	14/1/09-16/11/17	54	0	None detected	1.000	0.0
Blacksmiths Creek	14/5/08-16/11/17	57	11	>15% censored	-	-
Mair Bank	26/3/08-16/11/17	57	13	>15% censored	-	-
Snake Bank	14/5/08-16/11/17	56	14	>15% censored	-	-

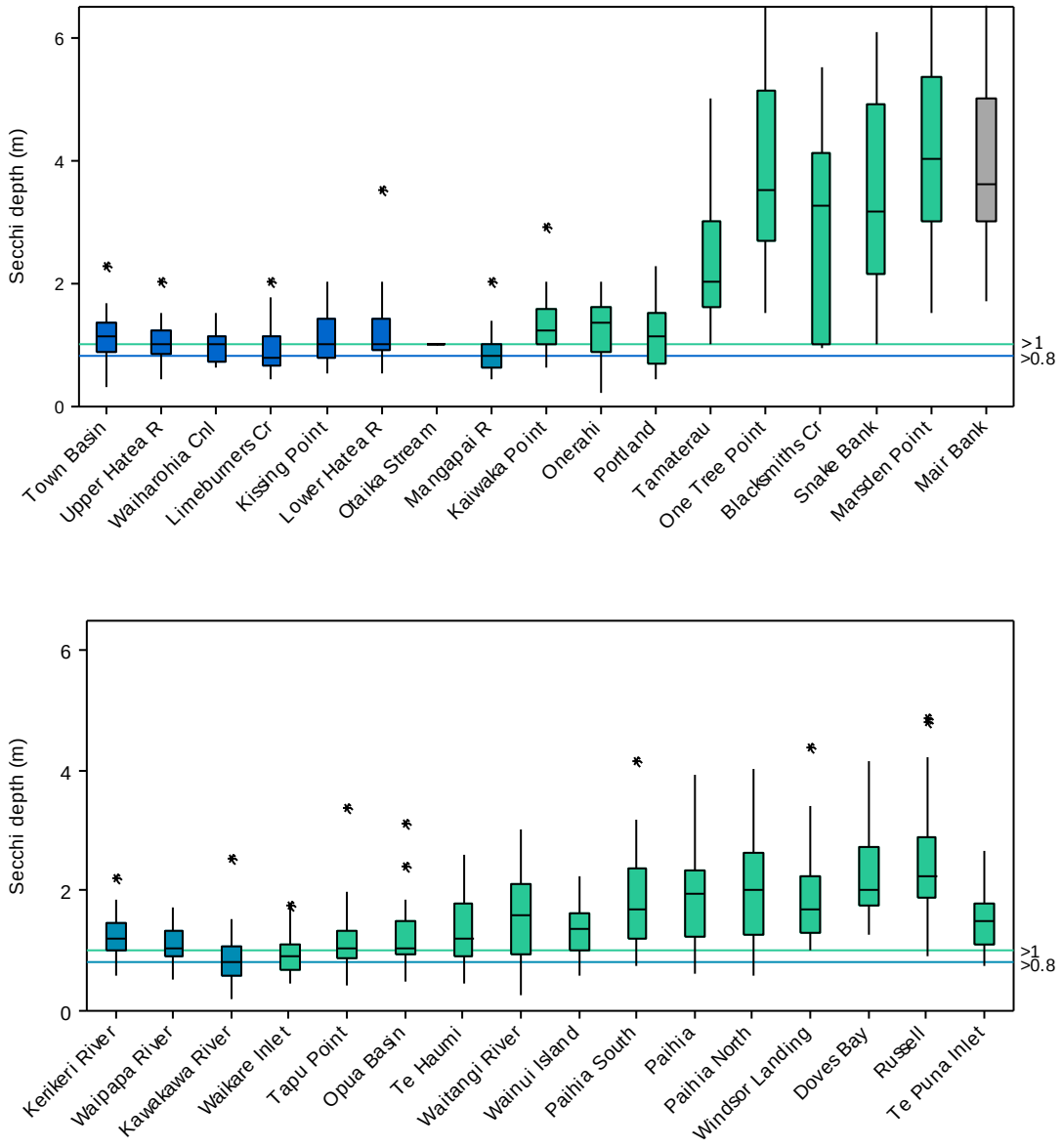

Figure 5: Secchi depth data collected from January 2013 to December 2017. Coastal water quality standards: estuaries >1.0m; tidal creeks >0.7m; and the Hātea River >0.8m.

3.2.2 Turbidity

The lowest median turbidity was recorded at sites close to the entrance of the Whangārei Harbour (Mair Bank, Marsden Point, Blacksmith Creek, One Tree Point and Snake Bank) (Table 7 & Figure 6). All these sites had a median turbidity of less than 1.2 NTU, and low turbidity consistently recorded at these sites (Figure 6). In the Kaipara Harbour, the lowest median turbidity was recorded at Five Fathom Channel (1.8 NTU) and in the Bay of Islands, the lowest median turbidity was recorded at Paihia North (2.39 NTU). Low median turbidity was also recorded at Russel and Doves Bay (Table 7 & Figure 6).

The highest median turbidity values were recorded at Otaika Creek (8.90 NTU), Mangapai River (8.26 NTU) and Kawaka River (7.25 NTU). These sites are all located in the tidal creek management unit.

Compliance with coastal water quality standards

All 41 sites recorded median turbidity values below the relevant coastal water quality standards (Table 7 & Figure 6)

Trend analysis

Trend analysis identified decreasing (positive) trends at six sites (Table 8). Four of these sites are in the Bay of Islands and two in the Kaipara Harbour. The decreasing trend for turbidity identified at Oruawharo River matches the increasing (positive) trend found at that site for secchi depth. Interestingly, decreasing (positive) trends for turbidity were not found at Hargreaves Basin or Russel, where positive trends were identified for secchi depth. No increasing (negative trends) were identified for turbidity.

Table 7: Turbidity (NTU) data collected from January 2013 to December 2017. Ranked lowest to highest median.

Site	Count	Minimum	Maximum	Mean	S.E.	Median	Compliance
Mair Bank	33	0.41	2.84	0.92	0.098	0.77	✓
Marsden Point	33	0.48	3.44	1.03	0.102	0.86	✓
Blacksmiths Creek	33	0.35	8.11	1.34	0.242	1.03	✓
One Tree Point	33	0.41	2.58	1.26	0.113	1.16	✓
Snake Bank	33	0.39	3.59	1.40	0.148	1.20	✓
Five Fathom Channel	60	0.50	7.20	2.14	0.173	1.80	✓
Paihia North	33	1.50	10.50	3.37	0.369	2.29	✓
Russell	33	0.80	7.31	2.53	0.206	2.31	✓
Doves Bay	33	0.97	8.25	2.63	0.226	2.43	✓
Tamaterau	33	0.68	7.30	2.76	0.261	2.50	✓
Windsor Landing	33	0.95	5.62	3.05	0.199	2.67	✓
Paihia	33	1.16	11.20	3.83	0.389	2.72	✓
Oruawharo River	58	1.00	18.00	4.19	0.340	3.45	✓
Paihia South	33	1.20	10.50	4.23	0.428	3.70	✓
Te Puna Inlet	33	1.83	8.03	4.13	0.305	3.86	✓
Te Kopua	60	1.10	11.00	4.46	0.288	3.90	✓
Onerahi	33	1.70	25.70	5.38	0.755	4.02	✓
Waitangi River	33	1.60	32.10	5.52	0.974	4.03	✓
Kerikeri River	33	1.67	17.10	4.68	0.514	4.12	✓
Upper Hātea River	33	2.11	14.30	5.03	0.503	4.14	✓
Town Basin	33	2.57	19.20	5.40	0.655	4.22	✓
Wainui Island	33	2.18	18.30	5.35	0.575	4.55	✓
Te Haumi	33	0.90	17.20	5.69	0.655	4.66	✓
Kaiwaka Point	33	1.88	12.40	5.37	0.449	4.73	✓
Waiharohia Canal	33	1.76	14.60	5.71	0.552	4.79	✓
Te Hoanga Point	60	1.80	20.00	5.72	0.461	4.80	✓
Waipapa River	33	1.50	20.90	5.71	0.667	4.89	✓
Lower Hātea River	33	1.20	11.40	5.08	0.392	5.15	✓
Ōpua Basin	33	1.89	13.90	5.93	0.494	5.23	✓
Kapua Point	60	1.60	21.00	6.22	0.476	5.50	✓
Tapu Point	33	1.40	22.10	6.58	0.659	5.58	✓
Hargreaves Basin	58	2.00	14.00	6.33	0.324	5.65	✓
Kissing Point	33	0.97	12.40	5.69	0.444	5.66	✓
Burgess Island	60	1.30	17.00	6.56	0.468	5.70	✓
Wahiwaka Creek	60	2.10	19.00	7.14	0.540	5.90	✓
Limeburners Creek	33	1.92	17.00	7.09	0.618	6.17	✓
Portland	33	2.13	21.70	7.02	0.729	6.22	✓
Waikare Inlet	33	3.22	18.20	8.34	0.712	6.69	✓
Kawakawa River	33	1.07	53.40	10.77	1.820	7.25	✓
Mangapai River	33	2.29	28.90	8.89	0.906	8.26	✓
Otaika Creek	33	2.80	112.80	14.05	3.340	8.90	✓

Table 8: Mann-Kendall seasonal trend analysis of turbidity (NTU).

Site	Sampling period	Count	Censored values	Trend	P-value	% annual change
Kapua Point	27/5/09-14/12/17	100	0	Decreasing	0.010	-4.96
Windsor Landing	16/7/08-16/11/17	56	1	Decreasing	0.010	-5.57
Paihia South	14/5/08-16/11/17	58	0	Decreasing	0.020	-5.06
Te Puna Inlet	14/5/08-16/11/17	56	0	Decreasing	0.040	-5.48
Oruawharo River	27/5/09-14/12/17	99	0	Decreasing	0.050	-4.92
Te Haumi	14/5/08-16/11/17	59	0	Decreasing	0.050	-3.70
Paihia North	14/5/08-16/11/17	56	1	None detected	0.090	-4.65
Paihia	14/5/08-16/11/17	56	0	None detected	0.100	-4.30
Kerikeri River	16/7/08-16/11/17	56	0	None detected	0.100	-5.56
Doves Bay	14/5/08-16/11/17	57	1	None detected	0.100	-2.64
Wahiwaka Creek	27/5/09-14/12/17	100	0	None detected	0.120	-3.94
Russell	14/5/08-16/11/17	57	4	None detected	0.130	-4.84
Hargreaves Basin	27/5/09-14/12/17	100	0	None detected	0.160	-2.17
Mangapai River	26/3/08-16/11/17	59	0	None detected	0.170	-2.49
Waitangi River	16/7/08-16/11/17	56	1	None detected	0.220	-3.94
Upper Hātea River	26/3/08-16/11/17	59	0	None detected	0.225	-2.28
Kaiwaka Point	26/3/08-16/11/17	59	0	None detected	0.290	-2.14
Burgess Island	27/5/09-14/12/17	100	0	None detected	0.300	-2.48
Five Fathom Channel	27/5/09-14/12/17	100	0	None detected	0.330	-2.48
Ōpua Basin	14/5/08-16/11/17	57	0	None detected	0.390	-1.96
Tapu Point	14/5/08-16/11/17	57	0	None detected	0.410	-2.44
Te Hoanga Point	27/5/09-14/12/17	100	0	None detected	0.440	1.43
Kawakawa River	14/5/08-16/11/17	57	0	None detected	0.460	-2.49
Lower Hātea River	26/3/08-16/11/17	59	0	None detected	0.481	-1.01
Waikare Inlet	14/5/08-16/11/17	57	0	None detected	0.510	1.38
Portland	26/3/08-16/11/17	59	0	None detected	0.583	-1.90
Wainui Island	14/5/08-16/11/17	57	1	None detected	0.620	-1.13
Waipapa River	14/5/08-16/11/17	57	0	None detected	0.650	1.47
Waiharohia Canal	26/3/08-16/11/17	59	0	None detected	0.667	-2.15
Tamaterau	26/3/08-16/11/17	58	2	None detected	0.687	-0.69
Town Basin	26/3/08-16/11/17	59	0	None detected	0.695	-0.48
Kissing Point	26/3/08-16/11/17	59	0	None detected	0.814	0.72
Te Kopua	27/5/09-14/12/17	100	0	None detected	0.840	-0.50
Onerahi	26/3/08-16/11/17	58	0	None detected	1.000	-0.29
Limeburners Creek	26/3/08-16/11/17	59	0	None detected	1.000	0.00
Mair Bank	26/3/08-16/11/17	57	17	>15% censored	-	-
Marsden Point	26/3/08-16/11/17	58	18	>15% censored	-	-
Blacksmiths Creek	26/3/08-16/11/17	59	16	>15% censored	-	-
Snake Bank	26/3/08-16/11/17	59	14	>15% censored	-	-
One Tree Point	26/3/08-16/11/17	59	16	>15% censored	-	-
Otaika Creek	17/1/13-16/11/17	33	0	Insufficient data	-	-

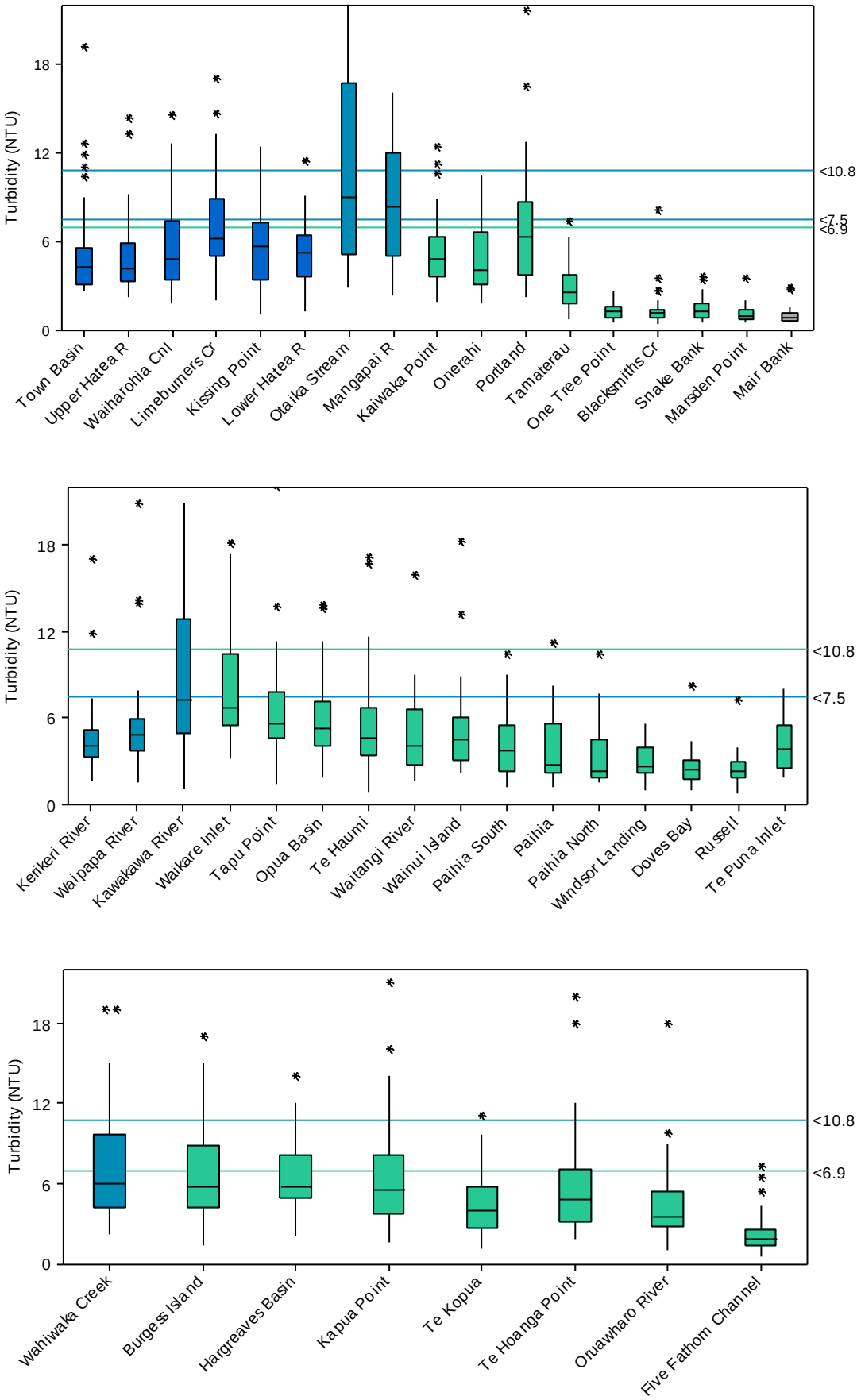

Figure 6: Turbidity data collected from January 2013 to December 2017. Coastal water quality standards: estuaries 6.9 NTU; tidal creeks 10.8 NTU; and Hātea River 7.5 NTU. Note some outliers exceed the y axis extent.

3.2.3 Total suspended solids

The lowest median total suspended solid concentrations were recorded at sites close to the entrance of the Whangārei Harbour (Table 9 & Figure 7). One Tree Point, Snake Bank, Mair Bank, Tamaterau and Marsden Point all recorded medians less than 6 g/m^3, indicating that water clarity is very good. In the Bay of Islands six sites (Paihia North, Kerikeri River, Waipapa River, Windsor landing, Doves Bay and Paihia South) all had a median TSS of 8 g/m^3 (Table 9). Most of these sites are located in the estuarine management unit away from freshwater inputs, but two sites (Kerikeri River and Waipapa River) are located in the tidal creek management unit. Interestingly these sites did not have particularly high secchi depth or low turbidity (See Section 3.2.1 & 3.2.2). In the Kaipara Harbour the lowest median TSS was recorded at Five Fathom Channel (8 g/m^3), which is closest to the entrance of the harbour.

The highest median suspended solid concentrations were recorded at Mangapai River (20 g/m^3) in Whangārei Harbour and at Wahiwaka Creek (18 g/m^3) in the Kaipara Harbour (Table 9 and Figure 7). These sites are both located in the tidal creek management unit.

Compliance with coastal water quality standards

There are no standards in the Proposed Regional Plan and the ANZECC 2000 guidelines do not include a trigger value for total suspended solids so there is no relevant guideline value to make an assessment.

Trend analysis

Total suspended solids have only been analysed in Whangārei and Bay of Islands since November 2014 so there was insufficient data to undertake trend analysis for these sites. Trend analysis performed on the eight sites in the Kaipara Harbour did not identify any significant trends (Table 10).

Table 9: Suspended solid (g/m^3) data collected from January 2013 to December 2017. Ranked lowest to highest median.

Site	Count	Minimum	Maximum	Mean	S.E.	Median
One Tree Point	22	2	18	6	0.78	5
Snake Bank	22	2	16	7	0.87	6
Mair Bank	22	1	30	7	1.32	6
Tamaterau	22	2	19	9	1.10	6
Marsden Point	22	2	14	6	0.72	6
Blacksmiths Creek	22	2	19	8	1.13	7
Paihia North	22	4	21	9	1.01	8
Kerikeri River	22	2	20	8	0.94	8
Waipapa River	22	4	16	8	0.73	8
Five Fathom Channel	60	2	32	9	0.69	8
Town Basin	22	3	23	10	1.17	8
Windsor Landing	22	3	26	10	1.26	8
Doves Bay	22	2	33	9	1.46	8
Paihia South	22	3	20	10	1.05	9
Waiharohia Canal	22	4	18	11	0.92	9
Russell	22	4	29	11	1.25	10
Ōpua Basin	22	5	38	13	1.67	10
Paihia	22	4	18	10	1.02	10
Wainui Island	22	3	44	13	2.11	10
Waitangi River	22	4	50	13	2.14	10
Te Haumi	22	2	43	14	2.13	11
Upper Hātea River	22	4	20	11	0.96	11
Te Puna Inlet	22	4	40	12	1.71	11
Te Kopua	60	5	37	13	0.83	12
Kaiwaka Point	22	6	27	12	1.03	12
Kissing Point	22	5	21	12	1.07	12
Lower Hātea River	22	5	26	13	1.41	12
Portland	22	6	32	14	1.55	12
Tapu Point	22	4	34	14	1.83	12
Waikare Inlet	22	6	38	15	1.91	12
Onerahi	22	4	34	14	1.72	13
Oruawharo River	58	4	47	14	0.97	13
Kawakawa River	22	7	90	19	3.75	14
Burgess Island	60	5	34	15	0.87	14
Te Hoanga Point	60	3	47	16	1.11	14
Kapua Point	60	5	58	17	1.23	15
Otaika Creek	22	6	43	18	2.36	15
Limeburners Creek	22	7	27	16	1.17	15
Hargreaves Basin	58	7	33	16	0.77	16
Wahiwaka Creek	60	6	53	20	1.24	18
Mangapai River	22	7	39	19	1.83	20

Table 10: Mann-Kendall seasonal trend analysis of total suspended solids.

Site	Sampling period	Count	Censored values	Trend	P-value	% annual change
Burgess Island	27/5/09-14/12/17	101	0	None detected	0.450	1.79
Five Fathom Channel	27/5/09-14/12/17	101	0	None detected	0.310	1.95
Te Kopua	27/5/09-14/12/17	101	0	None detected	0.070	3.19
Kapua Point	27/5/09-14/12/17	101	0	None detected	0.370	-2.47
Te Hoanga Point	27/5/09-14/12/17	101	0	None detected	0.070	2.79
Wahiwaka Creek	27/5/09-14/12/17	101	0	None detected	0.550	0.80
Oruawharo River	27/5/09-14/12/17	99	0	None detected	0.860	0.00
Hargreaves Basin	27/5/09-14/12/17	100	0	None detected	0.520	-0.32
Te Haumi	13/11/14-16/11/17	19	0	Insufficient data	-	-
Paihia South	13/11/14-16/11/17	19	0	Insufficient data	-	-
Russell	13/11/14-16/11/17	19	0	Insufficient data	-	-
Kawakawa River	13/11/14-16/11/17	19	0	Insufficient data	-	-
Ōpua Basin	13/11/14-16/11/17	19	0	Insufficient data	-	-
Tapu Point	14/3/13-16/11/17	20	0	Insufficient data	-	-
Waikare Inlet	14/3/13-16/11/17	20	0	Insufficient data	-	-
Paihia	13/11/14-16/11/17	19	0	Insufficient data	-	-
Paihia North	13/11/14-16/11/17	19	0	Insufficient data	-	-
Waitangi River	13/11/14-16/11/17	19	0	Insufficient data	-	-
Windsor Landing	13/11/14-16/11/17	19	0	Insufficient data	-	-
Kerikeri River	13/11/14-16/11/17	19	0	Insufficient data	-	-
Waipapa River	13/11/14-16/11/17	19	0	Insufficient data	-	-
Wainui Island	13/11/14-16/11/17	19	0	Insufficient data	-	-
Doves Bay	13/11/14-16/11/17	19	0	Insufficient data	-	-
Te Puna Inlet	13/11/14-16/11/17	19	0	Insufficient data	-	-
Mair Bank	26/11/14-16/11/17	19	0	Insufficient data	-	-
Marsden Point	26/11/14-16/11/17	19	0	Insufficient data	-	-
Blacksmiths Creek	26/11/14-16/11/17	19	0	Insufficient data	-	-
Snake Bank	26/11/14-16/11/17	19	0	Insufficient data	-	-
One Tree Point	26/11/14-16/11/17	19	0	Insufficient data	-	-
Tamaterau	26/11/14-16/11/17	19	0	Insufficient data	-	-
Mangapai River	26/11/14-16/11/17	19	0	Insufficient data	-	-
Portland	26/11/14-16/11/17	19	0	Insufficient data	-	-
Onerahi	26/11/14-16/11/17	19	0	Insufficient data	-	-
Kaiwaka Point	26/11/14-16/11/17	19	0	Insufficient data	-	-
Limeburners Creek	26/11/14-16/11/17	19	0	Insufficient data	-	-
Lower Hātea River	26/11/14-16/11/17	19	0	Insufficient data	-	-
Kissing Point	26/11/14-16/11/17	19	0	Insufficient data	-	-
Waiharohia Canal	26/11/14-16/11/17	19	0	Insufficient data	-	-
Upper Hātea River	26/11/14-16/11/17	19	0	Insufficient data	-	-
Town Basin	26/11/14-16/11/17	19	0	Insufficient data	-	-
Otaika Creek	17/1/13-16/11/17	19	0	Insufficient data	-	-

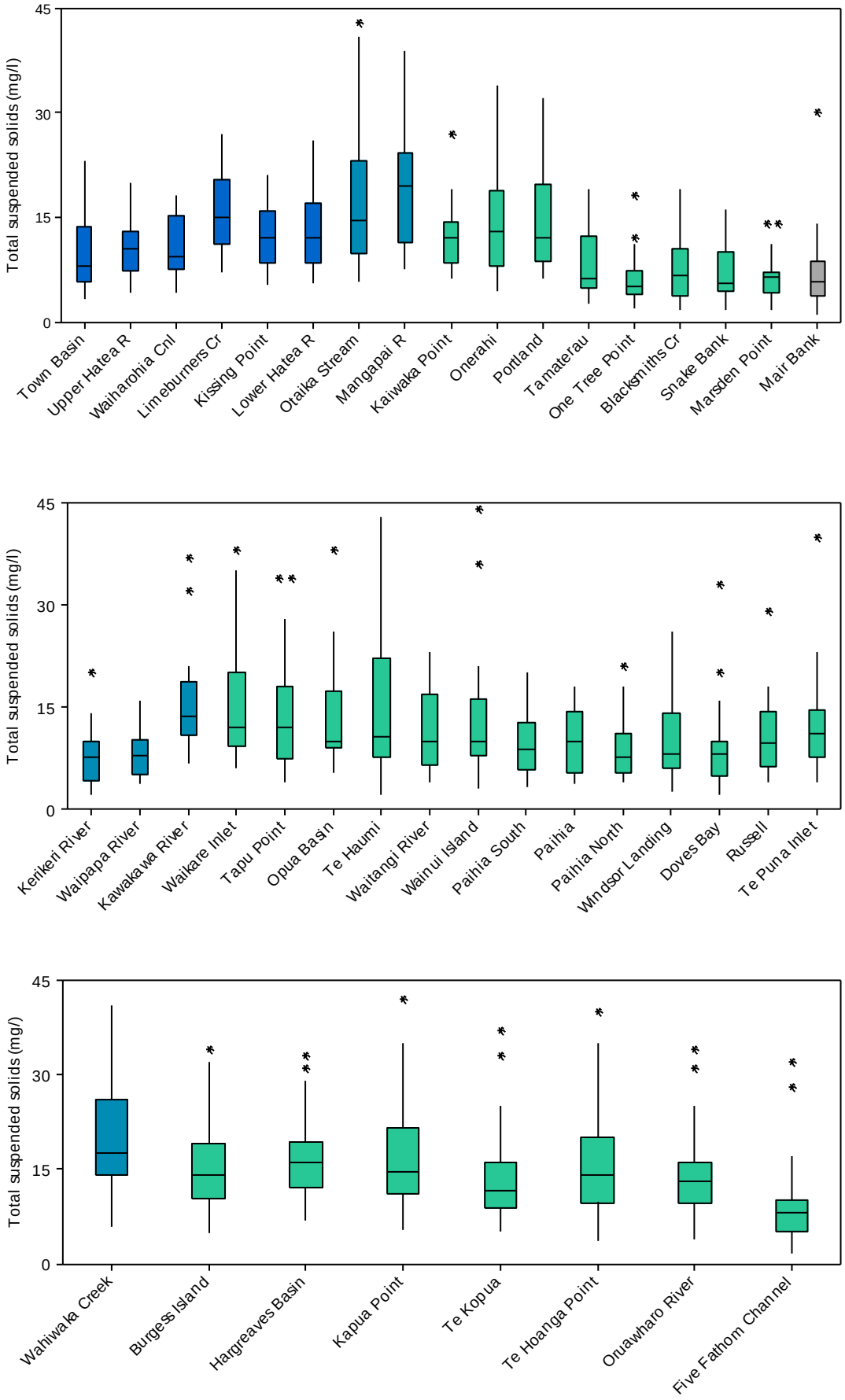

Figure 7: Suspended solid data collected from January 2013 to December 2017.

3.3 Faecal indicator bacteria

Microbial indicator organisms are used to measure the faecal contamination of the water and therefore its suitability for recreational activities and shellfish consumption.

3.3.1 Enterococci

The Ministry for the Environment's Microbiological Water Quality Guidelines for Marine and Freshwater Recreational Areas (Ministry for the Environment 2003) recommends that enterococci be used as the faecal indicator bacteria in marine waters. In the Proposed Regional Plan for Northland, the compliance metric for different management units is based on the 95th percentile (Table 2). The Microbiological Guidelines for Marine and Freshwater Recreational Areas (Ministry for Environment, 2003) also set concentrations for different levels of action. This three-tier system is analogous to traffic lights with a green (surveillance) mode, amber (alert) mode and a red (action) mode. For the surveillance/green mode (highly likely to be uncontaminated – 'suitable' for bathing) no single sample should exceed 140 enterococci per 100mL. The percentage of samples that exceeded 140 enterococci per 100mL is shown in Table 11.

Mair bank and all eight sites in the estuarine management unit had more than 50% of samples below the laboratory detection limit (<10) and concentrations of enterococci at these sites were very low. The highest median enterococci concentrations were recorded at sites in the Hātea River and Otaika Creek in Whangārei Harbour (Table 11). Interestingly, higher median enterococci concentrations were recorded at the Town Basin, Waiarohia Canal, Otaika Creek and the Upper Hātea River sites than at Limeburners Creek, which is the immediate receiving environment for discharges from the Whangārei waste water treatment plant.

In the Whangārei Harbour there were 30 samples that exceeded the MfE 'green/surveillance' mode of <140 enterococci/100mL. All but one of these exceedances occurred in the Hātea River or tidal creek management zones. The other exceedance occurred at Kaiwaka Point which is immediately downstream of the Hātea River zone. The worst event appears to have occurred on 17/3/2016, when exceedances were recorded at nine sites. The elevated concentrations at the Town Basin, Waiarohia Canal, Limeburners creek, Otaika and Mangapai on this date suggest multiple sources of contamination rather than one source or 'incident'. 39.25mm of rain was recorded at Robert Street, Whangārei, in the 24 hours prior to sampling being undertaken on 17/03/2019. This followed a period of low rainfall during which only 0.73 mm of rain was recorded in the two previous weeks (02/03/2016 – 15/03/2016).

In the Bay of Islands, the highest median enterococci concentrations were recorded at Waipapa River (20 enterococci/100mL). All other sites had a median of 10/100mL for more than 50% of the samples collected were below the laboratory detection limit (<10/100mL). In the Bay of Islands, only 20 samples exceeded the MfE 'green/surveillance' mode of <140 enterococci/100ml. Twelve of these exceedances occurred on 18/5/2017 and a further six exceedances occurred on 22/9/2016. Both these sample events coincided with heavy rainfall. On the 18/5/2017 47 mm of rain was recorded at Kerikeri (Bay of Islands Golf club) in the 24 hours before sampling was undertaken and on 22/9/2016, 52 mm was recorded in the 48 hours before sampling was undertaken.

In the Kaipara Harbour the highest median value was at Wahiwaka Creek (20 enterococci/100mL) and thirteen samples from this site exceeded the MfE 'green/surveillance' mode of <140 enterococci/100mL. The other seven sites in the Kaipara had more than 50% of samples below the detection limit and only one other sample at Kapua Point exceeded the MfE 'green/surveillance' mode threshold of <140 enterococci/100mL.

Compliance with the standard

Nine sites did not comply with the coastal water quality standards. In the Bay of Islands, two sites (Waitangi River and Paihia River) in the estuarine management unit had a 95th percentile of that exceeded 200 enterococci/100mL (Table 11). One site in the tidal creek management unit, Waipapa River (241 enterococci/100mL) had a 95th percentile of that exceeded 200 enterococci/100mL and another site, Kerikeri River (196 enterococci/100mL) was close to exceeding the standard.

In Whangārei, five sites in the Hātea River and the Otaika Creek site (3148 enterococci/100mL) had a 95th percentile that exceeded 500 enterococci/100mL (Table 11). All the sites in the estuarine management unit in Whangārei had 95th percentiles below the standard (200 enterococci/100mL) and the one open coast site (Mair bank) had a 95th percentiles below 40 enterococci/100mL. The 95th percentile at Otaika Creek exceeded the standard for the tidal creek management unit (≤ 200 enterococci/100mL) and four of the six sites in the Hātea River exceeded the standard of 500 enterococci/100mL.

In the Kaipara Harbour, Wahiwaka Creek (3148 enterococci/100mL) had a 95th percentile that exceeded the standard for tidal creeks (Table 11). All other sites were well below the standard.

Trend analysis

Trend analysis was only performed on two sites (Table 12). There were too many censored values at the other 39 sites to perform trend analysis. Both these sites were located in the Hātea River management unit. No significant trends were identified at either of these two sites.

Table 11: Enterococci (enterococci/100mL) data collected from January 2013 to December 2017. Ranked lowest to highest median.

Site	Count	Minimum	Maximum	Median	95th %tile	# of samples > 140	Compliance
Five Fathom Channel	59	<1.6	20	1	5	0	✓
Mair Bank	33	<10	41	<10	5	0	✓
Snake Bank	33	<10	75	<10	5	0	✓
One Tree Point	33	<10	20	<10	5	0	✓
Te Puna Inlet	33	<10	10	<10	5	0	✓
Oruawharo River	58	<1.6	10	3	9	0	✓
Marsden Point	33	<10	10	<10	9	0	✓
Blacksmiths Creek	33	<10	10	<10	9	0	✓
Russell	33	<10	148	<10	9	1 (3%)	✓
Te Kopua	59	<1.6	31	2	10	0	✓
Tamaterau	33	<10	10	<10	10	0	✓
Windsor Landing	33	1	20	<10	10	0	✓
Hargreaves Basin	58	<1.6	20	<10	13	0	✓
Kapua Point	59	<1.6	150	2	14	1 (2%)	✓
Portland	33	<10	31	<10	20	0	✓
Ōpua Basin	33	<10	399	<10	20	1 (3%)	✓
Te Hoanga Point	59	<1.6	110	3	23	0	✓
Onerahi	32	<10	31	<10	29	0	✓
Waikare Inlet	33	<10	383	<10	29	1 (3%)	✓
Burgess Island	59	<1.6	82	<10	37	0	✓
Wainui Island	33	<10	52	<10	38	0	✓
Tapu Point	33	<10	556	<10	47	1 (3%)	✓
Doves Bay	33	<10	52	<10	50	0	✓
Mangapai River	33	<10	1291	<10	61	1 (3%)	✓
Te Haumi	33	<10	199	<10	67	1 (3%)	✓
Kawakawa River	33	<10	1043	<10	111	1 (3%)	✓
Kaiwaka Point	33	<10	712	<10	123	1 (3%)	✓
Paihia North	33	1	298	<10	174	2 (6%)	✓
Paihia	33	1	238	<10	185	2 (6%)	✓
Kerikeri River	33	<10	355	10	196	4 (12%)	✓
Paihia South	33	1	441	<10	204	2 (6%)	×
Lower Hātea River	33	<10	3255	<10	213	2 (6%)	✓
Waipapa River	33	<10	269	20	241	2 (6%)	✓
Kissing Point	33	<10	6867	<10	302	2 (6%)	✓
Waitangi River	33	1	650	<10	419	2 (6%)	×
Limeburners Creek	33	<10	7270	30	543	5 (15%)	×
Upper Hātea River	33	<10	2755	30	730	4 (12%)	×
Town Basin	33	<10	2755	31	953	6 (18%)	×
Waiharohia Canal	33	<10	3130	31	1031	4 (12%)	×
Wahiwaka Creek	59	<1.6	4300	20	1473	13 (22%)	×
Otaika Creek	33	<10	9804	31	3148	5 (15%)	×

*Note: the lower median concentrations found at some sites in the Kaipara Harbour is a reflection of the lower detection limit of <1.6 enterococci/100mL for samples sent to Watercare laboratory compared to <10 enterococci/100mL for samples sent to Whangārei District Council laboratory for analysis.

Table 12: Mann-Kendall seasonal trend analysis of enterococci.

Site	Sampling period	Count	Censored values	Trend	P-value	% annual change
Town Basin	26/3/08-16/11/17	60	5	None detected	0.315	4.026
Waiharohia Canal	26/3/08-16/11/17	60	6	None detected	0.353	-4.519
Limeburners Creek	26/3/08-16/11/17	60	11	>15% censored	-	-
Upper Hātea River	26/3/08-16/11/17	60	11	>15% censored	-	-
Waipapa River	14/5/08-16/11/17	59	17	>15% censored	-	-
Kerikeri River	14/5/08-16/11/17	59	18	>15% censored	-	-
Wahiwaka Creek	27/5/09-14/12/17	100	23	>15% censored	-	-
Kawakawa River	14/5/08-16/11/17	59	29	>15% censored	-	-
Kissing Point	26/3/08-16/11/17	60	29	>15% censored	-	-
Lower Hātea River	26/3/08-16/11/17	60	35	>15% censored	-	-
Kaiwaka Point	26/3/08-16/11/17	60	40	>15% censored	-	-
Mangapai River	26/3/08-16/11/17	60	41	>15% censored	-	-
Paihia South	14/5/08-16/11/17	59	42	>15% censored	-	-
Ōpua Basin	14/5/08-16/11/17	59	42	>15% censored	-	-
Waitangi River	14/5/08-16/11/17	59	42	>15% censored	-	-
Te Haumi	14/5/08-16/11/17	59	43	>15% censored	-	-
Paihia North	14/5/08-16/11/17	57	45	>15% censored	-	-
Portland	26/3/08-16/11/17	60	45	>15% censored	-	-
Wainui Island	14/5/08-16/11/17	59	46	>15% censored	-	-
Tapu Point	14/5/08-16/11/17	59	50	>15% censored	-	-
Waikare Inlet	14/5/08-16/11/17	59	50	>15% censored	-	-
Paihia	14/5/08-16/11/17	58	50	>15% censored	-	-
Doves Bay	14/5/08-16/11/17	59	51	>15% censored	-	-
Windsor Landing	14/5/08-16/11/17	59	52	>15% censored	-	-
Onerahi	26/3/08-16/11/17	59	52	>15% censored	-	-
Russell	14/5/08-16/11/17	59	54	>15% censored	-	-
Burgess Island	27/5/09-14/12/17	100	55	>15% censored	-	-
Hargreaves Basin	27/5/09-14/12/17	100	56	>15% censored	-	-
Tamaterau	26/3/08-16/11/17	60	56	>15% censored	-	-
Te Puna Inlet	14/5/08-16/11/17	58	57	>15% censored	-	-
Mair Bank	26/3/08-16/11/17	59	57	>15% censored	-	-
Marsden Point	26/3/08-16/11/17	60	58	>15% censored	-	-
Blacksmiths Creek	26/3/08-16/11/17	60	58	>15% censored	-	-
Snake Bank	26/3/08-16/11/17	60	58	>15% censored	-	-
One Tree Point	26/3/08-16/11/17	60	58	>15% censored	-	-
Oruawharo River	27/5/09-14/12/17	100	66	>15% censored	-	-
Kapua Point	27/5/09-14/12/17	100	73	>15% censored	-	-
Te Hoanga Point	27/5/09-14/12/17	100	74	>15% censored	-	-
Te Kopua	27/5/09-14/12/17	100	79	>15% censored	-	-
Five Fathom Channel	27/5/09-14/12/17	100	89	>15% censored	-	-
Otaika Creek	17/1/13-16/11/17	30	6	Insufficient data	-	-

3.3.2 Faecal coliforms

Similar spatial patterns were observed for both enterococci and faecal coliforms, with the highest numbers of both micro-bacteria recorded at sites in the Hātea River and the tidal creek management units, and lower concentrations found at estuarine sites.

The lowest median faecal coliform concentrations were recorded at outer estuarine locations in the Whangārei Harbour and the Bay of Islands (Table 13). Twenty sites had more than half of all samples collected censored and all the sites located in the estuarine management unit had medians below 10/100mL.

The highest median faecal coliform concentration was recorded at Otaika Creek in Whangārei. Otaika Creek also had the highest median concentration of enterococci. The next highest median concentrations were recorded at the Town Basin (110/110mL) and Limeburners Creek (90/110mL), in the Hātea River. There is a clear pattern of decreasing concentrations down the Hātea River and towards the entrance of the Harbour.

In the Bay of Islands, the highest median values were recorded at the Waipapa River (60/100mL) and Kerikeri River (40/100mL), in Kerikeri Inlet.

Compliance with the standard

Three sites in the Bay of Islands (Te Haumi, Wainui Island, and Waitangi) exceeded the 90th percentile of ≤43/100mL, although the median values at all three sites were below the 14/100mL (Table 13). In Whangārei Harbour all eight sites in the estuarine management unit complied with the standard. This indicates that these sites were suitable for shellfish consumption.

In the Proposed Regional Plan for Northland, the Hātea River and Tidal Creek management units are not managed for shellfish consumption so there are no standards for faecal coliforms. Regardless, all six sites in the Hātea River had 90th percentiles above 43 faecal coliforms/100mL, which indicates that water quality was not suitable for shellfish consumption. In addition, the tidal creek sites Kerikeri River, Waipapa River, Otaika Creek and Mangapai River were not suitable for shellfish consumption.

Trend analysis

Trend analysis was only performed on six sites (Table 14) as there were too many censored values at the other 26 sites. No significant trends were identified at any of these seven sites.

Table 13: Faecal coliform (cfu/100mL) data collected from January 2013 to December 2017. Ranked lowest to highest median.

Site	Count	Censored values	Minimum	Maximum	Median	90th %ile	Compliance
Marsden Point	33	31	<2	40	<10	<10	✓
Snake Bank	33	32	<2	20	<10	<10	✓
Tamaterau	33	31	<2	30	<10	<10	✓
Mair Bank	33	30	<2	70	<10	<10	✓
Onerahi	32	28	<2	50	<10	<10	✓
Russell	33	30	<2	560	<10	<10	✓
Portland	33	25	<2	28	<10	9	✓
Blacksmiths Creek	33	28	<2	50	<10	9	✓
Te Puna Inlet	33	31	<2	130	<10	<10	✓
One Tree Point	33	31	<2	60	<10	<10	✓
Te Haumi	33	15	<2	530	<10	46	×
Ōpua Basin	33	19	<2	740	<10	27	✓
Windsor Landing	33	26	<2	210	<10	10	✓
Kaiwaka Point	33	24	<2	398	<10	18	✓
Waikare Inlet	33	22	<2	930	<10	28	✓
Wainui Island	33	21	<2	1390	<10	86	×
Paihia	33	21	<2	940	<10	20	✓
Paihia North	33	20	<2	780	<10	40	✓
Paihia South	33	19	<2	670	<10	28	✓
Doves Bay	33	25	<2	1140	<10	9	✓
Tapu Point	33	15	<2	1190	5	20	✓
Waitangi River	33	16	<2	3800	5	116	×
Mangapai River	33	15	<2	220	10	46	✓
Lower Hātea River	33	9	<2	5100	10	75	NA
Kawakawa River	33	11	<2	4400	12	244	NA
Kissing Point	33	5	<10	4300	26	156	NA
Kerikeri River	33	2	<10	3600	40	336	NA
Waiarohia Canal	33	1	<10	4000	60	328	NA
Waipapa River	33	0	8	2600	60	412	NA
Upper Hātea River	33	0	9	6909	63	1373	NA
Limeburners Creek	33	3	<10	33000	90	320	NA
Town Basin	33	0	18	5000	110	668	NA
Otaika Creek	33	1	<10	9500	150	654	NA

Table 14: Mann-Kendall seasonal trend analysis of faecal coliforms.

Site	Sampling period	Count	Censored values	Trend	P-value	% annual change
Waiharohia Canal	26/3/08-16/11/17	60	1	None detected	0.061	-12.827
Town Basin	26/3/08-16/11/17	60	0	None detected	0.181	-7.553
Upper Hātea River	26/3/08-16/11/17	60	1	None detected	0.267	-8.495
Kerikeri River	14/5/08-16/11/17	58	2	None detected	0.750	-1.660
Waipapa River	14/5/08-16/11/17	59	0	None detected	0.840	1.820
Limeburners Creek	26/3/08-16/11/17	60	5	None detected	0.848	-0.684
Kissing Point	26/3/08-16/11/17	60	12	>15% censored	-	-
Kawakawa River	14/5/08-16/11/17	59	13	>15% censored	-	-
Lower Hātea River	26/3/08-16/11/17	60	17	>15% censored	-	-
Waitangi River	14/5/08-16/11/17	59	19	>15% censored	-	-
Mangapai River	26/3/08-16/11/17	60	20	>15% censored	-	-
Te Haumi	14/5/08-16/11/17	59	22	>15% censored	-	-
Tapu Point	14/5/08-16/11/17	59	22	>15% censored	-	-
Paihia South	14/5/08-16/11/17	59	27	>15% censored	-	-
Paihia North	14/5/08-16/11/17	58	27	>15% censored	-	-
Ōpua Basin	14/5/08-16/11/17	59	28	>15% censored	-	-
Paihia	14/5/08-16/11/17	58	29	>15% censored	-	-
Wainui Island	14/5/08-16/11/17	59	29	>15% censored	-	-
Waikare Inlet	14/5/08-16/11/17	59	34	>15% censored	-	-
Kaiwaka Point	26/3/08-16/11/17	60	36	>15% censored	-	-
Doves Bay	14/5/08-16/11/17	59	40	>15% censored	-	-
Portland	26/3/08-16/11/17	60	40	>15% censored	-	-
Windsor Landing	14/5/08-16/11/17	59	44	>15% censored	-	-
Onerahi	26/3/08-16/11/17	59	48	>15% censored	-	-
Russell	14/5/08-16/11/17	59	50	>15% censored	-	-
Blacksmiths Creek	26/3/08-16/11/17	60	50	>15% censored	-	-
Te Puna Inlet	14/5/08-16/11/17	58	53	>15% censored	-	-
Mair Bank	26/3/08-16/11/17	59	56	>15% censored	-	-
Marsden Point	26/3/08-16/11/17	60	56	>15% censored	-	-
Tamaterau	26/3/08-16/11/17	60	56	>15% censored	-	-
One Tree Point	26/3/08-16/11/17	60	57	>15% censored	-	-
Snake Bank	26/3/08-16/11/17	60	59	>15% censored	-	-
Otaika Creek	17/1/13-16/11/17	30	1	Insufficient data	-	-

3.4 Nutrients and trophic state

While nutrients are essential for all forms of life, nutrients that enter the environment from anthropogenic sources, such as fertiliser, stormwater, treated wastewater, sewage overflows and failing septic systems, may exceed the needs of an ecosystem. Elevated nutrients in the water can cause excessive plant growth leading to algal blooms, which in turn can cause lowered levels of dissolved oxygen and water clarity. This can reduce the life-supporting capacity of the water and pose a significant human health risk through contact with toxic algal blooms and eating contaminated shellfish. Excessive plant growth can also look unattractive and can cause an unpleasant odour when it dies and decays.

Concentrations of total nitrogen, nitrate-nitrite nitrogen, ammoniacal nitrogen, total phosphorus and dissolved reactive phosphorus are direct measures of nutrient concentrations which may be responsible for over-enrichment, while chlorophyll *a* and dissolved oxygen are response indicators of nutrient enrichment. Water clarity can also be a response indicator of nutrient enrichment but has been reported separately in section 3.2.

3.4.1 Dissolved oxygen (mg/L)

The highest median dissolved oxygen concentration was recorded at the Marsden Point (8.0 mg/L) in Whangārei Harbour and Burgess Island (8.0 mg/L) in the Kaipara Harbour (Table 15 and Figure 8). The lowest median dissolved oxygen concentrations were recorded at Wahiwaka Creek (6.6 mg/L) in the Kaipara Harbour and Limeburners Creek (6.7 mg/L) in the Hātea River. These three sites are sheltered tidal creek environments located a long distance from the respective harbour entrances. In the Bay of Islands, the lowest median values were recorded at Te Haumi (7.0 mg/L).

Compliance with the standard

In the Proposed Regional Plan for Northland, there are standards for the median value and an absolute minimum of 4.6mg/L (Table 2). All 41 sites had median values above the relevant standards for the different management units. However, seven sites had values that fell below the threshold of 4.6mg/L at least once (Figure 8 & Table 15). The Town Basin (six occasions) and Limeburners Creek (four occasions) breached the threshold of 4.6mg/L most frequently (Table 15).

Trend analysis

Trend analysis was performed on 40 sites (Table 16). A decreasing trend was identified at two sites in the Kaipara Harbour (Wahiwaka Creek and Hargreaves Basin).

Table 15: Dissolved oxygen (mg/L) data collected from January 2013 to December 2017. Ranked highest to lowest median.

Site	Count	Minimum	Maximum	Median	DO<4.6	Compliance
Marsden Point	33	6.54	9.67	8.02	0	✓
Burgess Island	60	6.20	9.69	8.01	0	✓
Mair Bank	33	6.71	9.64	8.00	0	✓
One Tree Point	33	6.17	9.31	7.92	0	✓
Kerikeri River	33	5.70	10.36	7.90	0	✓
Five Fathom Channel	60	6.30	9.70	7.84	0	✓
Snake Bank	33	6.64	9.33	7.78	0	✓
Blacksmiths Creek	33	6.51	9.75	7.77	0	✓
Otaika Creek	33	4.28	10.73	7.73	1	×
Oruawharo River	58	5.90	9.56	7.72	0	✓
Waipapa River	33	5.70	10.30	7.70	0	✓
Town Basin	33	3.74	10.55	7.62	6	×
Tamaterau	33	6.07	9.28	7.58	0	✓
Waikare Inlet	33	5.79	9.10	7.57	0	✓
Onerahi	33	5.85	9.35	7.51	0	✓
Hargreaves Basin	58	5.68	9.85	7.50	0	✓
Te Kopua	60	5.70	9.94	7.47	0	✓
Russell	33	6.30	9.00	7.45	0	✓
Te Hoanga Point	60	5.50	10.00	7.44	0	✓
Paihia North	33	5.76	8.98	7.40	0	✓
Doves Bay	33	6.10	8.60	7.39	0	✓
Kaiwaka Point	33	5.30	9.24	7.36	0	✓
Paihia South	33	6.20	9.10	7.36	0	✓
Te Puna Inlet	33	6.30	8.91	7.34	0	✓
Portland	33	5.31	9.43	7.32	0	✓
Ōpua Basin	33	5.88	8.80	7.30	0	✓
Paihia	33	6.00	8.60	7.30	0	✓
Kapua Point	60	5.40	9.86	7.27	0	✓
Tapu Point	33	6.00	9.40	7.21	0	✓
Kawakawa River	33	5.50	9.69	7.20	0	✓
Waitangi River	33	5.66	9.89	7.20	0	✓
Windsor Landing	33	6.00	8.80	7.18	0	✓
Wainui Island	33	5.80	8.82	7.16	0	✓
Upper Hātea River	33	4.14	10.56	7.12	4	×
Waiharohia Canal	33	4.57	10.91	7.09	1	×
Te Haumi	33	5.26	8.80	7.04	0	✓
Lower Hātea River	33	4.70	9.28	6.92	0	✓
Mangapai River	33	3.96	9.39	6.81	2	×
Kissing Point	33	4.49	9.38	6.80	1	×
Limeburners Creek	33	3.91	9.69	6.77	4	×
Wahiwaka Creek	60	4.80	9.73	6.62	0	✓

Table 16: Mann-Kendall seasonal trend analysis of dissolved oxygen (mg/L).

Site	Sampling period	Count	Censored values	Trend	P-value	% annual change
Wahiwaka Creek	27/5/09-14/12/17	97	0	Decreasing	<0.001	-1.150
Hargreaves Basin	27/5/09-14/12/17	97	0	Decreasing	<0.001	-0.810
Te Hoanga Point	27/5/09-14/12/17	97	0	None detected	-	-
One Tree Point	26/3/08-16/11/17	59	0	None detected	-	-
Waiarohia Canal	26/3/08-16/11/17	59	0	None detected	-	-
Oruawharo River	27/5/09-14/12/17	97	0	None detected	-	-
Te Haumi	14/5/08-16/11/17	57	0	None detected	-	-
Town Basin	26/3/08-16/11/17	60	0	None detected	-	-
Upper Hātea River	26/3/08-16/11/17	60	0	None detected	-	-
Five Fathom Channel	27/5/09-14/12/17	96	0	None detected	-	-
Te Kopua	27/5/09-14/12/17	98	0	None detected	-	-
Limeburners Creek	26/3/08-16/11/17	60	0	None detected	-	-
Kerikeri River	14/5/08-16/11/17	56	0	None detected	-	-
Te Puna Inlet	14/5/08-16/11/17	56	0	None detected	-	-
Kapua Point	27/5/09-14/12/17	98	0	None detected	-	-
Blacksmiths Creek	26/3/08-16/11/17	59	0	None detected	-	-
Burgess Island	27/5/09-14/12/17	96	0	None detected	-	-
Kawakawa River	14/5/08-16/11/17	57	0	None detected	-	-
Mair Bank	26/3/08-16/11/17	58	0	None detected	-	-
Tamaterau	26/3/08-16/11/17	59	0	None detected	-	-
Waipapa River	14/5/08-16/11/17	56	0	None detected	-	-
Waikare Inlet	14/5/08-16/11/17	57	0	None detected	-	-
Kaiwaka Point	26/3/08-16/11/17	59	0	None detected	-	-
Onerahi	26/3/08-16/11/17	58	0	None detected	-	-
Doves Bay	14/5/08-16/11/17	56	0	None detected	-	-
Kissing Point	26/3/08-16/11/17	60	0	None detected	-	-
Portland	26/3/08-16/11/17	59	1	None detected	-	-
Tapu Point	14/5/08-16/11/17	57	0	None detected	-	-
Waitangi River	14/5/08-16/11/17	57	0	None detected	-	-
Marsden Point	26/3/08-16/11/17	59	0	None detected	-	-
Wainui Island	14/5/08-16/11/17	56	0	None detected	-	-
Lower Hātea River	26/3/08-16/11/17	59	0	None detected	-	-
Russell	14/5/08-16/11/17	57	0	None detected	-	-
Paihia North	14/5/08-16/11/17	57	0	None detected	-	-
Paihia South	14/5/08-16/11/17	57	0	None detected	-	-
Ōpua Basin	14/5/08-16/11/17	57	0	None detected	-	-
Mangapai River	26/3/08-16/11/17	59	0	None detected	-	-
Snake Bank	26/3/08-16/11/17	59	0	None detected	-	-
Paihia	14/5/08-16/11/17	57	0	None detected	-	-
Windsor Landing	14/5/08-16/11/17	56	0	None detected	-	-
Otaika Creek	17/1/13-16/11/17	29	0	Insufficient data	-	-

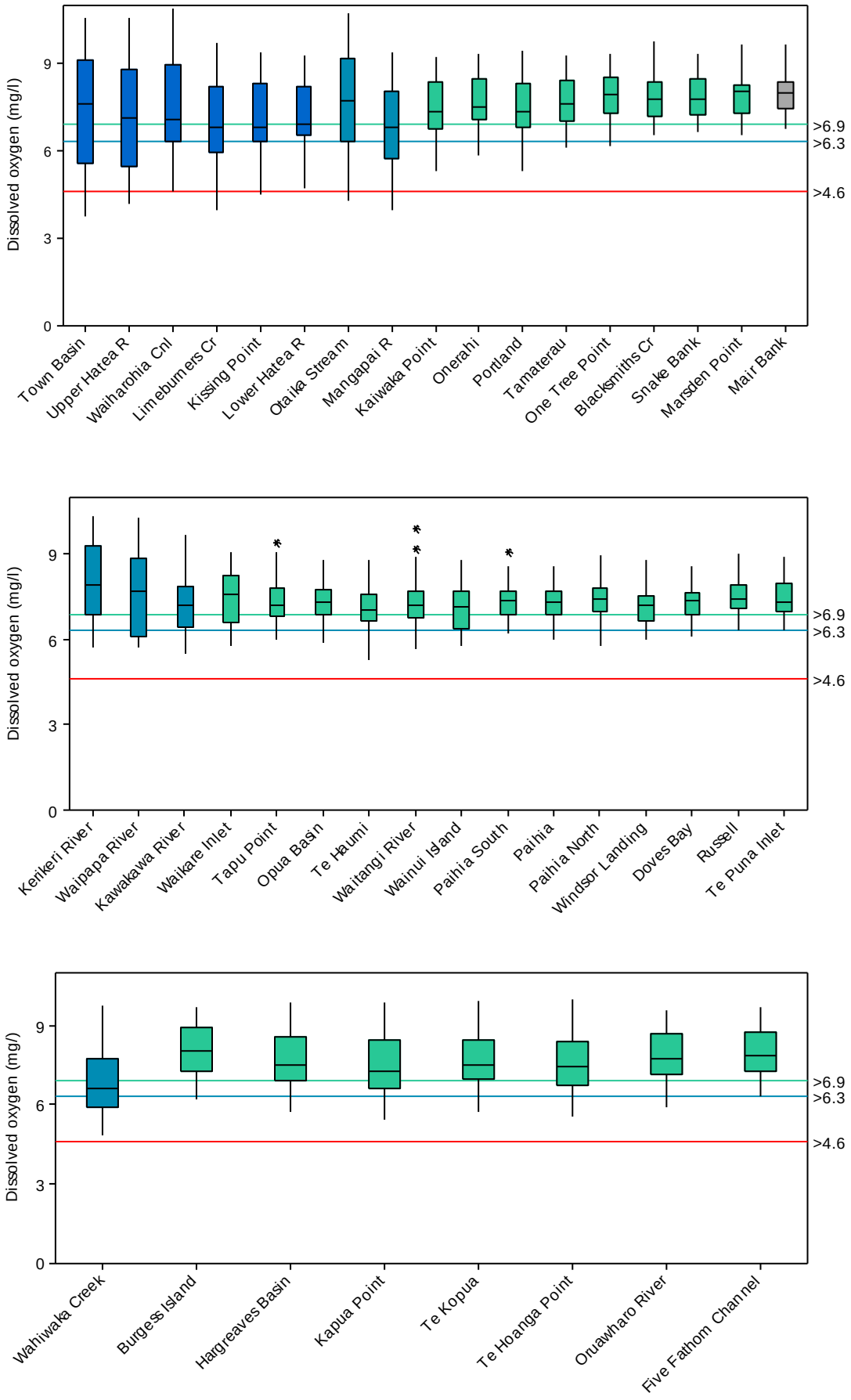

Figure 8: Dissolved oxygen data collected from January 2013 to December 2017. Coastal water quality standards (median): estuaries 6.9 mg/L; tidal creeks 6.3 mg/L; Hātea River 6.2 mg/L; and 4.6 mg/L minimum.

3.4.2 Dissolved oxygen (% saturation)

The highest median levels of dissolved oxygen saturation were recorded at One Tree Point (100.2%), in Whangārei Harbour and Five Fathom Channel (99.5%) in the Kaipara Harbour (Table 17). High median dissolved oxygen saturations were also recorded at other sites close to the entrance of the Whangārei Harbour including Mair Bank (99.5%), Snake Bank (99.2%), Marsden Point (99.2%) and Blacksmith Creek (98.7%). In the Bay of Islands, the highest median dissolved oxygen saturations were recorded at Te Puna (97.0%) and Russel (96.6%). These sites are all close to the entrance of the harbours or estuaries or in exposed locations with high water flows where you would expect the water to be well aerated.

The lowest medians were recorded at tidal creek environments in Whangārei Harbour (Limeburners Creek, Otaika Creek and Mangapai River, and at Wahiwaka Creek in the Kaipara Harbour (Table 17). The Limeburners Creek site is the receiving environment for waste water from the Whangārei waste water treatment plant and Wahiwaka creek is located downstream of discharges from the Maungaturoto waste water treatment plant, the Kaiwaka waste water treatment plant and a discharge from the Fonterra Maungaturoto milk processing plant. In the Bay of Islands, the lowest median dissolved oxygen was recorded at the Kawakawa River (87.1%), which is located in the tidal creek management unit.

Compliance with the standard

In the Proposed Regional Plan, there are no standards for dissolved oxygen (% saturation).

Trend analysis

Trend analysis was performed on 41 sites (Table 18). A decreasing trend was identified at two sites in the Kaipara Harbour (Wahiwaka Creek and Hargreaves Basin).

Table 17: Dissolved oxygen (% saturation) data collected from January 2013 to December 2017. Ranked highest to lowest median.

Site	Count	Minimum	Maximum	Mean	S.E.	Median
One Tree Point	33	88.3	117.6	100.0	1.00	100.2
Five Fathom Channel	60	81.8	121.8	99.5	0.76	99.5
Mair Bank	33	94.0	117.4	101.4	0.95	99.5
Snake Bank	33	92.4	113.7	100.3	0.86	99.2
Marsden Point	33	92.4	116.5	100.5	1.01	99.2
Blacksmiths Creek	33	91.2	118.4	99.7	1.09	98.7
Oruawharo River	58	79.8	109.3	97.3	0.71	97.9
Onerahi	33	84.9	107.3	97.2	0.86	97.6
Tamaterau	33	88.0	108.2	97.4	0.79	97.4
Te Puna Inlet	33	87.3	109.2	96.9	0.87	97.0
Burgess Island	60	77.1	116.4	96.9	0.76	97.0
Russell	33	85.2	106.5	96.2	0.86	96.6
Te Kopua	60	78.5	112.9	95.1	0.81	95.2
Hargreaves Basin	58	77.5	109.0	94.9	0.73	95.1
Te Hoanga Point	60	77.1	107.9	94.0	0.83	95.1
Portland	33	77.4	108.2	94.1	1.03	94.7
Doves Bay	33	82.2	101.6	93.7	0.77	93.9
Kaiwaka Point	33	77.4	105.8	92.8	1.01	93.3
Paihia North	33	80.8	103.5	92.7	1.08	93.0
Kapua Point	60	76.8	112.0	92.9	0.89	92.9
Paihia	33	80.6	101.8	92.9	1.04	92.7
Paihia South	33	81.6	107.6	93.4	1.14	92.5
Ōpua Basin	33	78.6	107.4	92.4	1.25	92.4
Windsor Landing	33	79.6	100.9	91.7	0.88	91.4
Te Haumi	33	66.0	101.5	89.3	1.45	90.9
Waikare Inlet	33	77.3	106.0	92.3	1.28	90.7
Wainui Island	33	79.6	102.2	90.2	1.11	90.5
Tapu Point	33	80.8	101.4	91.7	0.97	90.4
Waitangi River	33	79.5	106.8	91.1	1.10	90.3
Kerikeri River	33	72.6	100.2	89.4	1.38	90.0
Lower Hātea River	33	68.3	104.0	88.8	1.40	89.0
Town Basin	33	49.4	115.6	83.1	2.94	88.9
Waipapa River	33	70.0	100.4	87.1	1.54	88.6
Kissing Point	33	65.1	104.3	87.1	1.67	87.6
Waiharohia Canal	33	64.5	149.2	88.0	2.73	87.6
Kawakawa River	33	75.1	103.9	87.0	1.28	87.1
Upper Hātea River	33	58.3	138.3	84.2	2.80	85.5
Wahiwaka Creek	60	66.8	106.7	84.1	1.18	84.7
Mangapai River	33	58.1	105.3	83.4	1.82	84.5
Otaika Creek	33	56.4	126.9	84.2	2.62	84.2
Limeburners Creek	33	55.8	106.0	82.5	2.30	83.9

Table 18: Mann-Kendall seasonal trend analysis of dissolved oxygen (% saturation).

Site	Sampling period	Count	Censored values	Trend	P-value	% annual change
Hargreaves Basin	27/5/09-14/12/17	97	0	Decreasing	<0.001	-0.69
Wahiwaka Creek	27/5/09-14/12/17	97	0	Decreasing	0.01	-0.94
One Tree Point	26/3/08-16/11/17	57	0	None detected	-	-
Kaiwaka Point	26/3/08-16/11/17	57	0	None detected	-	-
Five Fathom Channel	27/5/09-14/12/17	96	0	None detected	-	-
Upper Hātea River	26/3/08-16/11/17	58	0	None detected	-	-
Town Basin	26/3/08-16/11/17	58	0	None detected	-	-
Oruawharo River	27/5/09-14/12/17	97	0	None detected	-	-
Te Puna Inlet	14/5/08-16/11/17	54	0	None detected	-	-
Limeburners Creek	26/3/08-16/11/17	58	0	None detected	-	-
Blacksmiths Creek	26/3/08-16/11/17	57	0	None detected	-	-
Portland	26/3/08-16/11/17	57	0	None detected	-	-
Ōpua Basin	14/5/08-16/11/17	55	0	None detected	-	-
Te Hoanga Point	27/5/09-14/12/17	97	0	None detected	-	-
Russell	14/5/08-16/11/17	55	0	None detected	-	-
Te Kopua	27/5/09-14/12/17	98	0	None detected	-	-
Waipapa River	14/5/08-16/11/17	54	0	None detected	-	-
Kerikeri River	14/5/08-16/11/17	54	0	None detected	-	-
Paihia	14/5/08-16/11/17	55	0	None detected	-	-
Paihia North	14/5/08-16/11/17	55	0	None detected	-	-
Tapu Point	14/5/08-16/11/17	55	0	None detected	-	-
Te Haumi	14/5/08-16/11/17	55	0	None detected	-	-
Mair Bank	26/3/08-16/11/17	56	0	None detected	-	-
Snake Bank	26/3/08-16/11/17	57	0	None detected	-	-
Lower Hātea River	26/3/08-16/11/17	57	0	None detected	-	-
Windsor Landing	14/5/08-16/11/17	54	0	None detected	-	-
Waiharohia Canal	26/3/08-16/11/17	58	0	None detected	-	-
Wainui Island	14/5/08-16/11/17	54	0	None detected	-	-
Paihia South	14/5/08-16/11/17	55	0	None detected	-	-
Onerahi	26/3/08-16/11/17	56	0	None detected	-	-
Marsden Point	26/3/08-16/11/17	57	0	None detected	-	-
Kapua Point	27/5/09-14/12/17	98	0	None detected	-	-
Waitangi River	14/5/08-16/11/17	55	0	None detected	-	-
Mangapai River	26/3/08-16/11/17	57	0	None detected	-	-
Waikare Inlet	14/5/08-16/11/17	55	0	None detected	-	-
Doves Bay	14/5/08-16/11/17	54	0	None detected	-	-
Kissing Point	26/3/08-16/11/17	58	0	None detected	-	-
Burgess Island	27/5/09-14/12/17	96	0	None detected	-	-
Kawakawa River	14/5/08-16/11/17	55	0	None detected	-	-
Tamaterau	26/3/08-16/11/17	57	0	None detected	-	-
Otaika Creek	17/1/13-16/11/17	29	0	Insufficient data	-	-

3.4.3 Chlorophyll-*a*

The lowest median chlorophyll-*a* concentrations were recorded at sites close to the entrance of the Whangārei Harbour (Blacksmith Creek, Marsden Point and Snake Bank) (Table 18 & Figure 9).

The highest median chlorophyll-*a* concentrations were found at sites in the Kaipara Harbour. Te Hoanga Point, Te Kopua, Burgess Island, Oruawharo River, Wahiwaka Creek, Kapua point and Hargreaves Basin all had chlorophyll-*a* concentrations above 0.003 mg/L. In the Bay of Islands, the highest median chlorophyll-*a* concentration was found at Waikare Inlet (0.0033 mg/L) and in Whangārei Harbour the highest medians were recorded at the Waiharohia Canal and the Upper Hātea River sites (both 0.0028 mg/L).

Compliance with the standard

One site, Hargreaves Basin (0.0041 mg/L), in the Kaipara Harbour exceeded the relevant coastal standard in the Proposed Regional Plan (Table 19 & Figure 9).

Trend analysis

Trend analysis was performed on the eight sites in the Kaipara Harbour, but no trends were detected (Table 20). Chlorophyll-*a* was only added to the Whangārei Harbour and Bay of Islands programmes in January 2013 so there was insufficient data to perform trend analysis for these sites.

Table 19: Chlorophyll-*a* (mg/L) data collected from January 2013 to December 2017. Ranked lowest to highest median.

Site name	Count	Minimum	Maximum	Mean	S.E.	Median	Compliance
Blacksmiths Creek	33	<0.006	0.0034	0.0013	0.0002	0.0013	✓
Marsden Point	33	<0.006	0.0047	0.0017	0.0002	0.0013	✓
Snake Bank	33	<0.006	0.0096	0.0017	0.0003	0.0013	✓
Mair Bank	33	<0.006	0.0041	0.0015	0.0002	0.0014	✓
Waitangi River	33	<0.006	0.0059	0.0017	0.0002	0.0014	✓
One Tree Point	33	<0.006	0.0052	0.0017	0.0002	0.0015	✓
Tamaterau	33	<0.006	0.0065	0.0017	0.0002	0.0015	✓
Kerikeri River	33	<0.006	0.0084	0.0024	0.0003	0.0016	✓
Onerahi	33	<0.006	0.0062	0.0021	0.0003	0.0018	✓
Paihia South	33	<0.006	0.0067	0.0020	0.0003	0.0018	✓
Russell	33	<0.006	0.0055	0.0021	0.0002	0.0018	✓
Doves Bay	33	<0.006	0.0050	0.0020	0.0002	0.0019	✓
Te Haumi	33	<0.006	0.0086	0.0021	0.0003	0.0019	✓
Kaiwaka Point	33	<0.006	0.0057	0.0023	0.0003	0.0020	✓
Paihia	33	<0.006	0.0056	0.0022	0.0002	0.0020	✓
Paihia North	33	<0.006	0.0060	0.0022	0.0003	0.0020	✓
Otaika Creek	33	<0.006	0.1300	0.0067	0.0039	0.0021	✓
Windsor Landing	33	<0.006	0.0053	0.0022	0.0002	0.0021	✓
Kissing Point	33	<0.006	0.0094	0.0029	0.0004	0.0022	✓
Lower Hātea River	33	<0.006	0.0099	0.0029	0.0004	0.0022	✓
Mangapai River	33	0.0005	0.0057	0.0023	0.0002	0.0022	✓
Portland	33	<0.006	0.0061	0.0024	0.0002	0.0022	✓
Limeburners Creek	33	<0.006	0.0100	0.0026	0.0004	0.0023	✓
Wainui Island	33	<0.006	0.0054	0.0024	0.0002	0.0023	✓
Waipapa River	33	0.0005	0.0082	0.0028	0.0003	0.0024	✓
Five Fathom Channel	60	0.0010	0.0320	0.0041	0.0006	0.0025	✓
Kawakawa River	33	<0.006	0.0130	0.0032	0.0004	0.0025	✓
Ōpua Basin	33	<0.006	0.0250	0.0037	0.0007	0.0026	✓
Town Basin	33	<0.006	0.0390	0.0048	0.0012	0.0026	✓
Tapu Point	33	<0.006	0.0170	0.0036	0.0005	0.0027	✓
Upper Hātea River	33	<0.006	0.0330	0.0042	0.0010	0.0028	✓
Waiharohia Canal	33	<0.006	0.0390	0.0040	0.0011	0.0028	✓
Te Puna Inlet	33	<0.006	0.0200	0.0039	0.0007	0.0029	✓
Te Hoanga Point	60	<0.006	0.0140	0.0038	0.0003	0.0030	✓
Te Kopua	60	0.0012	0.0160	0.0038	0.0003	0.0030	✓
Waikare Inlet	33	<0.006	0.0087	0.0041	0.0004	0.0033	✓
Burgess Island	60	0.0007	0.0250	0.0046	0.0005	0.0034	✓
Oruawharo River	58	0.0017	0.0170	0.0044	0.0004	0.0034	✓
Wahiwaka Creek	60	0.0008	0.0260	0.0044	0.0005	0.0035	✓
Kapua Point	60	<0.006	0.0140	0.0040	0.0004	0.0036	✓
Hargreaves Basin	58	0.0013	0.0190	0.0051	0.0005	0.0041	×

Table 20: Mann-Kendall seasonal trend analysis of chlorophyll-*a* (mg/L).

Site	Sampling period	Count	Censored values	Trend	P-value	% annual change
Burgess Island	27/5/09-14/12/17	100	0	None detected	-	-
Five Fathom Channel	27/5/09-14/12/17	100	0	None detected	-	-
Te Kopua	27/5/09-14/12/17	100	1	None detected	-	-
Kapua Point	27/5/09-14/12/17	100	2	None detected	-	-
Te Hoanga Point	27/5/09-14/12/17	100	2	None detected	-	-
Wahiwaka Creek	27/5/09-14/12/17	100	0	None detected	-	-
Oruawharo River	27/5/09-14/12/17	99	2	None detected	-	-
Hargreaves Basin	27/5/09-14/12/17	100	2	None detected	-	-
Te Haumi	17/01/13-16/11/17	33	0	Insufficient data	-	-
Paihia South	17/01/13-16/11/17	33	0	Insufficient data	-	-
Russell	17/01/13-16/11/17	33	0	Insufficient data	-	-
Kawakawa River	17/01/13-16/11/17	33	0	Insufficient data	-	-
Ōpua Basin	17/01/13-16/11/17	33	0	Insufficient data	-	-
Tapu Point	17/01/13-16/11/17	33	0	Insufficient data	-	-
Waikare Inlet	17/01/13-16/11/17	33	0	Insufficient data	-	-
Paihia	17/01/13-16/11/17	33	0	Insufficient data	-	-
Paihia North	17/01/13-16/11/17	33	0	Insufficient data	-	-
Waitangi River	17/01/13-16/11/17	33	0	Insufficient data	-	-
Windsor Landing	17/01/13-16/11/17	33	0	Insufficient data	-	-
Kerikeri River	17/01/13-16/11/17	33	0	Insufficient data	-	-
Waipapa River	17/01/13-16/11/17	33	0	Insufficient data	-	-
Wainui Island	17/01/13-16/11/17	33	0	Insufficient data	-	-
Doves Bay	17/01/13-16/11/17	33	0	Insufficient data	-	-
Te Puna Inlet	17/01/13-16/11/17	33	0	Insufficient data	-	-
Mair Bank	17/01/13-16/11/17	33	0	Insufficient data	-	-
Marsden Point	17/01/13-16/11/17	33	0	Insufficient data	-	-
Blacksmiths Creek	17/01/13-16/11/17	33	0	Insufficient data	-	-
Snake Bank	17/01/13-16/11/17	33	0	Insufficient data	-	-
One Tree Point	17/01/13-16/11/17	33	0	Insufficient data	-	-
Tamaterau	17/01/13-16/11/17	33	0	Insufficient data	-	-
Mangapai River	17/01/13-16/11/17	33	0	Insufficient data	-	-
Portland	17/01/13-16/11/17	33	0	Insufficient data	-	-
Onerahi	17/01/13-16/11/17	33	0	Insufficient data	-	-
Kaiwaka Point	17/01/13-16/11/17	33	0	Insufficient data	-	-
Limeburners Creek	17/01/13-16/11/17	33	0	Insufficient data	-	-
Lower Hātea River	17/01/13-16/11/17	33	0	Insufficient data	-	-
Kissing Point	17/01/13-16/11/17	33	0	Insufficient data	-	-
Waiharohia Canal	17/01/13-16/11/17	33	0	Insufficient data	-	-
Upper Hātea River	17/01/13-16/11/17	33	0	Insufficient data	-	-
Town Basin	17/01/13-16/11/17	33	0	Insufficient data	-	-
Otaika Creek	17/01/13-16/11/17	33	0	Insufficient data	-	-

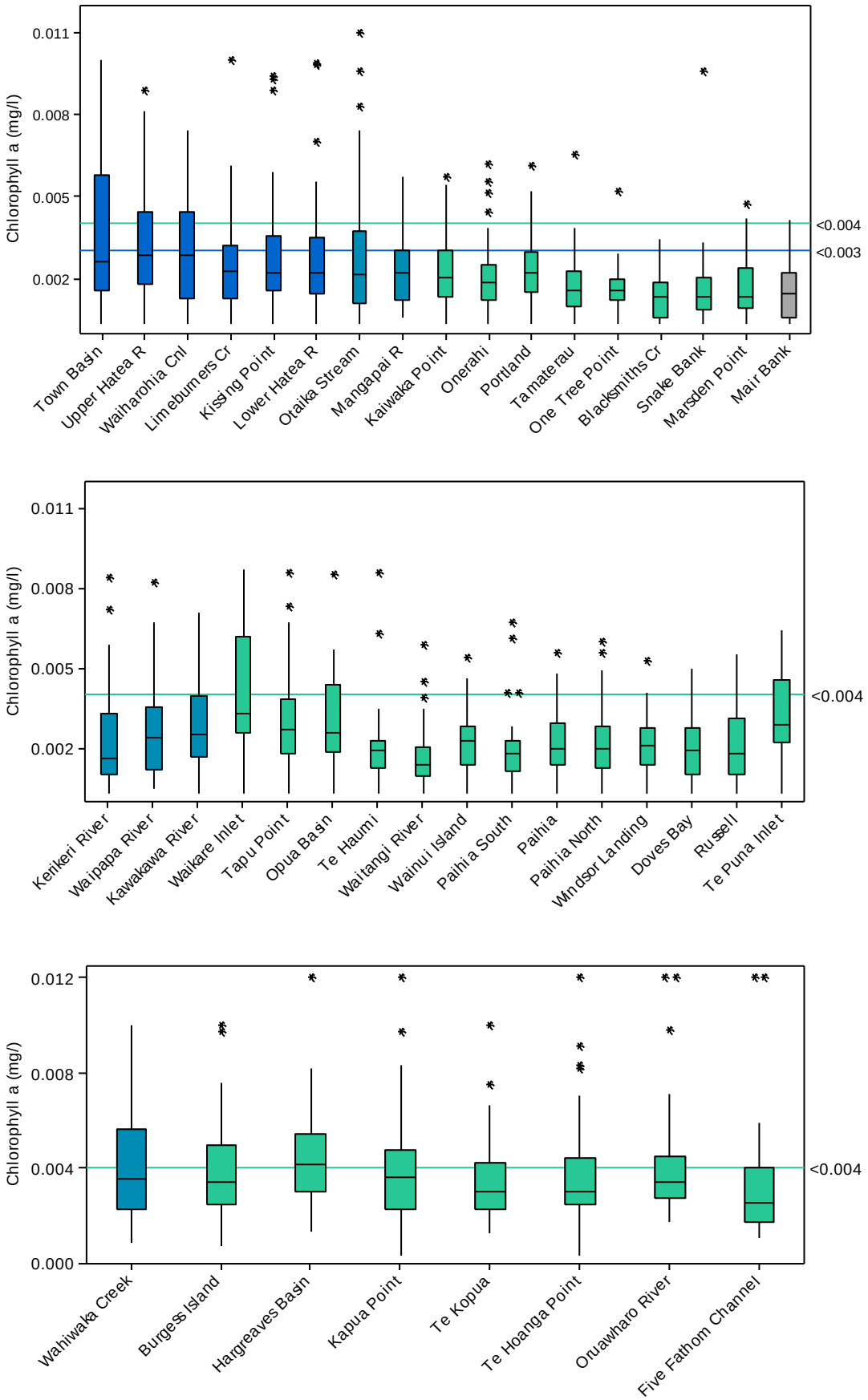

Figure 9: Chlorophyll-*a* data collected from January 2013 to December 2017. Coastal standards: tidal creeks 0.004 mg/L; estuaries: 0.004 mg/L; and Hātea River 0.003 mg/L. Note: graphs have different scales and some outliers exceed the top of the graphs.

3.4.4 Total nitrogen

The lowest median total nitrogen concentrations were recorded at sites close to the entrance of the Whangārei Harbour (Table 21 & Figure 10). Low concentrations were also recorded at Five Fathom Channel in the Kaipara Harbour and at Russel and Te Puna in the Bay of Islands.

In Whangārei Harbour the highest median total nitrogen concentrations were recorded at Limeburners Creek (0.92 mg/L) and Waiarohia Canal (0.83 mg/L) (Table 21 & Figure 10). Other sites in the Hātea River management unit also had high median concentrations as well as Otaika Creek (0.71 mg/L). In the Bay of Islands, Waipapa River (0.45 mg/L) and Kerikeri River (0.43 mg/L), which are both located in the tidal creek management unit in the Kerikeri Inlet, had the highest median total nitrogen concentrations. In the Kaipara harbour, the highest median concentration was recorded at Wahiwaka Creek (0.29 mg/L), which is in the tidal creek management unit, and is located downstream of discharges from the Maungaturoto waste water treatment plant, the Kaiwaka waste water treatment plant and a discharge form the Fonterra Maungaturoto milk processing plant.

Compliance with the standards

In Whangārei Harbour, Limeburners Creek (0.92 mg/L), had a median that exceeded the coastal water quality standard for the Hātea River management unit (<0.860 mg/L) and Otaika Creek (0.710 mg/L) had a median value that exceeded the standard for the tidal creek management unit (<0.220 mg/L). All sites in the estuarine management unit had medians below the standard (0.023 mg/L) although Kaiwaka point (0.210 mg/L) was close to exceeding the standard (<0.220 mg/L). This site is immediately downstream of the Hātea River unit, where total nitrogen concentrations are very high.

In the Bay of Islands and the Kaipara harbours all sites complied with the relevant standards.

Trend analysis

Trend analysis was only performed on seven sites (Table 22) in the Kaipara Harbour. Total nitrogen has only been analysed at sites in the Bay of Islands and Whangārei Harbour since January 2016 so there is insufficient data to perform meaningful trend analysis. Trend analysis identified increasing (negative) trends for total nitrogen at five sites in the Kaipara Harbour (Table 22).

Table 21: Total nitrogen (mg/L) data collected from January 2013 to December 2017. Ranked lowest to highest median.

Site name	Count	Minimum	Maximum	Mean	S.E.	Median	Compliance
Mair Bank	15	0.026	0.390	0.098	0.023	0.079	✓
Marsden Point	15	0.030	0.150	0.087	0.009	0.088	✓
One Tree Point	15	0.022	0.180	0.100	0.011	0.092	✓
Snake Bank	15	0.035	0.580	0.120	0.034	0.092	✓
Five Fathom Channel	60	<0.01	0.410	0.118	0.014	0.098	✓
Russell	15	0.019	0.280	0.109	0.015	0.100	✓
Te Puna Inlet	15	0.034	0.220	0.107	0.014	0.100	✓
Blacksmiths Creek	15	<0.01	0.130	0.096	0.009	0.110	✓
Oruawharo River	58	<0.01	0.710	0.131	0.015	0.115	✓
Doves Bay	15	0.053	0.560	0.172	0.038	0.120	✓
Paihia	15	0.057	0.860	0.173	0.050	0.120	✓
Paihia North	15	0.032	0.210	0.127	0.012	0.130	✓
Tamaterau	15	0.071	0.190	0.124	0.009	0.130	✓
Windsor Landing	15	0.056	1.300	0.201	0.079	0.130	✓
Te Kopua	60	<0.01	0.350	0.139	0.013	0.135	✓
Ōpua Basin	15	0.077	0.230	0.141	0.010	0.140	✓
Paihia South	15	0.073	0.410	0.156	0.022	0.140	✓
Te Haumi	15	0.068	1.400	0.215	0.085	0.140	✓
Te Hoanga Point	60	0.010	6.300	0.267	0.104	0.140	✓
Tapu Point	15	0.058	0.330	0.151	0.018	0.150	✓
Kapua Point	60	<0.01	0.730	0.166	0.015	0.160	✓
Onerahi	15	0.120	0.330	0.175	0.016	0.160	✓
Portland	15	0.097	0.230	0.165	0.008	0.160	✓
Waikare Inlet	15	0.074	0.330	0.165	0.018	0.160	✓
Wainui Island	15	0.120	0.740	0.239	0.043	0.170	✓
Waitangi River	15	0.095	1.400	0.296	0.087	0.170	✓
Hargreaves Basin	58	0.036	1.000	0.205	0.020	0.185	✓
Burgess Island	60	<0.01	8.300	0.385	0.136	0.195	✓
Kaiwaka Point	15	0.110	0.360	0.211	0.017	0.210	✓
Mangapai River	15	0.140	0.780	0.272	0.039	0.240	✓
Kawakawa River	15	0.130	9.100	1.065	0.607	0.250	✓
Wahiwaka Creek	60	0.076	0.640	0.306	0.019	0.285	✓
Lower Hātea River	15	0.150	0.820	0.424	0.057	0.390	✓
Kerikeri River	15	0.220	0.890	0.473	0.047	0.430	✓
Kissing Point	15	0.170	1.100	0.545	0.078	0.430	✓
Waipapa River	15	0.210	2.400	0.563	0.137	0.450	✓
Town Basin	15	0.450	0.930	0.660	0.035	0.650	✓
Otaika Creek	15	0.520	1.300	0.791	0.056	0.710	×
Upper Hātea River	15	0.430	1.100	0.714	0.046	0.710	✓
Waiarohia Canal	15	0.330	0.990	0.778	0.045	0.830	✓
Limeburners Creek	15	0.210	6.200	1.926	0.506	0.920	×

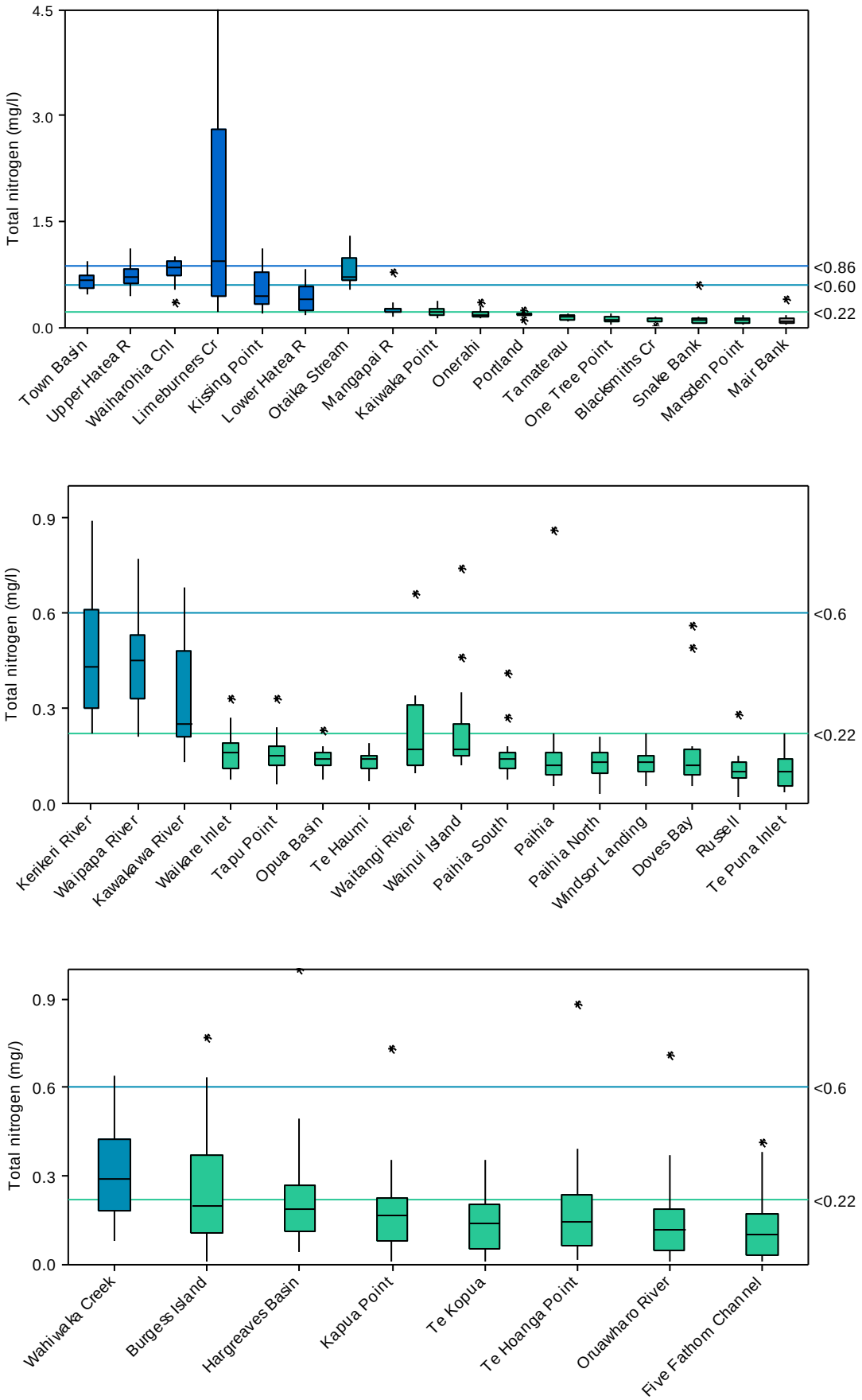

Figure 10: Total nitrogen data collected from January 2013 to December 2017. Coastal standards: estuaries (0.22 mg/L); tidal creeks (0.60 mg/L); and the Hātea River (0.86 mg/L). Note: graphs have different scales.

Table 22: Mann-Kendall seasonal trend analysis of total nitrogen (mg/L).

Site	Sampling period	Count	Censored values	Trend	P-value	% annual change
Wahiwaka Creek	27/5/09-14/12/17	101	0	Increasing	<0.001	7.65
Te Kopua	27/5/09-14/12/17	101	7	Increasing	0.010	8.34
Hargreaves Basin	27/5/09-14/12/17	100	0	Increasing	0.020	4.44
Kapua Point	27/5/09-14/12/17	101	4	Increasing	0.040	6.60
Te Hoanga Point	27/5/09-14/12/17	101	3	Increasing	0.040	8.57
Burgess Island	27/5/09-14/12/17	101	3	None detected	-	-
Oruawharo River	27/5/09-14/12/17	99	5	None detected	-	-
Five Fathom Channel	27/5/09-14/12/17	101	19	>15% censored	-	-
Te Haumi	21/01/16-16/11/17	15	0	Insufficient data	-	-
Paihia South	21/01/16-16/11/17	15	0	Insufficient data	-	-
Russell	21/01/16-16/11/17	15	0	Insufficient data	-	-
Kawakawa River	21/01/16-16/11/17	15	0	Insufficient data	-	-
Ōpua Basin	21/01/16-16/11/17	15	0	Insufficient data	-	-
Tapu Point	21/01/16-16/11/17	15	0	Insufficient data	-	-
Waikare Inlet	21/01/16-16/11/17	15	0	Insufficient data	-	-
Paihia	21/01/16-16/11/17	15	0	Insufficient data	-	-
Paihia North	21/01/16-16/11/17	15	0	Insufficient data	-	-
Waitangi River	21/01/16-16/11/17	15	0	Insufficient data	-	-
Windsor Landing	21/01/16-16/11/17	15	0	Insufficient data	-	-
Kerikeri River	21/01/16-16/11/17	15	0	Insufficient data	-	-
Waipapa River	21/01/16-16/11/17	15	0	Insufficient data	-	-
Wainui Island	21/01/16-16/11/17	15	0	Insufficient data	-	-
Doves Bay	21/01/16-16/11/17	15	0	Insufficient data	-	-
Te Puna Inlet	21/01/16-16/11/17	15	0	Insufficient data	-	-
Mair Bank	21/01/16-16/11/17	15	0	Insufficient data	-	-
Marsden Point	21/01/16-16/11/17	15	0	Insufficient data	-	-
Blacksmiths Creek	21/01/16-16/11/17	15	0	Insufficient data	-	-
Snake Bank	21/01/16-16/11/17	15	0	Insufficient data	-	-
One Tree Point	21/01/16-16/11/17	15	0	Insufficient data	-	-
Tamaterau	21/01/16-16/11/17	15	0	Insufficient data	-	-
Mangapai River	21/01/16-16/11/17	15	0	Insufficient data	-	-
Portland	21/01/16-16/11/17	15	0	Insufficient data	-	-
Onerahi	21/01/16-16/11/17	15	0	Insufficient data	-	-
Kaiwaka Point	21/01/16-16/11/17	15	0	Insufficient data	-	-
Limeburners Creek	21/01/16-16/11/17	15	0	Insufficient data	-	-
Lower Hātea River	21/01/16-16/11/17	15	0	Insufficient data	-	-
Kissing Point	21/01/16-16/11/17	15	0	Insufficient data	-	-
Waiharohia Canal	21/01/16-16/11/17	15	0	Insufficient data	-	-
Upper Hātea River	21/01/16-16/11/17	15	0	Insufficient data	-	-
Town Basin	21/01/16-16/11/17	15	0	Insufficient data	-	-
Otaika Creek	21/01/16-16/11/17	15	0	Insufficient data	-	-

3.4.5 Ammoniacal nitrogen

The lowest median ammoniacal nitrogen concentrations were recorded at Te Puna Inlet, One Tree point and Five Fathom Channel (Table 23 & Figure 11). Other sites close to the entrance of the Whangārei Harbour (Blacksmith Creek, Mair Bank, Marsden Point, One Tree Point and Snake Bank) also had low median concentrations of ammoniacal nitrogen.

The highest median concentration of ammoniacal nitrogen was recorded at Limeburners Creek (Table 23 and Figure 11). Limeburners Creek is the receiving environment for discharges from the Whangārei waste water treatment plant. The other five sites in the Hātea River and Otaika Creek in Whangārei also had high median concentrations. In the Kaipara Harbour the highest median concentration was recorded at Wahiwaka Creek (0.032 mg/L) and in the Bay of Islands the highest median concentrations were found at the Waipapa River (0.031 mg/L) and Kerikeri River (0.028 mg/L) sites (Table 23). The Wahiwaka Creek site is located downstream of discharges from the Maungaturoto waste water treatment plant, the Kaiwaka waste water treatment plant and a discharge from the Fonterra Maungaturoto milk processing plant. There are no waste water discharges into either the Waipapa River or Kerikeri River, but these are the main freshwater inputs to the Kerikeri Inlet.

Compliance with the standards

One site in the Hātea River management unit, Limeburners Creek (1.00 mg/L), had a median that exceeded the coastal water quality standard (<0.099 mg/L) and Otaika Creek (0.046 mg/L) had a median value that exceeded the standard for the tidal creek management unit (< 0.043 mg/L) (Table 23). Two sites in the estuarine management unit (Hargreaves Basin and Kaiwaka Point) had median concentrations that just exceeded the standard (<0.023 mg/L), and three more sites (Wainui Island, Waitangi River and Burgess Island) were close to exceeding the standard (Table 23).

Trend analysis

Trend analysis was only performed on eleven sites (Table 24). There were too many censored values at 29 sites and insufficient data to perform trend analysis at Otaika Creek. Hargreaves Basin was the only site in the estuary management unit with sufficient data for trend analysis. The other ten sites with sufficient data for trend analysis were located in either the Hātea River or the tidal creek management units.

Trend analysis identified increasing (negative trends) at two sites (Hargreaves Basin and Wahiwaka Creek) and a decreasing (positive trend) at one site (Waiarohia Canal). The decreasing trends at Wahiwaka creek and Hargreaves are a concern. The median concentration at Hargreaves Basin was 0.023 mg/L, which is just above the standard (<0.023 mg/L) so any further increase at this site will be of concern. Although the median concentration at Wahiwaka creek is currently below the standard for tidal creeks, the concentrations are still elevated so further increases are a concern. The decreasing trend at Waiarohia is encouraging as concentrations at this site are elevated and the median (1.00 mg/L) is currently slightly above the coastal water quality standard (<0.99 mg/L).

Table 23: Ammoniacal nitrogen (mg/L) data collected from January 2013 to December 2017. Ranked lowest to highest median concentration.

Site name	Count	Minimum	Maximum	Mean	S.E.	Median	Compliance
Te Puna Inlet	33	<0.005	0.020	0.006	0.0009	<0.005	✓
One Tree Point	33	<0.005	0.054	0.009	0.0019	<0.005	✓
Five Fathom Channel	60	<0.005	0.090	0.011	0.0021	0.005	✓
Snake Bank	33	<0.005	0.026	0.008	0.0011	0.006	✓
Marsden Point	33	<0.005	0.036	0.008	0.0013	0.006	✓
Mair Bank	33	<0.005	0.025	0.007	0.0011	0.006	✓
Russell	33	<0.005	0.065	0.009	0.0020	0.007	✓
Waikare Inlet	33	<0.005	0.048	0.011	0.0020	0.007	✓
Blacksmiths Creek	33	<0.005	0.180	0.015	0.0054	0.009	✓
Ōpua Basin	33	<0.005	0.064	0.014	0.0026	0.009	✓
Oruawharo River	58	<0.005	0.100	0.016	0.0022	0.011	✓
Paihia	33	<0.005	0.039	0.015	0.0021	0.011	✓
Windsor Landing	33	<0.005	0.032	0.013	0.0016	0.012	✓
Tapu Point	33	<0.005	0.078	0.015	0.0029	0.012	✓
Te Kopua	60	<0.005	0.092	0.017	0.0020	0.012	✓
Doves Bay	33	<0.005	0.062	0.015	0.0025	0.013	✓
Tamaterau	33	<0.005	0.055	0.015	0.0024	0.013	✓
Paihia North	33	<0.005	0.094	0.017	0.0031	0.013	✓
Portland	33	<0.005	0.051	0.017	0.0023	0.014	✓
Kapua Point	60	<0.005	0.085	0.020	0.0021	0.015	✓
Paihia South	33	<0.005	0.045	0.016	0.0019	0.016	✓
Onerahi	33	<0.005	0.057	0.018	0.0025	0.017	✓
Te Hoanga Point	60	<0.005	0.090	0.022	0.0024	0.018	✓
Te Haumi	33	<0.005	0.054	0.020	0.0025	0.018	✓
Mangapai River	33	<0.005	0.190	0.025	0.0056	0.018	✓
Kawakawa River	33	<0.005	0.120	0.026	0.0040	0.019	✓
Burgess Island	60	<0.005	0.130	0.024	0.0030	0.021	✓
Waitangi River	33	<0.005	0.049	0.021	0.0021	0.021	✓
Wainui Island	33	<0.005	0.064	0.022	0.0030	0.022	✓
Hargreaves Basin	58	<0.005	0.089	0.027	0.0029	0.023	×
Kaiwaka Point	33	<0.005	0.084	0.027	0.0036	0.023	×
Kerikeri River	33	<0.005	0.088	0.036	0.0043	0.028	✓
Waipapa River	33	<0.005	0.093	0.032	0.0035	0.031	✓
Wahiwaka Creek	60	<0.005	0.093	0.036	0.0029	0.032	✓
Lower Hātea River	33	<0.005	0.140	0.047	0.0057	0.041	✓
Otaika Creek	33	0.0120	0.120	0.053	0.0046	0.046	×
Kissing Point	33	<0.005	0.230	0.069	0.0085	0.056	✓
Town Basin	33	0.0051	0.150	0.065	0.0068	0.061	✓
Waiharohia Canal	33	0.0069	0.280	0.084	0.0108	0.066	✓
Upper Hātea River	33	<0.005	0.190	0.084	0.0084	0.077	✓
Limeburners Creek	33	<0.005	0.280	0.101	0.0113	0.100	×

Table 24: Mann-Kendall seasonal trend analysis of ammoniacal nitrogen (mg/L).

Site	Sampling period	Count	Censored values	Trend	P-value	% annual change
Hargreaves Basin	27/5/09-14/12/17	100	15	Increasing	0.01	5.71
Waiharohia Canal	26/3/08-16/11/17	60	1	Decreasing	0.03	-8.00
Wahiwaka Creek	27/5/09-14/12/17	101	14	Increasing	0.04	5.00
Upper Hātea River	26/3/08-16/11/17	60	2	None detected	-	-
Town Basin	26/3/08-16/11/17	60	1	None detected	-	-
Waipapa River	14/5/08-16/11/17	59	4	None detected	-	-
Kerikeri River	14/5/08-16/11/17	59	7	None detected	-	-
Lower Hātea River	26/3/08-16/11/17	60	3	None detected	-	-
Limeburners Creek	26/3/08-16/11/17	60	2	None detected	-	-
Kaiwaka Point	26/3/08-16/11/17	60	6	None detected	-	-
Kissing Point	26/3/08-16/11/17	60	2	None detected	-	-
Waitangi River	14/5/08-16/11/17	59	10	>15% censored	-	-
Mangapai River	26/3/08-16/11/17	60	10	>15% censored	-	-
Kawakawa River	14/5/08-16/11/17	59	12	>15% censored	-	-
Wainui Island	14/5/08-16/11/17	59	12	>15% censored	-	-
Portland	26/3/08-16/11/17	60	14	>15% censored	-	-
Te Haumi	14/5/08-16/11/17	59	17	>15% censored	-	-
Paihia North	14/5/08-16/11/17	59	20	>15% censored	-	-
Tamaterau	26/3/08-16/11/17	60	20	>15% censored	-	-
Onerahi	26/3/08-16/11/17	60	21	>15% censored	-	-
Burgess Island	27/5/09-14/12/17	101	22	>15% censored	-	-
Kapua Point	27/5/09-14/12/17	101	22	>15% censored	-	-
Paihia South	14/5/08-16/11/17	59	22	>15% censored	-	-
Paihia	14/5/08-16/11/17	59	23	>15% censored	-	-
Windsor Landing	14/5/08-16/11/17	59	23	>15% censored	-	-
Te Hoanga Point	27/5/09-14/12/17	101	24	>15% censored	-	-
Doves Bay	14/5/08-16/11/17	59	24	>15% censored	-	-
Oruawharo River	27/5/09-14/12/17	99	25	>15% censored	-	-
Ōpua Basin	14/5/08-16/11/17	59	25	>15% censored	-	-
Tapu Point	14/5/08-16/11/17	59	28	>15% censored	-	-
Waikare Inlet	14/5/08-16/11/17	59	29	>15% censored	-	-
Blacksmiths Creek	26/3/08-16/11/17	60	30	>15% censored	-	-
Snake Bank	26/3/08-16/11/17	60	30	>15% censored	-	-
Te Kopua	27/5/09-14/12/17	101	31	>15% censored	-	-
Russell	14/5/08-16/11/17	59	31	>15% censored	-	-
Marsden Point	26/3/08-16/11/17	60	34	>15% censored	-	-
Mair Bank	26/3/08-16/11/17	59	35	>15% censored	-	-
One Tree Point	26/3/08-16/11/17	60	36	>15% censored	-	-
Te Puna Inlet	14/5/08-16/11/17	59	40	>15% censored	-	-
Five Fathom Channel	27/5/09-14/12/17	101	50	>15% censored	-	-
Otaika Creek	17/1/13-16/11/17	30	0	Insufficient data	-	-

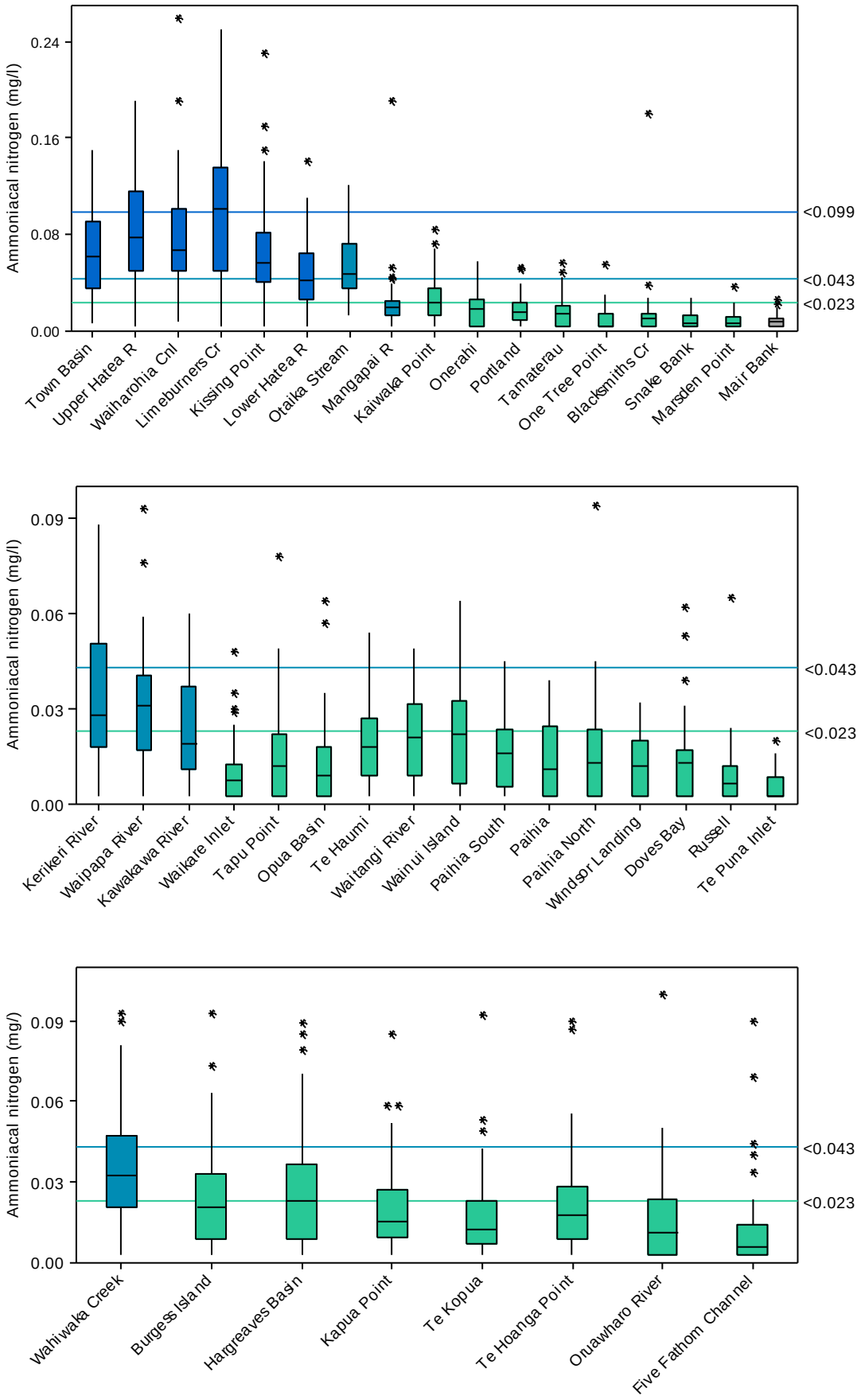

Figure 11: Ammoniacal nitrogen data collected from January 2013 to December 2017. Coastal standards: estuaries 0.023 mg/L; tidal creeks 0.043 mg/L: and the Hātea River 0.099 mg/L. Note: graphs have different scale.

3.4.6 Nitrate-nitrite nitrogen

The lowest median was recorded at Te Puna (0.001 mg/L) in the Bay of Islands with low medians also recorded at sites close to the entrance of the Whangārei Harbour (Mair Bank, Marsden Point, One Tree Point, Snake Bank and Blacksmith Creek) and at Five Fathom Channel in the Kaipara Harbour (Table 25 & Figure 12).

The highest median concentration of NNN was found at Waiarohia Canal (0.575 mg/L) in Whangārei Harbour (Table 14 and Figure 12). The other five sites in the Hātea River and the Otaika Creek in Whangārei also had high median nitrate-nitrite nitrogen concentrations. All these sites had median concentrations >0.1 mg/L. In the Bay of Islands, the highest median concentration was recorded at Kerikeri River (0.145 mg/L), which was double the next highest site in the Bay of Islands. In the Kaipara Harbour the highest median concentrations were recorded at Burgess Island (0.0525 mg/L) and at Wahiwaka Creek (0.0280 mg/L). Like the Otaika Creek and Hātea River sites, Burgess Island, Wahiwaka Creek and Waipapa River are all inner estuarine sites close to freshwater inputs.

Compliance with the standards

One site in the estuary management unit, Burgess Island (0.053 mg/L), had a median concentration that exceeded the coastal water quality standard (<0.048 mg/L) and Otaika Creek (0.360 mg/L) had a median value that exceeded the standard for the tidal creek management unit (< 0.218 mg/L) (Table 25).

Trend analysis

Trend analysis was only performed on fourteen sites (Table 26). There were too many censored values at 26 sites and insufficient data to perform trend analysis at Otaika Creek. Trend analysis identified an increasing trend (negative trend) at one site, Limeburners Creek (Table 26). The increasing trend at Limeburners Creek is a concern, as concentrations at this site are elevated and close to the coastal water quality standard for the Hātea River management unit.

Table 25: Nitrate-nitrite nitrogen (mg/L) data collected from January 2013 to December 2017. Ranked lowest to highest median.

Site name	Count	Minimum	Maximum	Mean	S.E.	Median	Compliance
Te Puna Inlet	33	<0.002	0.032	0.006	0.002	<0.002	✓
Mair Bank	33	<0.002	0.120	0.014	0.004	0.003	✓
Marsden Point	33	<0.002	0.100	0.011	0.004	0.003	✓
One Tree Point	33	<0.002	0.072	0.010	0.003	0.003	✓
Snake Bank	33	<0.002	0.069	0.014	0.003	0.003	✓
Blacksmiths Creek	33	<0.002	0.063	0.010	0.003	0.004	✓
Five Fathom Channel	60	<0.002	0.240	0.037	0.008	0.006	✓
Tamaterau	33	<0.002	0.079	0.016	0.003	0.006	✓
Waikare Inlet	33	<0.002	0.091	0.017	0.004	0.007	✓
Russell	33	<0.002	0.100	0.021	0.005	0.007	✓
Tapu Point	33	<0.002	0.120	0.026	0.006	0.007	✓
Ōpua Basin	33	<0.002	0.096	0.022	0.005	0.008	✓
Te Kopua	60	<0.002	0.230	0.034	0.006	0.009	✓
Oruawharo River	58	<0.002	0.240	0.030	0.006	0.009	✓
Mangapai River	33	<0.002	0.052	0.014	0.002	0.010	✓
Portland	33	<0.002	0.073	0.017	0.003	0.011	✓
Te Haumi	33	<0.002	0.087	0.026	0.005	0.011	✓
Te Hoanga Point	60	<0.002	0.230	0.038	0.006	0.012	✓
Onerahi	33	<0.002	0.160	0.023	0.005	0.014	✓
Paihia	33	<0.002	0.100	0.031	0.006	0.016	✓
Paihia South	33	<0.002	0.110	0.033	0.006	0.017	✓
Kapua Point	60	<0.002	0.220	0.033	0.006	0.018	✓
Paihia North	33	<0.002	0.130	0.033	0.007	0.018	✓
Kawakawa River	33	<0.002	0.260	0.049	0.011	0.019	✓
Hargreaves Basin	58	<0.002	0.230	0.041	0.006	0.021	✓
Waitangi River	33	<0.002	0.310	0.059	0.014	0.021	✓
Windsor Landing	33	<0.002	0.094	0.031	0.005	0.030	✓
Doves Bay	33	<0.002	0.140	0.037	0.006	0.035	✓
Kaiwaka Point	33	<0.002	0.250	0.060	0.011	0.039	✓
Wainui Island	33	<0.002	0.260	0.049	0.010	0.039	✓
Burgess Island	60	<0.002	0.500	0.116	0.018	0.053	×
Wahiwaka Creek	60	<0.002	0.250	0.080	0.009	0.068	✓
Lower Hātea River	33	<0.002	0.650	0.184	0.029	0.140	✓
Waipapa River	33	<0.002	0.480	0.168	0.024	0.150	✓
Kerikeri River	33	<0.002	0.550	0.217	0.029	0.180	✓
Kissing Point	33	<0.002	0.920	0.318	0.042	0.230	✓
Otaika Creek	33	<0.002	0.750	0.364	0.032	0.360	×
Town Basin	33	0.084	0.880	0.433	0.031	0.390	✓
Upper Hātea River	33	0.069	0.910	0.468	0.032	0.460	✓
Waiharohia Canal	33	0.110	0.750	0.515	0.027	0.540	✓
Limeburners Creek	33	0.001	4.100	1.257	0.240	0.550	✓

Table 26: Mann-Kendall seasonal trend analysis of nitrate-nitrite nitrogen (mg/L).

Site	Sampling period	Samples	Censored	Trend	P-value	% annual change
Limeburners Creek	12/11/08-16/11/17	56	1	Increasing	0.03	11.33
Wahiwaka Creek	27/5/09-14/12/17	101	5	None detected	-	-
Town Basin	12/11/08-16/11/17	56	0	None detected	-	-
Lower Hātea River	14/1/09-16/11/17	55	3	None detected	-	-
Waiharohia Canal	12/11/08-16/11/17	56	0	None detected	-	-
Kaiwaka Point	12/11/08-16/11/17	56	6	None detected	-	-
Upper Hātea River	12/11/08-16/11/17	56	0	None detected	-	-
Hargreaves Basin	27/5/09-14/12/17	100	11	None detected	-	-
Wainui Island	12/11/08-16/11/17	56	8	None detected	-	-
Waipapa River	12/11/08-16/11/17	56	3	None detected	-	-
Waitangi River	12/11/08-16/11/17	56	8	None detected	-	-
Kapua Point	27/5/09-14/12/17	101	15	None detected	-	-
Kissing Point	12/11/08-16/11/17	56	1	None detected	-	-
Kerikeri River	12/11/08-16/11/17	56	2	None detected	-	-
Kawakawa River	12/11/08-16/11/17	56	9	>15% censored	-	-
Mangapai River	12/11/08-16/11/17	56	9	>15% censored	-	-
Te Haumi	12/11/08-16/11/17	56	10	>15% censored	-	-
Paihia South	12/11/08-16/11/17	56	10	>15% censored	-	-
Windsor Landing	12/11/08-16/11/17	56	10	>15% censored	-	-
Paihia North	12/11/08-16/11/17	56	12	>15% censored	-	-
Doves Bay	12/11/08-16/11/17	56	12	>15% censored	-	-
Ōpua Basin	12/11/08-16/11/17	56	13	>15% censored	-	-
Paihia	12/11/08-16/11/17	56	13	>15% censored	-	-
Onerahi	12/11/08-16/11/17	56	14	>15% censored	-	-
Tapu Point	12/11/08-16/11/17	56	15	>15% censored	-	-
Tamaterau	12/11/08-16/11/17	56	15	>15% censored	-	-
Portland	12/11/08-16/11/17	56	15	>15% censored	-	-
Burgess Island	27/5/09-14/12/17	101	16	>15% censored	-	-
Te Hoanga Point	27/5/09-14/12/17	101	16	>15% censored	-	-
Russell	12/11/08-16/11/17	56	16	>15% censored	-	-
Snake Bank	12/11/08-16/11/17	56	17	>15% censored	-	-
Te Kopua	27/5/09-14/12/17	101	18	>15% censored	-	-
Mair Bank	12/11/08-16/11/17	56	18	>15% censored	-	-
Marsden Point	12/11/08-16/11/17	56	18	>15% censored	-	-
Blacksmiths Creek	12/11/08-16/11/17	56	18	>15% censored	-	-
One Tree Point	12/11/08-16/11/17	56	19	>15% censored	-	-
Waikare Inlet	12/11/08-16/11/17	56	20	>15% censored	-	-
Oruawharo River	27/5/09-14/12/17	99	21	>15% censored	-	-
Te Puna Inlet	12/11/08-16/11/17	56	29	>15% censored	-	-
Five Fathom Channel	27/5/09-14/12/17	101	32	>15% censored	-	-
Otaika Creek	17/1/13-16/11/17	33	1	Insufficient data	-	-

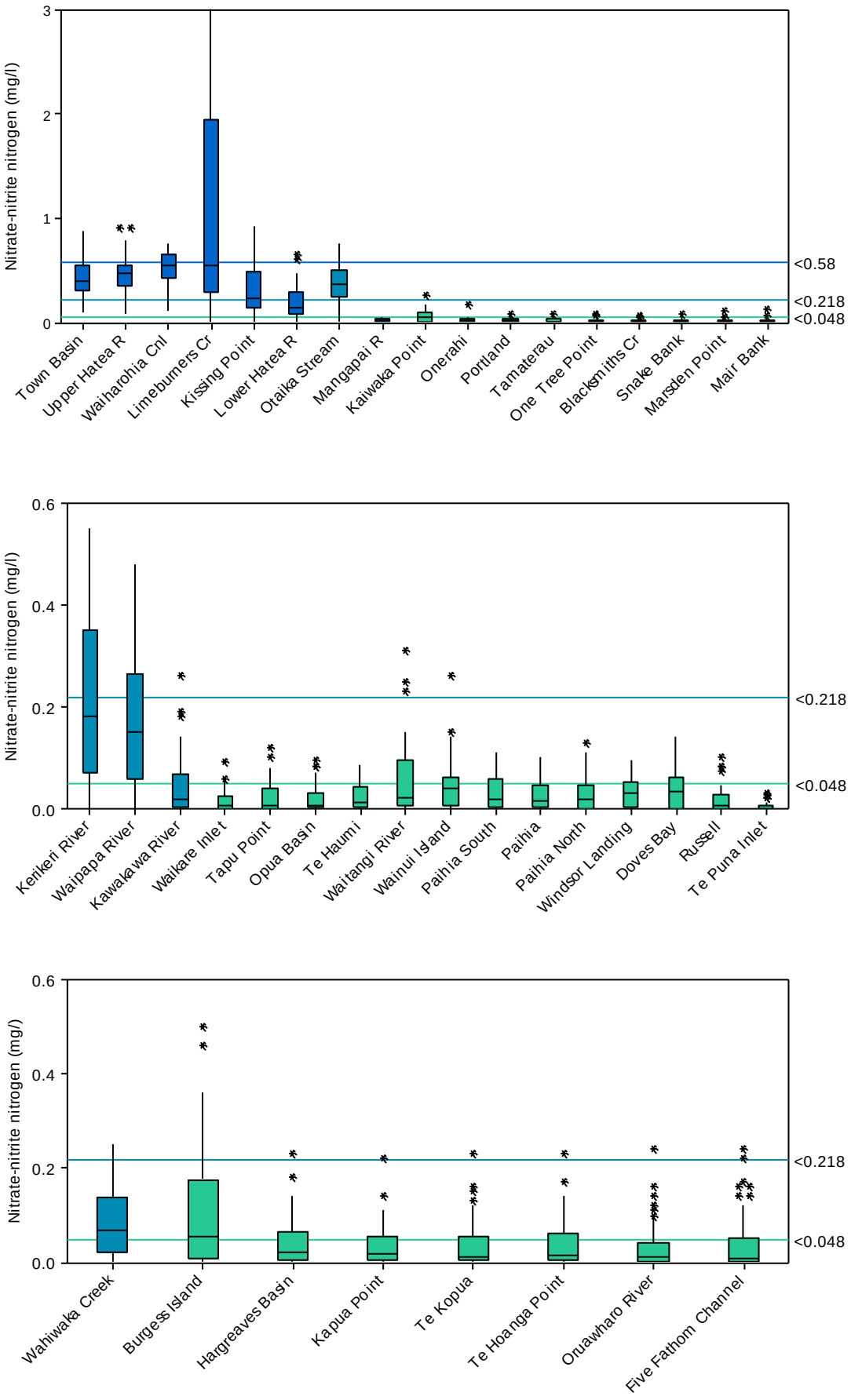

Figure 12: Nitrate-nitrite nitrogen data collected from January 2013 to December 2017. Coastal standards: estuaries (0.048 mg/L); tidal creeks (0.218 mg/L); and the Hātea River (0.580 mg/L). Note: scales change on graphs.

3.4.7 Total phosphorus

The lowest median concentrations were recorded at sites close to the entrance of the Whangārei Harbour (Marsden Point, Blacksmith Creek, Mair Bank, One Tree Point and Snake Bank) and the Kaipara Harbour (Otamatea Channel), and at more exposed outer estuarine sites in the Bay of Islands (Russel, Doves Bay and Paihia) (Table 27 & Figure 13).

The highest median concentrations of total phosphorus were found at Limeburners Creek (0.120 mg/L), Waiarohia Canal (0.099 mg/L) and the Upper Hātea River (0.0.079 mg/L) in the Whangārei Harbour (Table 27 and Figure 13). The other three sites in the Hātea River and the Wahiwaka Creek site in the Kaipara Harbour also had elevated median total phosphorus concentrations. In the Bay of Islands, the highest median concentration was recorded at the Kawakawa river site (0.027mg/L)

Compliance with the standards

In total four sites exceeded the coastal water quality standards. Two sites in the estuary management unit, Kaiwaka Point (0.030 mg/L) and Kapua Point (0.031 mg/L) had a median concentration that exceeded the coastal water quality standard (<0.030 mg/L) (Table 27). Wahiwaka Creek (0.056 mg/L) had a median value that exceeded the standard for the tidal creek management unit (<0.040 mg/L) and Limeburners Creek (0.120 mg/L) had a median that exceeded the standard for the Hātea River management unit (<0.119 mg/L).

Trend analysis

Trend analysis was only performed on 41 sites (Table 28). Decreasing (positive) trends were identified at twenty sites. Decreasing trends were identified at both Kaiwaka Point and Kapua Point. Both these sites currently have median values that exceed the coastal water quality standard, so decreases at these sites are positive.

Decreasing trends were identified at 13 of the 16 sites in Whangārei Harbour, for which there was sufficient data to perform trend analysis.

Decreasing trends were also identified at four sites in the Bay of Islands and three of these sites (Ōpua, Tapu Point and Waikare Inlet) are all located relatively close to each other in an around the confluence of the Kawakawa Rover and the Waikare Inlet.

Table 27: Total phosphorus (mg/L) data collected from January 2013 to December 2017. Ranked lowest to highest median.

Site name	Count	Minimum	Maximum	Mean	S.E.	Median	Compliance
Marsden Point	33	0.005	0.031	0.010	0.001	0.008	✓
Blacksmiths Creek	33	0.006	0.020	0.011	0.001	0.009	✓
Mair Bank	33	0.002	0.081	0.012	0.002	0.009	✓
One Tree Point	33	0.003	0.022	0.011	0.001	0.010	✓
Snake Bank	33	0.002	0.018	0.010	0.001	0.010	✓
Russell	33	0.005	0.024	0.012	0.001	0.012	✓
Doves Bay	33	0.008	0.044	0.015	0.001	0.013	✓
Five Fathom Channel	60	0.008	0.041	0.015	0.001	0.014	✓
Paihia North	33	0.006	0.025	0.014	0.001	0.014	✓
Paihia	33	0.008	0.030	0.015	0.001	0.015	✓
Paihia South	33	0.007	0.078	0.017	0.002	0.015	✓
Tamaterau	33	0.008	0.029	0.016	0.001	0.015	✓
Te Puna Inlet	33	0.008	0.047	0.016	0.001	0.015	✓
Windsor Landing	33	0.010	0.027	0.016	0.001	0.015	✓
Kerikeri River	33	0.007	0.080	0.019	0.002	0.016	✓
Waipapa River	33	0.005	0.043	0.017	0.001	0.016	✓
Waitangi River	33	0.009	0.059	0.018	0.002	0.016	✓
Te Haumi	33	0.011	0.041	0.018	0.001	0.017	✓
Wainui Island	33	0.012	0.044	0.019	0.001	0.017	✓
Ōpua Basin	33	0.012	0.036	0.019	0.001	0.018	✓
Tapu Point	33	0.011	0.310	0.029	0.009	0.019	✓
Onerahi	33	0.010	0.091	0.023	0.002	0.020	✓
Waikare Inlet	33	0.009	0.042	0.022	0.001	0.021	✓
Oruawharo River	58	0.008	0.190	0.026	0.003	0.022	✓
Portland	33	0.009	0.053	0.023	0.001	0.022	✓
Te Kopua	60	0.009	0.059	0.026	0.001	0.025	✓
Burgess Island	60	0.010	0.050	0.028	0.001	0.026	✓
Kawakawa River	33	0.014	0.160	0.034	0.005	0.027	✓
Mangapai River	33	0.010	0.064	0.028	0.002	0.028	✓
Te Hoanga Point	60	0.013	0.051	0.029	0.001	0.029	✓
Kaiwaka Point	33	0.017	0.082	0.031	0.002	0.030	×
Kapua Point	60	0.014	0.049	0.032	0.001	0.031	×
Otaika Creek	33	0.006	0.190	0.046	0.007	0.033	✓
Hargreaves Basin	58	0.016	0.085	0.037	0.001	0.036	✓
Lower Hātea River	33	0.019	0.110	0.052	0.004	0.046	✓
Wahiwaka Creek	60	0.030	0.110	0.057	0.002	0.056	×
Kissing Point	33	0.024	0.160	0.072	0.007	0.058	✓
Town Basin	33	0.012	0.320	0.080	0.010	0.064	✓
Upper Hātea River	33	0.019	0.160	0.082	0.006	0.079	✓
Waiharohia Canal	33	0.024	0.260	0.103	0.008	0.099	✓
Limeburners Creek	33	0.033	0.960	0.243	0.042	0.120	×

Table 28: Mann-Kendall seasonal trend analysis of total phosphorus (mg/L).

Site	Sampling period	Count	Censored values	Trend	P-value	% annual change
Mangapai River	26/3/08-16/11/17	60	0	Decreasing	<0.001	-7.113
Portland	26/3/08-16/11/17	60	0	Decreasing	<0.001	-7.85
Onerahi	26/3/08-16/11/17	60	0	Decreasing	<0.001	-6.924
Kaiwaka Point	26/3/08-16/11/17	60	0	Decreasing	<0.001	-6.24
Upper Hātea River	26/3/08-16/11/17	60	0	Decreasing	0.001	-7.079
Tamaterau	26/3/08-16/11/17	60	0	Decreasing	0.004	-5.231
Marsden Point	26/3/08-16/11/17	60	1	Decreasing	0.005	-6.953
Waiharohia Canal	26/3/08-16/11/17	60	0	Decreasing	0.005	-7.271
Snake Bank	26/3/08-16/11/17	60	3	Decreasing	0.008	-7.399
Five Fathom Channel	27/5/09-14/12/17	101	0	Decreasing	0.010	-4.24
Russell	14/5/08-16/11/17	59	1	Decreasing	0.010	-4.23
One Tree Point	26/3/08-16/11/17	60	2	Decreasing	0.013	-5.759
Oruawharo River	27/5/09-14/12/17	99	0	Decreasing	0.020	-4.15
Waikare Inlet	14/5/08-16/11/17	59	0	Decreasing	0.020	-3.79
Blacksmiths Creek	26/3/08-16/11/17	60	1	Decreasing	0.025	-6.513
Ōpua Basin	14/5/08-16/11/17	59	0	Decreasing	0.030	-3.86
Town Basin	26/3/08-16/11/17	60	0	Decreasing	0.039	-4.791
Mair Bank	26/3/08-16/11/17	59	3	Decreasing	0.040	-5.452
Kapua Point	27/5/09-14/12/17	101	0	Decreasing	0.050	-2.4
Tapu Point	14/5/08-16/11/17	59	0	Decreasing	0.050	-3.39
Te Puna Inlet	14/5/08-16/11/17	59	0	None detected	-	-
Paihia South	14/5/08-16/11/17	59	1	None detected	-	-
Waipapa River	14/5/08-16/11/17	59	1	None detected	-	-
Windsor Landing	14/5/08-16/11/17	59	1	None detected	-	-
Doves Bay	14/5/08-16/11/17	59	1	None detected	-	-
Waitangi River	14/5/08-16/11/17	59	0	None detected	-	-
Te Haumi	14/5/08-16/11/17	59	1	None detected	-	-
Wainui Island	14/5/08-16/11/17	59	1	None detected	-	-
Burgess Island	27/5/09-14/12/17	101	0	None detected	-	-
Paihia North	14/5/08-16/11/17	59	1	None detected	-	-
Limeburners Creek	26/3/08-16/11/17	60	0	None detected	-	-
Paihia	14/5/08-16/11/17	59	0	None detected	-	-
Wahiwaka Creek	27/5/09-14/12/17	101	0	None detected	-	-
Kawakawa River	14/5/08-16/11/17	59	0	None detected	-	-
Kissing Point	26/3/08-16/11/17	60	0	None detected	-	-
Kerikeri River	14/5/08-16/11/17	59	0	None detected	-	-
Hargreaves Basin	27/5/09-14/12/17	100	0	None detected	-	-
Lower Hātea River	26/3/08-16/11/17	60	0	None detected	-	-
Te Kopua	27/5/09-14/12/17	101	0	None detected	-	-
Te Hoanga Point	27/5/09-14/12/17	101	0	None detected	-	-
Otaika Creek	17/1/13-16/11/17	33	0	Insufficient data		

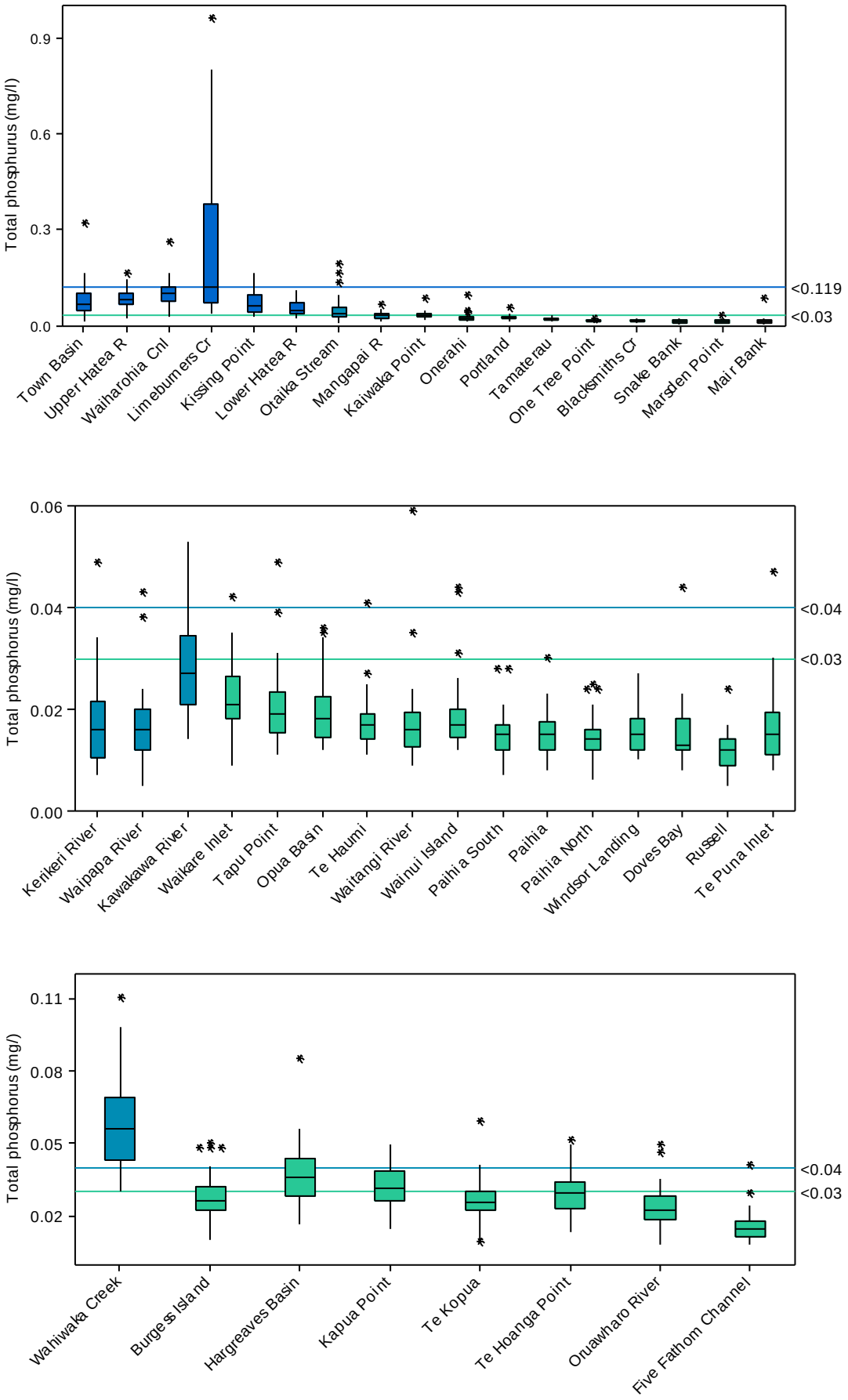

Figure 13: Total phosphorus data collected from January 2013 to December 2017. Coastal standards: estuaries (<0.03 mg/L); tidal creeks (<0.040 mg/L); and Hātea River (<0.119mg/L). Note scales change on graphs.

3.4.8 Dissolved reactive phosphorus

The lowest median concentration of dissolved reactive phosphorus was recorded at Waipapa River (0.006 mg/L) which is a tidal creek sites located in the upper Kerikeri Inlet in the Bay of Islands (Table 29 & Figure 14). Low median values were also recorded at sites close to the entrance of the Whangārei Harbour (Blacksmith Creek, Mair Bank, Marsden Point) and at Kerikeri Inlet and Te Puna, in the Bay of Islands.

The highest median concentrations were recorded at the six sites in the Hātea River in Whangārei Harbour and at Wahiwaka Creek in the Kaipara Harbour (Table 29 & Figure 14). These sites all had median values > 0.035 mg/L. In the Bay of Islands, the highest median concentration was recorded at the Kawakawa River site, which is one of the main freshwater inputs to the Bay of Islands system. This site had the highest median concentration of total phosphorus in the Bay of Islands (Table 27).

Compliance with the standards

In total, eight sites had median concentrations that exceeded the relevant standard for dissolved reactive phosphorus. Six sites in the estuary management unit had a median that exceeded the coastal water quality standard (<0.0170 mg/L) (Table 29). Five of these sites were in the Kaipara Harbour. Wahiwaka Creek (0.039 mg/L), which is also in the Kaipara Harbour exceeded the standard for the tidal creek management unit. Limeburners Creek (0.100 mg/L) had a median that exceeded the standard for the Hātea River management unit (<0.092 mg/L).

Trend analysis

Trend analysis was only performed on 36 sites (Table 30). There were too many censored values at four sites and insufficient data at Otaika Creek.

Six decreasing (positive) trends were identified (Table 30). Five of these sites were in the Whangārei Harbour and the decreasing trends identified at the Town Basin, Upper Hātea River and Kaiwaka Points, are positive as dissolved reactive phosphorus concentrations recorded in the Hātea River, and immediately downstream of this management unit are elevated.

Increasing (negative) trends were identified at five sites (Table 30). Of most concern is the increasing trends identified at Wahiwaka Creek and Te Kopua in the Kaipara Harbour. Median concentrations at both these sites are already high and above the relevant coastal water quality standards (Table 29).

Table 29: Dissolved reactive phosphorus (mg/L) data collected from January 2013 to December 2017. Ranked lowest to highest median.

Site name	Count	Minimum	Maximum	Mean	S.E.	Median	Compliance
Waipapa River	33	0.0020	0.016	0.007	0.001	0.006	✓
Blacksmiths Creek	33	<0.005	0.013	0.008	0.000	0.007	✓
Kerikeri River	33	<0.005	0.039	0.009	0.001	0.007	✓
Mair Bank	33	<0.005	0.014	0.008	0.001	0.007	✓
Marsden Point	33	<0.005	0.013	0.007	0.000	0.007	✓
Te Puna Inlet	33	0.0040	0.012	0.007	0.000	0.007	✓
One Tree Point	33	<0.005	0.014	0.008	0.000	0.008	✓
Russell	33	0.0030	0.016	0.009	0.001	0.008	✓
Snake Bank	33	<0.005	0.018	0.008	0.001	0.008	✓
Doves Bay	33	0.0020	0.025	0.010	0.001	0.009	✓
Paihia	33	0.0030	0.017	0.010	0.000	0.009	✓
Windsor Landing	33	0.0020	0.014	0.010	0.001	0.009	✓
Five Fathom Channel	60	0.0020	0.021	0.010	0.000	0.010	✓
Ōpua Basin	33	0.0050	0.020	0.011	0.001	0.010	✓
Paihia North	33	0.0040	0.019	0.010	0.000	0.010	✓
Paihia South	33	<0.002	0.017	0.010	0.001	0.010	✓
Tapu Point	33	0.0050	0.038	0.011	0.001	0.010	✓
Waikare Inlet	33	<0.005	0.024	0.011	0.001	0.010	✓
Waitangi River	33	0.0060	0.020	0.011	0.001	0.010	✓
Tamaterau	33	0.0080	0.034	0.012	0.001	0.011	✓
Te Haumi	33	0.0040	0.017	0.011	0.000	0.011	✓
Wainui Island	33	0.004	0.026	0.011	0.001	0.011	✓
Otaika Creek	33	0.0030	0.059	0.014	0.002	0.012	✓
Kawakawa River	33	0.0090	0.023	0.014	0.001	0.013	✓
Onerahi	33	0.0090	0.023	0.014	0.001	0.013	✓
Portland	33	0.0080	0.036	0.014	0.001	0.013	✓
Mangapai River	33	0.0080	0.021	0.014	0.001	0.014	✓
Oruawharo River	58	0.0060	0.030	0.015	0.001	0.014	✓
Burgess Island	60	0.0060	0.031	0.018	0.001	0.018	×
Te Kopua	60	0.0090	0.035	0.019	0.001	0.019	×
Kaiwaka Point	33	0.0090	0.032	0.020	0.001	0.020	×
Te Hoanga Point	60	0.0110	0.033	0.021	0.001	0.020	×
Kapua Point	60	0.0080	0.044	0.023	0.001	0.023	×
Hargreaves Basin	58	0.0110	0.042	0.025	0.001	0.025	×
Lower Hātea River	33	0.0080	0.110	0.040	0.004	0.035	✓
Wahiwaka Creek	60	0.0120	0.063	0.038	0.001	0.039	×
Town Basin	33	0.0120	0.130	0.053	0.005	0.047	✓
Kissing Point	33	0.0090	0.140	0.060	0.006	0.050	✓
Upper Hātea River	33	0.0180	0.130	0.070	0.005	0.072	✓
Waiarohia Canal	33	0.0200	0.160	0.075	0.005	0.074	✓
Limeburners Creek	33	0.0090	0.790	0.211	0.040	0.100	×

Table 30: Mann-Kendall seasonal trend analysis of dissolved reactive phosphorus (mg/L).

Site	Sampling period	Count	Censored values	Trend	P-value	% annual change
Wahiwaka Creek	27/5/09-14/12/17	101	0	Increasing	<0.001	4.130
Mangapai River	26/3/08-16/11/17	59	0	Decreasing	0.004	-5.626
Portland	26/3/08-16/11/17	59	1	Decreasing	0.007	-7.105
Te Kopua	27/5/09-14/12/17	101	0	Increasing	0.010	2.770
Waitangi River	16/7/08-16/11/17	58	6	Increasing	0.010	4.000
Town Basin	26/3/08-16/11/17	59	0	Decreasing	0.019	-7.194
Upper Hātea River	26/3/08-16/11/17	59	0	Decreasing	0.025	-3.475
Paihia South	16/7/08-16/11/17	58	5	Increasing	0.030	3.720
Kaiwaka Point	26/3/08-16/11/17	59	0	Decreasing	0.047	-2.503
Five Fathom Channel	27/5/09-14/12/17	101	2	Decreasing	0.050	-2.010
Paihia North	16/7/08-16/11/17	58	4	None detected	0.060	3.700
Waiharohia Canal	26/3/08-16/11/17	59	0	None detected	0.065	-6.161
Paihia	16/7/08-16/11/17	58	4	None detected	0.070	3.690
Onerahi	26/3/08-16/11/17	59	1	None detected	0.113	-2.532
Kawakawa River	16/7/08-16/11/17	58	1	None detected	0.140	3.070
Wainui Island	16/7/08-16/11/17	58	5	None detected	0.140	3.330
Burgess Island	27/5/09-14/12/17	101	0	None detected	0.170	-1.830
Kapua Point	27/5/09-14/12/17	101	0	None detected	0.170	0.000
Te Hoanga Point	27/5/09-14/12/17	100	0	None detected	0.170	0.000
Oruawharo River	27/5/09-14/12/17	99	3	None detected	0.170	-2.370
Hargreaves Basin	27/5/09-14/12/17	100	6	None detected	0.170	4.370
Te Haumi	16/7/08-16/11/17	58	5	None detected	0.220	2.380
Limeburners Creek	26/3/08-16/11/17	59	0	None detected	0.225	5.523
Ōpua Basin	16/7/08-16/11/17	58	2	None detected	0.270	1.670
Windsor Landing	16/7/08-16/11/17	58	4	None detected	0.310	1.590
One Tree Point	26/3/08-16/11/17	59	7	None detected	0.360	-1.787
Snake Bank	26/3/08-16/11/17	59	8	None detected	0.445	0.000
Doves Bay	16/7/08-16/11/17	58	5	None detected	0.460	0.000
Blacksmiths Creek	26/3/08-16/11/17	59	8	None detected	0.631	0.000
Tapu Point	16/7/08-16/11/17	58	2	None detected	0.650	0.000
Te Puna Inlet	16/7/08-16/11/17	58	6	None detected	0.650	0.000
Kissing Point	26/3/08-16/11/17	59	0	None detected	0.666	1.627
Marsden Point	26/3/08-16/11/17	59	8	None detected	0.719	0.000
Waikare Inlet	16/7/08-16/11/17	58	6	None detected	0.740	0.000
Lower Hātea River	26/3/08-16/11/17	58	0	None detected	0.809	0.408
Tamaterau	26/3/08-16/11/17	59	4	None detected	0.937	0.000
Russell	16/7/08-16/11/17	58	9	>15% censored	-	-
Mair Bank	26/3/08-16/11/17	58	9	>15% censored	-	-
Waipapa River	16/7/08-16/11/17	58	14	>15% censored	-	-
Kerikeri River	16/7/08-16/11/17	57	16	>15% censored	-	-
Otaika Creek	17/1/13-16/11/17	33	0	Insufficient data	-	-

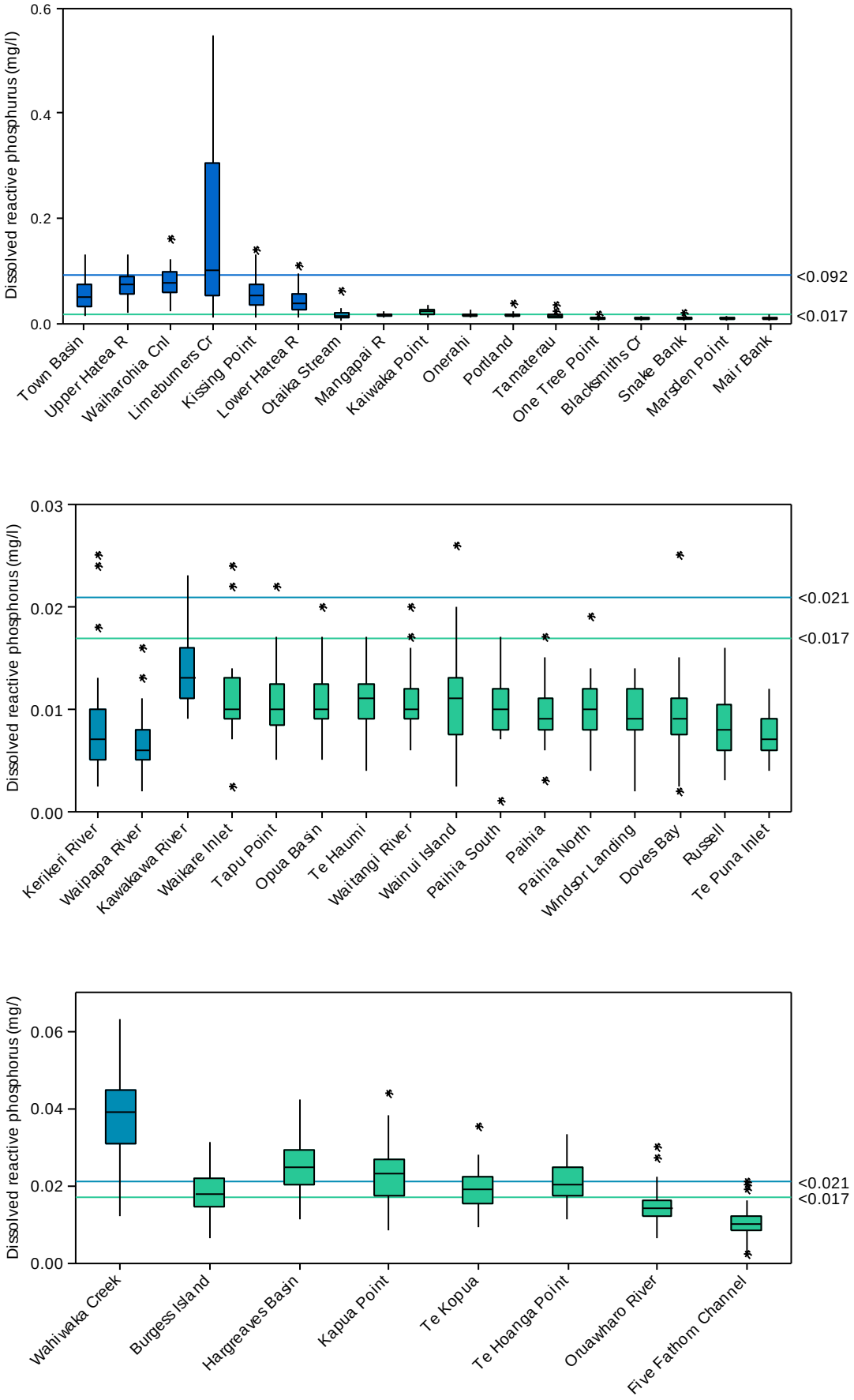

Figure 14: Dissolved reactive phosphorus data collected from January 2013 to December 2017. Coastal standards for: estuaries (0.017 mg/L); tidal creeks (0.021 mg/L); and Hātea River (0.092 mg/L). Note scales change on graphs.

3.5 Metal contaminants

3.5.1 Total Zinc

Zinc concentrations were typically low, with a large number of censored values recorded at most sites. At eight sites, all samples returned a censored value (<0.01 mg/L), which indicates that zinc concentrations at these sites are likely to be low (Table 31). Most of these sites are estuarine sites in the outer Whangārei Harbour or Bay of Islands.

The highest concentration recorded was at Marsden Point (5.1 mg/L), which is located close to the entrance of the Whangārei Harbour. A concentration of 2.0 mg/L was also recorded at the Lower Hātea River site. These two values were several orders of magnitude higher than other results collected during the sampling period.

Compliance with the standards

The coastal water quality standard for zinc is a maximum concentration of 0.015 mg/L in the Hātea River, tidal creek and estuaries management unit and a maximum of 0.007 mg/L in the open coastal management unit. Seventeen sites did not exceed the standard during the sampling period (Table 31). Most of these sites are located in the estuarine management unit but, two tidal creek sites (Kawaka River and Kerikeri River) also did not exceed the standard.

Twenty-four sites had at least one sample that exceeded the standard. Most of these sites had only one or two samples that exceeded the standard but four sites (Otaika Creek, Russell, Waiarohia Canal and Limeburners Creek) had three or more samples that exceeded the standard. Otaika Creek is a tidal creek site and both Waiharohia Canal and Limeburners Creek are located in the Hātea River unit. The number of exceedances at Russell is unexpected, as this is an estuarine site in a relatively exposed location with good flushing away from freshwater inputs.

Trend analysis

Total zinc has only been sampled since July 2015 so there is insufficient data for trend analysis.

Table 31: Zinc (mg/L) data collected from July 2015 to December 2017. Ranked lowest to highest maximum value.

Site	Count	Censored	Minimum	Maximum	Exceedances	Compliance
Kapua Point	27	27	<0.01	<0.01	0	✓
Mair Bank	18	18	<0.01	<0.01	0	✓
One Tree Point	18	18	<0.01	<0.01	0	✓
Ōpua Basin	18	18	<0.01	<0.01	0	✓
Paihia	18	18	<0.01	<0.01	0	✓
Paihia North	18	18	<0.01	<0.01	0	✓
Portland	18	18	<0.01	<0.01	0	✓
Te Haumi	18	18	<0.01	<0.01	0	✓
Paihia South	18	17	<0.01	0.01	0	✓
Waitangi River	18	17	<0.01	0.01	0	✓
Windsor Landing	18	16	<0.01	0.01	0	✓
Wainui Island	18	17	<0.01	0.011	0	✓
Doves Bay	18	17	<0.01	0.012	0	✓
Kawakawa River	18	17	<0.01	0.012	0	✓
Onerahi	18	17	<0.01	0.012	0	✓
Tamaterau	18	17	<0.01	0.013	0	✓
Kerikeri River	18	17	<0.01	0.014	0	✓
Te Hoanga Point	27	25	<0.01	0.015	1 (3.7%)	×
Te Kopua	27	26	<0.01	0.021	1 (3.7%)	×
Oruawharo River	27	25	<0.01	0.03	1 (3.7%)	×
Mangapai River	18	16	<0.01	0.016	1 (5.6%)	×
Tapu Point	18	17	<0.01	0.017	1 (5.6%)	×
Upper Hātea River	18	11	<0.01	0.02	1 (5.6%)	×
Waikare Inlet	18	17	<0.01	0.021	1 (5.6%)	×
Te Puna Inlet	18	17	<0.01	0.03	1 (5.6%)	×
Waipapa River	18	16	<0.01	0.034	1 (5.6%)	×
Kaiwaka Point	18	16	<0.01	0.066	1 (5.6%)	×
Marsden Point	18	17	<0.01	5.10	1 (5.6%)	×
Hargreaves Basin	27	23	<0.01	0.025	2 (7.4%)	×
Burgess Island	27	25	<0.01	0.026	2 (7.4%)	×
Wahiwaka Creek	27	24	<0.01	0.064	2 (7.4%)	×
Blacksmiths Creek	18	15	<0.01	0.019	2 (11.1%)	×
Kissing Point	18	13	<0.01	0.023	2 (11.1%)	×
Town Basin	18	10	<0.01	0.024	2 (11.1%)	×
Five Fathom Channel	27	22	<0.01	0.035	3 (11.1%)	×
Snake Bank	18	16	<0.01	0.04	2 (11.1%)	×
Lower Hātea River	18	14	<0.01	2.00	2 (11.1%)	×
Otaika Creek	18	8	<0.01	0.022	3 (16.7%)	×
Russell	18	15	<0.01	0.042	3 (16.7%)	×
Waiarohia Canal	18	9	<0.01	0.032	6 (33.3%)	×
Limeburners Creek	18	7	<0.01	0.038	7 (38.9%)	×

3.5.2 Total copper

Copper concentrations were typically low, with a large number of censored values recorded at most sites. The highest concentration of copper was recorded at Tamaterau (0.24 mg/L) (Table 32). A concentration of 0.18 mg/L was also recorded at the Lower Hātea River site. These two values were an order of magnitude higher than all other results collected during the sampling period.

Compliance with the standards

The coastal water quality standard for copper is a maximum of 0.0013 mg/L in the Hātea River, tidal creek and estuaries management unit and a maximum of 0.0003 mg/L in the open coastal management unit (Table 2). Forty sites had at least one sample that exceeded the standard (Table 32). Only one (Russel) did not exceed the standard during the sampling period. The highest number of samples that exceeded the standards were recorded at sites in the Hātea River management unit. All six sites in this management unit had at least four samples that exceeded the coastal water quality standard.

Trend analysis

Total copper has only been sampled since July 2015 so there is insufficient data for trend analysis.

Table 32: Copper (mg/L) data collected from July 2015 to December 2017. Ranked lowest to highest maximum value.

Site	Count	Censored	Minimum	Maximum	Exceedances	Compliance
Russell	18	18	<0.002	0.001	0	✓
Doves Bay	18	17	<0.002	0.003	1 (5.6%)	×
Te Puna Inlet	18	17	<0.002	0.003	1 (5.6%)	×
Windsor Landing	18	17	<0.002	0.003	1 (5.6%)	×
Snake Bank	18	17	<0.002	0.005	1 (5.6%)	×
Kerikeri River	18	17	<0.002	0.006	1 (5.6%)	×
Te Haumi	18	16	<0.002	0.004	2 (11.1%)	×
Wainui Island	18	16	<0.002	0.004	2 (11.1%)	×
Burgess Island	27	24	<0.002	0.005	2 (11.1%)	×
Kapua Point	27	24	<0.002	0.006	2 (11.1%)	×
Waikare Inlet	18	16	<0.002	0.006	2 (11.1%)	×
Paihia North	18	16	<0.002	0.007	2 (11.1%)	×
Marsden Point	18	16	<0.002	0.008	2 (11.1%)	×
Onerahi	18	16	<0.002	0.008	2 (11.1%)	×
Mair Bank	18	16	<0.002	0.009	2 (11.1%)	×
Waipapa River	18	16	<0.002	0.018	2 (11.1%)	×
Waitangi River	18	16	<0.002	0.037	2 (11.1%)	×
Five Fathom Channel	27	23	<0.002	0.005	4 (14.8%)	×
Oruawharo River	27	23	<0.002	0.006	4 (14.8%)	×
Te Kopua	27	23	<0.002	0.006	4 (14.8%)	×
Hargreaves Basin	27	23	<0.002	0.007	4 (14.8%)	×
Te Hoanga Point	27	23	<0.002	0.007	4 (14.8%)	×
Paihia South	18	15	<0.002	0.004	3 (16.7%)	×
Paihia	18	15	<0.002	0.005	3 (16.7%)	×
Mangapai River	18	15	<0.002	0.006	3 (16.7%)	×
One Tree Point	18	15	<0.002	0.007	3 (16.7%)	×
Otaika Creek	18	15	<0.002	0.007	3 (16.7%)	×
Tapu Point	18	15	<0.002	0.009	3 (16.7%)	×
Ōpua Basin	18	15	<0.002	0.020	3 (16.7%)	×
Tamaterau	18	15	<0.002	0.240	3 (16.7%)	×
Portland	18	14	<0.002	0.005	4 (22.2%)	×
Kawakawa River	18	14	<0.002	0.008	4 (22.2%)	×
Wahiwaka Creek	27	21	<0.002	0.012	6 (22.2%)	×
Kaiwaka Point	18	14	<0.002	0.014	4 (22.2%)	×
Blacksmiths Creek	18	14	<0.002	0.018	4 (22.2%)	×
Lower Hātea River	18	14	<0.002	0.180	4 (22.2%)	×
Town Basin	18	13	<0.002	0.008	5 (27.8%)	×
Waiarohia Canal	18	12	<0.002	0.007	6 (33.3%)	×
Limeburners Creek	18	11	<0.002	0.007	7 (38.9%)	×
Upper Hātea River	18	11	<0.002	0.007	7 (38.9%)	×
Kissing Point	18	11	<0.002	0.009	7 (38.9%)	×

3.6 Water quality index

In the estuary management unit, the highest water quality scores were recorded at sites located close to the entrances of the Whangārei Harbour, and at Paihia North and Russel in the Bay of Islands (Table 33). These sites are all relatively exposed sites located away from inputs of freshwater. The lowest water quality scores were recorded at Waikare Inlet, Kaiwaka Point and Tapu Point. Waikare Inlet and Tapu Point are located in sheltered water in the inner bay of Islands close to the confluence of freshwater inputs from the Kawakawa River.

In the tidal creek management unit, the highest water quality scores were recorded at Kerikeri Inlet and Waipapa River, which are both located in the Kerikeri Inlet. The lowest scores were recorded at Otaika Creek, in the Whangārei Harbour and Wahiwaka Creek in the Kaipara Harbour.

In the Hātea River management unit, the lowest scores were recorded at Limeburners Creek and Waiharohia Canal. There was a clear pattern of increasing scores (improving water quality) for sites further down the Hātea River management unit.

Table 33: Water quality scores for data collected between January 2013 and December 2017. Ranked highest (best) to lowest index score.

a) Estuarine management unit.

Site	Samples	F1 (Scope)	F2 (Frequency)	F3 (Magnitude)	Index score
One Tree Point	33	28.6	2.2	0.2	83.5
Blacksmiths Creek	60	42.9	3	0.3	75.2
Tamaterau	33	42.9	3.5	0.5	75.2
Windsor Landing	60	42.9	7.4	1.7	74.9
Mair Bank	58	57.1	2.2	0.7	67
Snake Bank	33	57.1	2.6	2.2	67
Paihia North	60	57.1	7.8	0.5	66.7
Russell	33	71.4	5.6	1	58.6
Doves Bay	33	71.4	7.4	1	58.5
Te Haumi	33	71.4	10	4.7	58.3
Onerahi	33	71.4	11.7	4.1	58.1
Wainui Island	33	71.4	14.3	3.5	57.9
Portland	58	71.4	14.7	4.5	57.8
Kapua Point	33	71.4	27.4	8.8	55.5
Marsden Point	33	57.1	2.6	59.6	52.3
Paihia	33	85.7	7.8	1.4	50.3
Five Fathom Channel	33	85.7	9.3	5.6	50.1
Paihia South	33	85.7	10.8	1.9	50.1
Te Puna Inlet	33	85.7	10.8	4.1	50.1
Ōpua Basin	33	85.7	13.9	5.2	49.8
Oruawharo River	33	85.7	12.6	7	49.8
Waitangi River	33	85.7	13.4	7.4	49.7
Te Kopua	60	85.7	16.4	5	49.5
Te Hoanga Point	60	85.7	24	12.8	48.1
Burgess Island	33	85.7	25.2	18.8	47.3
Hargreaves Basin	33	85.7	31.8	12.6	46.7
Tapu Point	33	100	16	9.7	41.3
Kaiwaka Point	33	100	19.5	7.1	41
Waikare Inlet	33	100	21.2	8.4	40.8

b) Tidal creek management unit.

Site	Samples	F1 (Scope)	F2 (Frequency)	F3 (Magnitude)	Index score
Kerikeri River	33	71.4	9.5	1.8	58.4
Waipapa River	33	85.7	10.4	3.2	50.1
Kawakawa River	33	85.7	16	14.4	49
Mangapai River	33	100	13.9	4.1	41.7
Wahiwaka Creek	60	100	28.8	15.2	39.3
Otaika Creek	33	100	24.2	30.4	38.1

c) Hātea River management unit.

Site	Samples	F1 (Scope)	F2 (Frequency)	F3 (Magnitude)	Index score
Lower Hātea River	33	85.7	24.7	52.9	40.1
Kissing Point	33	100	26.4	45.6	34.7
Upper Hātea River	33	100	29.9	49.6	33.3
Town Basin	33	100	29.9	50.0	33.2
Waiharohia Canal	33	100	32.0	55.2	31.5
Limeburners Creek	33	100	33.8	75.0	25.2

4. Discussion

4.1 Water clarity

Good water clarity is important for healthy functioning of marine ecosystems. Water clarity can be reduced by human activities that increase levels of suspended solids entering the coastal environment. High levels of material in the water column can restrict light transmission, which affects the amount of photosynthesis (primary production) of aquatic plants and consequently other species that are dependent on them, such as fish and shellfish. Seaweeds and seagrass typically require more light for photosynthesis than phytoplankton and are particularly susceptible to reduced light levels of suspended sediments by nature of being attached to the seabed (Thrush *et al*., 2004). Reduced water clarity can also affect the feeding efficiency of visual predators like fish and sea birds and sediment particles can clog the feeding structures and gills of fish and suspension feeding animals like cockles and pipi that filter their food from the water column (Australian New Zealand Environment Conservation Council, 2000). High levels of suspended solids may also protect bacteria from ultraviolet light, (Oliver and Cosgrove, 1975). Water clarity is also an important attribute for recreation and aesthetic values as poor water clarity makes the water less desirable for swimming and recreational activities.

Water clarity can be affected by the amount of sediment in the water column but also algal growth. Reduced water clarity can therefore be an indicator of trophic state. Water clarity may decrease during spring as warmer temperatures stimulate algal growth and increase as cooler weather causes algal growth to decrease. In addition, soil erosion and run-off from rainfall may result in higher concentrations of suspended solids in streams and rivers flowing to the coast, which will decrease water clarity. In shallow environments, resuspension of sediment from the seabed by wave action of tidal currents may also increase suspended solids in the water column and thus reduce water clarity.

Secchi depth, turbidity and total suspended solids are all related to water clarity. Secchi depth is a measure of the transparency of the water body. Turbidity is a measure of the degree to which light is scattered in water by particles, such as sediment and algae. Total suspended solids is a measure of the amount of suspended material in the water column.

A similar spatial trend was observed for turbidity, total suspended solids and secchi depth. Sites with the lowest turbidity and total suspended solids recorded the highest secchi depth and sites with the highest turbidity and TSS generally recorded the lowest secchi depth.

Sites with the lowest turbidity and total suspended solids recorded the highest secchi depth were located near the entrance of the Whangārei Harbour and water clarity at these sites appears to be particularly good. These five sites are located a long way from freshwater inputs of sediment and are in deep water so they are unlikely to be affected by resuspension of seabed sediment.

Sites with the highest turbidity and total suspended solids and the lowest secchi depth (Mangapai River, Otaika Creek, Waikare Inlet, Kawakawa and Wahiwaka Creek) were generally located in the tidal creek management unit, close to freshwater inputs. Generally, areas that receive freshwater input will have higher turbidity and total suspended solids (and lower secchi depth) as freshwater inputs carry material entrained in run-off from the land or from river and stream bank erosion. These areas are also depositional zones of sediment, due to flocculation of sediments within the fresh/saline water mixing interface, so may be susceptible to re-suspension of 'historically' deposited material. An exception to this was relatively low concentrations of total suspended solids at both Kerikeri River and Waipapa River in the Bay of Islands.

Overall there was good compliance with the coastal water quality standards for turbidity and secchi depth. Three sites had median secchi depths that breached the coastal water quality standards, but all 41 sites had median turbidity values below the relevant coastal water quality standards.

Trend analysis performed on secchi depth identified increasing (positive) trends at three sites and decreasing (negative) trends at seven sites. Trend analysis on turbidity data identified decreasing (positive) trends at six sites. There was only sufficient data to perform trend analysis for total suspended solids at eight sites in the Kaipara harbour and no trends were identified.

4.2 Faecal indicator bacteria

Microbiological indicator organisms are used to measure the faecal contamination of the water and therefore its suitability for recreational activities. Indicator organisms are used because there is a wide variety of pathogens that may be present in faecal material, it would be difficult and expensive to test for all of them. The New Zealand Marine Bathing Study showed that enterococci are the indicator most closely correlated with health effects in New Zealand marine waters, while faecal coliforms and *E.coli* were not as well correlated with health risks. The Microbiological Water Quality Guidelines for Marine and Freshwater Recreational Areas recreational guidelines (Ministry for the Environment and the Ministry of Health, 2003) therefore recommends that enterococci are used as the faecal indicator in marine waters. However, enterococci may be present in the environment from other sources under certain conditions. For example, enterococci can occur naturally in mangroves so sites with a lot of mangroves nearby may naturally have elevated levels of enterococci. For this reason, in estuarine and brackish environments it may be necessary to use a combination of indicators to assess the risk of faecal contamination.

Faecal coliforms are also used as an indicator of the suitability of coastal water for shellfish consumption. The Microbiological Water Quality Guidelines for Marine and Freshwater Recreational Areas (Ministry for the Environment 2003) set the following guideline for recreational shellfish-gathering: “Median faecal coliform content of samples taken over a shellfish gathering seasons shall not exceed a most probable number (MPN) of 14 per 100mL and not more than 10% of samples should exceed an MPN of 43 per 100mL”. These standards are utilised in the coastal water quality standards in the Proposed Regional Plan for Northland, for the estuarine and open coast management units (Table 2). There are no coastal water quality standards for faecal coliforms for the Hātea River or tidal creek management units in the Proposed Regional Plan as these areas are not typically used for shellfish gathering or aquaculture.

Enterococci were measured at all of council’s 41 coastal sites and faecal coliform concentrations were also monitored at sites in the Whangārei Harbour and the Bay of Islands, but not at the nine sites in the Kaipara Harbour.

Similar spatial patterns were observed for both enterococci and faecal coliforms, with the highest concentrations of both micro-bacteria recorded at sites in tidal creek locations and lower concentrations at outer estuarine sites. The highest median concentrations of both enterococci and faecal coliforms were recorded at sites in the Hātea River and at Otaika Creek in Whangārei Harbour. The Hātea River receives freshwater input from the surrounding catchment (which may carry bacteria entrained in run-off from the land) and receives treated waste water discharges from the Whangārei waste water treatment plant. The Otaika Creek is a rural catchment with a high proportion of pasture used for both beef and dairy farming.

In the Proposed Regional Plan, the coastal water quality standards for the different coastal management units are based on the Ministry for the Environments microbial assessment categories for marine waters. The criteria for the open coast, where contact recreation is popular is based on the criteria for Grade A, with the standard for the estuarine and tidal creek management units based on Grade B and the standard for the Hātea River management unit, where expectations around contact recreation are lower, based on Grade C.

Two estuarine (Paihia South and Waitangi River) did not comply with the standard for enterococci. Paihia South is a popular swimming site for locals and tourists so the results at this site are a concern. Waitangi River is not known to be a popular swimming site, although it is used for secondary contact recreation (kayaking and

waka ama). Three tidal creek sites (Otaika Creek, Wahiwaka Creek and Waipapa River) also exceeded the relevant standard. All three sites are unlikely to be used for contact recreation, although Waipapa River is occasionally used for secondary contact, including kayaking and paddle boarding (Authors observation). Four sites in the Hātea River also exceeded the relevant standard and although primary contact does not take place in the Hātea River, it is a popular area for paddle boarding, rowing, and waka ama (Authors observations).

In the Proposed Regional Plan, only the estuarine and open coast management units are managed for shellfish consumption. The coastal water quality standard is based on the guideline for recreational shellfish-gathering in The Microbial Water Quality Guidelines for Marine and Freshwater Recreational Areas (Ministry for the Environment 2003), which requires the median faecal coliform content of samples taken over a shellfish gathering season shall not exceed a most probable number (MPN) of 14 per 100mL and not more than 10% of samples should exceed a MPN of 43 per 100mL. Three sites Te Haumi, Wainui Island and Waitangi River did not comply with the coast water quality standard. There are cockle beds within the Waitangi Estuary (Griffiths 2013), Te Haumi is a popular cockle bed and people collect oysters from the foreshore near Wainui Island (Authors observations), so these results are a concern. The Hātea River and tidal creek management units are not managed for shellfish consumption so there is no relevant standard. Regardless, all six sites in the Hātea River and four tidal creek sites were not suitable for shellfish consumption. None of the sites are known to support shellfish beds and are unlikely to be used for shellfish consumption

Because of the large number of censored values in the datasets, Trend analysis could only be performed on two sites for enterococci and seven sites for faecal coliforms. No significant trends were identified.

4.3 Nutrients and trophic state

While nutrients are essential for all forms of life, nutrients that enter the environment from anthropogenic sources, such as fertiliser, stormwater, treated wastewater, sewage overflows and failing septic systems, may exceed the needs of an ecosystem. Elevated nutrients in the water can cause excessive plant growth leading to algal blooms, which in turn can cause lowered levels of dissolved oxygen and water clarity. This can reduce the life-supporting capacity of the water and pose a significant human health risk through contact with toxic algal blooms and eating contaminated shellfish. Excessive plant growth can also look unattractive and can cause an unpleasant odour when it dies and decays.

The current scientific consensus is that nitrogen is the main limiting nutrient in coastal waters, particularly in the summer and where bacterial denitrification rates are high, but that phosphorus limitation may be important in spring (Rees, 2009). Consequently, it is important to monitor and manage the levels of both nitrogen and phosphorus.

Concentrations of different nutrients (for example, phosphorus and ammonium) are direct measures of the nutrient levels, which may be responsible for over-enrichment, while chlorophyll *a* and dissolved oxygen are 'response indicators' of nutrient enrichment. Water clarity can also be a 'response indicator' of nutrient enrichment as phytoplankton can reduce light transmission. However, as sediment run-off from the land also influences water clarity, this parameter has been reported separately (see section 4.1).

4.3.1 Dissolved oxygen

Dissolved oxygen is a measure of the quantity of oxygen available to aquatic life in the water column. Oxygen is required by marine organisms (for example, fish, invertebrates and microorganisms) for efficient functioning (ANZECC, 2002) and reduced oxygen levels have been shown to cause lethal and sub-lethal effects (physiological and behavioural) in a variety of organisms, especially in fish (Canadian Council of Ministers of the Environment, 1999). Significant decreases in dissolved oxygen levels can occur when there is an excess of organic material in the system, for example, sewage effluent or dead plant material.

Dissolved oxygen levels fluctuate diurnally and seasonally. Diurnal changes are caused by the respiration of plants and animals and the photosynthetic activity of aquatic plants during the day. Plants and animals consume oxygen for respiration throughout the day and night but during the daytime oxygen is released by aquatic plants as a bi-product of photosynthesis so typically oxygen levels are higher during the day and decrease at night when photosynthesis ceases. Seasonal variations are related to changes in water temperature, as cold water holds more oxygen than warm water and to seasonal changes in the abundance of plants and animals.

A similar spatial pattern was observed for both the concentration of dissolved oxygen and dissolved oxygen saturation. Otaika Creek was a noticeable exception to this, with a high median dissolved oxygen concentration but a low median dissolved oxygen saturation. Sites in tidal creek locations generally had lower dissolved oxygen levels than outer estuary sites. Tidal creek sites are less exposed than outer estuarine sites, which have more mixing of surface waters by wind and wave, which increases the rate at which oxygen from the air can be absorbed into the water.

The coastal water quality standards for dissolved oxygen, require that the median value is above the relevant standard for each management unit and that dissolved oxygen does not fall below 4.9 mg/L. All 41 sites had median dissolved oxygen concentrations above the relevant standard for the different management units but seven sites had at least one sample below the minimum value of 4.9 mg/L. These sites were all located in the Hātea River or tidal creek management unit within the Whangārei Harbour.

Trend analysis identified a decreasing (negative trend) at two sites (Wahiwaka Creek and Burgess islands) in the Kaipara harbour.

4.3.2 Chlorophyll-*a*

Chlorophyll-*a* is a green pigment found in plants that is used to absorb sunlight during photosynthesis. Chlorophyll-*a* concentrations are therefore an indicator of phytoplankton abundance and biomass in coastal waters, which is in turn an indicator of trophic status.

The lowest median chlorophyll-*a* concentrations were recorded at exposed outer estuarine sites towards the entrance of the Whangārei Harbour. The highest median chlorophyll-*a* concentrations were found at five sites in the Kaipara Harbour. These sites were all estuarine sites located in the different arms of the Harbour. The higher chlorophyll-*a* concentrations in the Kaipara Harbour may be influenced by the sampling protocols. The Kaipara harbour is sampled within two hours of high tide, while the other sites are sampled without regard to tidal height. Only one site, Hargreaves Basin had a median that exceeded the relevant coastal water quality standard.

Trend analysis could only be performed on eight sites in the Kaipara Harbour and no trends were identified.

4.3.3 Total nitrogen

Total nitrogen is a measure of all forms of dissolved and particulate nitrogen present in a water sample. The highest median concentration of highest total nitrogen was at Limeburners Creek and high results were recorded at all sites in the Hātea River management unit. Limeburners Creek is the receiving environment for discharges from the Whangārei waste water treatment plant, and this is likely to be a significant source of nutrients at this site. However, total nitrogen concentrations decrease steady at sites downstream of Limeburners Creek and outside of the Hātea River management unit, concentrations within thin the estuarine management unit of the Whangārei Harbour were similar to sites in the Bay of Islands and Kaipara Harbour. Elevated concentrations of total nitrogen were also recorded at Otaika Creek which is a tidal creek site within the Whangārei Harbour.

Trend analysis could only be performed on seven sites in the Kaipara Harbour. Increasing (negative trends) were identified at five sites.

4.3.4 Ammoniacal nitrogen

Total ammoniacal nitrogen is the concentration of nitrogen present either as ammonia (NH_3) or ammonium (NH_4). The proportion of the different forms is dependent on pH, temperature and salinity. At the average pH of seawater approximately 95% of ammoniacal nitrogen is in the ammonium (NH_4) form. Ammonium (NH_4) is the form of nitrogen taken up most readily by phytoplankton and assimilated into amino acids. Ammonia (NH3) is the more toxic form to aquatic life. Ammoniacal forms of nitrogen occurs in a number of waste products. The main sources to coastal water include livestock effluent entrained in rainfall run-off, wastewater (including sewage and household wastewater containing ammonia-based cleaning products), industrial discharges and atmospheric deposition of ammonia from combustion. Synthetically produced ammonia is also an important fertiliser.

Similar spatial patterns were observed for both ammoniacal nitrogen and total nitrogen with the lowest medians recorded at outer harbour sites in the Whangārei Harbour and the Kaipara Harbour and higher concentrations at sites in the Hātea River and at Otaika Creek, in Whangārei Harbour. Elevated concentrations were also recorded at Wahiwaka Creek in the Kaipara Harbour and at Waipapa River and Kerikeri River in the Bay of Islands. The Wahiwaka creek site is located downstream of discharges from the Maungaturoto waste water treatment plant, the Kaiwaka waste water treatment plant and a discharge from the Fonterra Maungaturoto milk processing plant. The Waipapa River and Kerikeri River sites are both tidal creek sites in the upper reaches of the Kerikeri Inlet and they are the immediate receiving environment for their respective freshwater inputs, which together drain the majority of the catchment, which has a high proportion of exotic grassland for cattle and dairy farming (52%) and horticulture (18%).

Four sites, Limeburners Creek, Otaika Creek, Kaiwaka Point and Hargreaves Basin, recorded median values that exceeded the relevant coastal water quality standards. Trend analysis could only be performed on 11 sites. Two increasing (negative) trends and one decreasing (positive)trend were identified.

4.3.5 Nitrate-nitrite nitrogen

Nitrate-nitrite nitrogen is a common contaminant in rural and urban areas and originates from waste water discharges, septic systems, fertilisers and animal effluent. Nitrate may also occur naturally due to the dissolution of nitrate bearing rock within the aquifer.

A similar spatial pattern was again observed for nitrate-nitrite nitrogen with the lowest concentrations generally recorded at more exposed outer estuarine sites and the highest concentrations recorded in the Hātea River and Otaika Creek and at other tidal creek sites.

Two sites, Otaika Creek and Burgess Island had median values that exceeded the relevant Coastal Water Quality standards. Trend analysis could only be performed at 14 sites. An increasing (negative) trend was identified at Limeburners Creek, which is concerning as nitrate-nitrite concentrations at this site are elevated.

4.3.6 Total phosphorus

The measurement of total phosphorus includes the total of all filterable and particulate forms of phosphorus. Phosphorus occurs naturally in water as a result of the weathering of rocks and soils, and the decomposition of organic material. Human sources of phosphorus include human sewage, cleaning products and detergents, fertilisers and animal effluent. Human activities, such as urban development and forestry that can cause soil

erosion, will also release phosphorus, which may reach waterways. The drainage of wetlands for development may also expose phosphorus that was buried.

The lowest median concentrations of total phosphorus were recorded at outer estuarine sites in the Whangārei Harbour and the Kaipara Harbour, and at exposed estuarine sites in the Bay of Islands. The highest median concentrations were found at sites in the Hātea River in the Whangārei Harbour and at the Wahiwaka Creek site in the Kaipara Harbour. All of the sites in the Bay of Islands recorded relatively low median total phosphorus concentrations, with the highest median recorded at the Kawakawa River site.

Five sites, Limeburners Creek, Wahiwaka Creek, Otaika Creek, Kapua Point and Kaiwaka Point recorded median values that exceeded the relevant coastal water quality standards. Trend analysis identified decreasing (positive) trends at twenty sites. The decreasing trends identified at Kapua Point and Kaiwaka Point, are positive as these sites recorded medians that exceeded the coastal water quality standard.

4.3.7 Dissolved reactive phosphorus

Dissolved reactive phosphorus is the fraction that consists largely of the inorganic orthophosphate (PO_4) form of phosphorus. The inorganic orthophosphate fraction is the form of phosphorus that is directly taken up by algae. The amount of dissolved reactive phosphorus therefore indicates the amount of phosphorus that is immediately available for algal growth.

Interestingly low median concentrations of dissolved reactive phosphorus were recorded at both the Kerikeri River and the Waipapa River, which are both tidal creek sites located in the upper Kerikeri Inlet in the Bay of Islands. Low median values were also recorded at sites close to the entrance of the Whangārei Harbour and at Russel and Te Puna in the Bay of Islands. The highest median concentrations were recorded at the six sites in the Hātea River in Whangārei Harbour and at Wahiwaka Creek in the Kaipara Harbour. Eight of the 41 sites recorded median values that exceeded the relevant coastal water quality standards.

Trend analysis identified decreasing trends at six sites but increasing (negative trends) were identified at four sites. The decreasing trends identified at Kapua Point and Kaiwaka Point, is positive as these sites recorded medians above the coastal water quality standard. The decreasing trends observed at the Town Basin and the Upper Hātea River are also positive as the dissolved reactive phosphorus concentrations at these two sites are elevated.

In contrast, the increasing trends at Wahiwaka Creek and Te Kopua are of concern as the median concentrations at these sites were already above the relevant coastal water quality standards. The increases identified at Waitangi and Paihia South are of less concern as the median concentrations at these two sites were well below the coastal water quality standards.

4.4 Metal contamination

Metal concentrations were generally low, with a large number of censored values (below the laboratory detection limits) recorded at most sites. The coastal water quality standards set a maximum concentration, that all samples must fall below. Twenty-four sites had at least one sample that exceeded the standard for zinc and 40 of the 41 sites recorded at least one sample that exceeded the standard for copper during the sampling period (July 2015-December 2017). Most sites recorded a relatively small number of exceedances, in absolute and percentage terms. The exceptions to this were the sites in the Hātea River management unit. At Limeburners Creek and Waiarohia Canal over 30% of samples exceeded the standard for both copper and zinc.

4.5 Water quality index

The water quality index was calculated using the different water quality standards for each management unit, to allow for a more balanced comparison of how the sites scored against each other. For sites in the estuarine management unit, the highest scores were recorded at sites close to the entrance of the Whangārei Harbour and the lowest scores inner estuarine sites close to boundaries with the tidal creek management unit.

In the tidal creek management unit, the highest scores were recorded at the Kerikeri River and Waipapa River sites, which are both located in the Kerikeri inlet. The sites with the lowest scores were Otaika Creek in Whangārei Harbour and Wahiwaka Creek in the Kaipara Harbour. The Otaika Creek is a rural catchment with a high proportion of pasture used for both beef and dairy farming. The Wahiwaka Creek site is located in the Otamatea River, a rural catchment with a high proportion of pasture sheep, beef and dairy farming. It is also downstream of discharges from the Kaiwaka and Maungaturoto waste water treatment plants and Fonterra's Maungaturoto dairy processing plant.

In the Hātea River management unit there was a clear pattern of decreasing scores further up the Hātea River towards Limeburners Creek and Waiarohia Canal. The Hātea River has a predominantly urban catchment, with some agriculture and forestry in the north of the catchment. The Whangārei waste water treatment plant discharges into the Limeburners Creek, which itself flows into the Hātea River. There are also a number of stormwater discharges into the Hātea River, as well as industrial discharges, a marina and mooring facilities.

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6. Appendices

Appendix 1. Site co-ordinates (NZGD 2000, New Zealand Transverse Mercator).

Site name	Harbour	x	y
Mangapai River	Whangārei Harbour	1719865	6033523
Town Basin	Whangārei Harbour	1719871	6045912
Upper Hātea River	Whangārei Harbour	1720380	6045570
Portland	Whangārei Harbour	1721786	6037296
Limeburners Creek	Whangārei Harbour	1720611	6044292
Lower Hātea River	Whangārei Harbour	1721994	6043396
Kissing Point	Whangārei Harbour	1721885	6044481
Kaiwaka Point	Whangārei Harbour	1722500	6040598
Tamaterau	Whangārei Harbour	1727464	6037880
One Tree Point	Whangārei Harbour	1731336	6035303
Blacksmiths Creek	Whangārei Harbour	1733188	6033389
Marsden Point	Whangārei Harbour	1735580	6032934
Mair Bank	Whangārei Harbour	1736610	6032428
Onerahi	Whangārei Harbour	1724164	6040654
Snake Bank	Whangārei Harbour	1733359	6035404
Waiarohia Canal	Whangārei Harbour	1720529	6045073
Otaika Creek	Whangārei Harbour	1718363	6039770
Russell	Bay of Islands	1701888	6097331
Doves Bay	Bay of Islands	1694300	6104732
Windsor Landing	Bay of Islands	1693649	6103601
Te Puna Inlet	Bay of Islands	1690999	6109039
Paihia North	Bay of Islands	1699171	6095533
Paihia South	Bay of Islands	1699765	6094870
Te Haumi	Bay of Islands	1700137	6093454
Paihia	Bay of Islands	1699668	6095520
Ōpua Basin	Bay of Islands	1701677	6091826
Tapu Point	Bay of Islands	1702577	6091929
Wainui Island	Bay of Islands	1691548	6104195
Waikare Inlet	Bay of Islands	1706238	6092261
Waitangi River	Bay of Islands	1698190	6096284
Waipapa River	Bay of Islands	1688786	6103513
Kerikeri River	Bay of Islands	1688797	6103181
Kawakawa River	Bay of Islands	1701646	6089648
Oruawharo River	Kaipara Harbour	1716739	5981218
Hargreaves Basin	Kaipara Harbour	1724856	5982210
Wahiwaka Creek	Kaipara Harbour	1724505	5997524
Te Hoanga Point	Kaipara Harbour	1719737	5991165
Te Kopua Point	Kaipara Harbour	1714843	5992950
Kapua Point	Kaipara Harbour	1710941	5995981
Burgess Island	Kaipara Harbour	1694354	5995293
Five Fathom Channel	Kaipara Harbour	1703620	5986591

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